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Proceedings

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Forward & Executive Report

The organizers of the International Conference on Systematic Innovation (ICSI) in Taiwan are pleased to present the proceedings of the conference, which includes 51 English papers and 15 Chinese Papers accepted for presentation at the conference. Author and non-author participants from more than 14 countries will interact in the conference.

This conference is organized by The Society of Systematic Innovation (SSI), the IFIP Computer-aided Innovation, and the Journal of Systematic Innovation (IJoSI) which is an affiliation of the SSI. Whether the papers included in the proceedings are work-in-progress or finished products, the conference and proceedings offer their authors an opportunity to disseminate the results of their research and receive early feedback from colleagues, without the long wait associated with publication in peer-reviewed journals. On the other hand, the presentations and the proceedings do not preclude the option of submitting the work in an extended and finished form for publication in a special or general issue of the IJoSI, or another peer-reviewed journal.

The organizers are indebted to a number of people who gave their time to make the conference a reality and to publish these proceedings. The list of organizations and working team who have contributed tremendous amount of time and efforts to create this conference are acknowledged at the end of this program brochure. There are more contributors who are beyond the list.

The conference is intended to be annual and international. **The 5th ICSI conference will be in the American innovation center of the Silicon Valley (Northern California) during July 16-18, 2014**. We welcome proposals for locations of future conferences in various countries. Please submit your proposal to myself. In addition, you are cordially invited to submit scholarly papers to the IJoSI at www.IJoSI.org. The conference and the journal are synergetic and closely related. The journal is intended to be with academic rigor while addressing real-world problems and opportunities. The conference provides platform for papers to be reviewed and feedback collected.

As the host, our team tried our best to provide the best services we possibly can. We hope that you will find the participation in this conference rewarding. However, due to the overwhelming work we need to do, it is quite likely that we overlooked something. If there is anything that you need assistance, please feel free to let the attendant(s) at the service desk know. We are here to serve you.

With best regards,

D. Daniel Sheu, Ph.D., MBA, CMfgE
General Chair & Chair of Organizing Committee
The 2013 Joint International Conference on Systematic Innovation
Professor, National Tsing Hua University, Taiwan, R.O.C.
President, the Society of Systematic Innovation
Editor-in-Chief, the International Journal of Systematic Innovation
Director, Education & Training, the Society of Manufacturing Engineers, Taipei Chapter
Editorial Board, Computers & Industrial Engineering, an SCI indexed international journal
2013.06.27

Paper List

Part 1. Full Papers in English

Part 2. Full Chinese Papers Preceded by English Title and Abstract

Paper ID: 03

The Application Analysis of TRIZ in Solving Problems of the Glasses for Nearsightedness

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Abstract

The theory and method of TRIZ is applied to emphatically analyze the painful problem caused by the oppression of glasses on nose and ears by usage of conflict analysis, function analysis and trimming, evolutionary problem analysis and the ideal solution of the problem analysis. With the applications of principles of invention, cutting and replacement function, dynamic growth law and the ideal final resolution, a series of proposals are presented. These proposals effectively support improvements and guide innovations in structure and function of glasses for nearsightedness, which promotes the development of glasses industry.

Keywords: contradiction, function, glasses, TRIZ.

1. Introduction

The nearsighted problem has developed to be a social problem in China in these years. The nearsighted people have amounted to 30 percent of the total population ranking the first in the world reaching 0.36 billion, in which pupils wear glasses in a ratio of 30%, high school students of 50% and college students of 75%(Chen,2011). Wearing glasses has caused a series of problems to the comfort and health for individuals. As a most effective innovation weapon, TRIZ theory has provided most popular methods to conduct creative practices in a more efficient and more scientific mode to promote development of enterprises and industries (Xie et al., 2010). Therefore, we use the methods of TRIZ to analyze the unexpected results for wearing glasses, put forward the solutions, lead to innovation and provide proposals for the development of glasses industry.

2. The theory and method of TRIZ

In 1946, Genrich Altshuller put forward a systematic and practical innovation theory named as TRIZ from the study of 2.5 million invention patents. TRIZ theory includes innovative ways to break through the inertia of thinking, the theory of evolution of technology system, 40 principles of invention, 39 general technical parameters and contradiction matrix, material-field analysis model, inventive problem standard solution, inventive problem resolution algorithm (ARIZ), the principle of separation of physical contradictions, the scientific effects and phenomena knowledge base and so on (Zhou, 2011). TRIZ theory consists of four layers as concept, analysis methods, problem-solving methods and systematic approaches plus CAI system (Tan, 2010). Based on the problem-solving methods, one can reduce the blindness of the trial-and-error method. Based on the problem analysis methods, one can reduce the influence of the inertia of thinking. And based on knowledge base which is the core of the concept layer, one can eliminate the limitations of the individual on knowledge and ability. With the use of the TRIZ innovative method, the innovation and problem-solving can be improved in high efficiency and quality.

3. Problems of nearsighted glasses

The structure of nearsighted glasses is shown in Figure 1. It causes a lot of problems described in Table 1. The Q5 is the most universal among the problems. Therefore, we use the TRIZ theory to make the solutions and lead to the innovation of glasses.

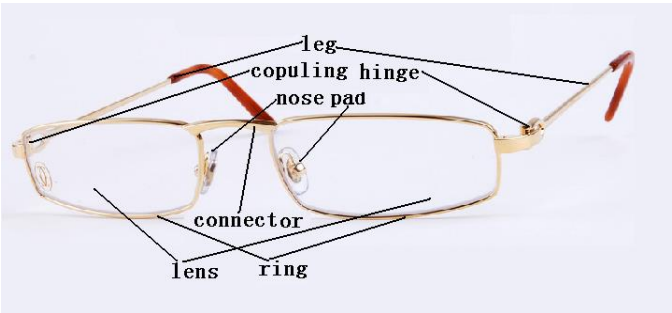

Figure 1. Graph of glasses structure

Table 1. Description of nearsighted glasses problems

sequence	description	consequence
Q1	being breakable	unsafe
Q2	easily hanging dust and fog	inconvenient
Q3	being apt to slippage in sweating	unsafe and inconvenient
Q4	eroding the nose, cheek and ears	painful
Q5	pressuring nose and ear	painful

4. Confliction analysis based solutions

The problem-solving process of conflict-analysis based TRIZ method is shown in Figure 2.

4.1 Description of the specific problem

The problem of Q5 is that the existing weight of glasses is heavy to press the nose and ears into impression and pain. With the conflict analysis, the contradiction proves to be the truth that the nearsighted people must wear nearsighted glasses but with the fact of the glasses pressing the nose and ears. Furthermore, the conflict occurs that the glasses compress the nose and ears so as to being red and swollen in pain.

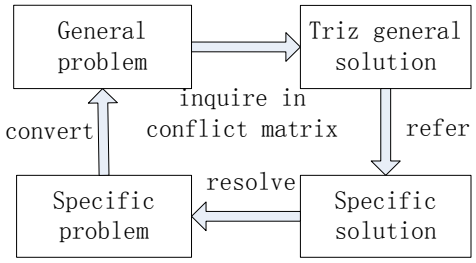

Figure 2. Problem-solving process of conflict-analysis based TRIZ method

Technical conflict problem is that nearsighted glasses helps nearsighted people to look clear, but meanwhile it hurts the nose and ears in different degrees due to its weight. Inside, the physical conflict is that glasses must have some weight to build up certain strength and structure stability, while the weight will produce pressure and thus the weight is just the physical conflict factor.

4.2 The generality of conflict problem

On basis of the technical conflict analysis, the improvement parameter and deterioration parameter could be chosen. The improvement parameter A is the weight of stationary object which is the No.2 in the 39 general-purpose engineering parameters (seen in (Tan, 2010)). And the aim is to decrease the weight. The deterioration parameter B is structure stability or strength which is the No.13 or No.14 in the 39

general-purpose engineering parameters. And the result is the descent of stability or strength. Inside the technical conflict, the weight of glasses is just the physical conflict parameter. We aim to reduce the weight to improve the conformability and at the same to enhance the weight to hold the stability and strength.

Thus, a generalized vector (A2, B13) or (A2, B14) could be gotten according the above conflict analysis.

4.3 The principles of invention based solution analysis of conflict problem

With the vector (A2, B13) to query contradiction matrix (seen in (Tan, 2010)), the principles of the invention could be obtained as copying, inert atmosphere, segmentation, and composite materials. With the vector (A2, B15) to query contradiction matrix, the principles of the invention could be obtained as mechanics substitution, taking out, preliminary action, and cheap short-living objects.

4.4 A particular solution gotten from the general solution

We could draw some particular solutions by learning from the general solution and its guidance below: (1) based on the principle of segmentation, a proposal is to discard the frame to reduce the weight and connect the temples and lenses directly with the solution such as sucker care eyeglass frames (China Patent CN93222878.X), rimless eyeglasses, and so on; (2) based on the principle of taking out, a proposal is to leave the lens only and remove all other parts with the solution such as wearing contact lens; (3) based on the principle of cheap short-living objects, a proposal is to use lightweight low-cost skeleton, such as paper frame which can be thrown away after a few days, with the lens be reused; (4) based on the principle of mechanics substitution, a proposal is to use a flexible alternative to the glass material with a lighter material into to a solution such as wearing the resin glasses instead of glass lenses; (5) based on the principle of composite materials, a proposal is to use lightweight unbreakable polymer material instead of a metal frame and glass to reduce weight such as using a resin material for the lens and a plate frame instead of metal frame.

5. Function analysis and trimming based solutions

The function analysis of Q5 is shown in Figure 3. The glasses consists of five main components such as the nose pads, rings, coupling hinges, legs and lenses. The super system comprises the bridge of the nose, cheek, ears and eyes. The production is the focusing image in the eyes, which is not shown in the figure. As can be seen from the functional analysis, oppression is the harmful effect while the others are standard effect.

By use of trimming and function replacement, some proposals could be made as follows: (1) To keep lens and crop the other four components, a recommended solution is to wear contact lens. (2)To crop legs and coupling hinges, a recommended solution is to wear nose glasses. (3) To crop rings, a recommended solution is to wear rimless eyeglasses. (4) To crop legs, coupling hinges and nose pads, a recommended solution is to wear helmet glasses.

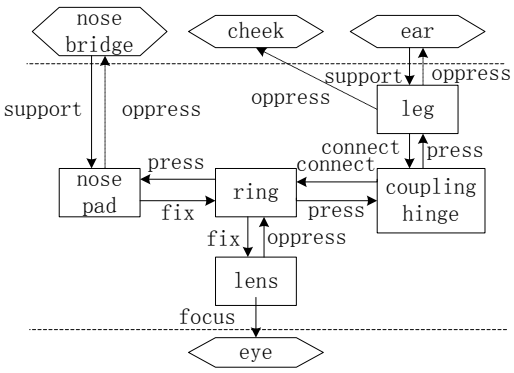

Figure 3. Chart of function analysis of Q5

6. Technology system evolution analysis based solutions

There are eight patterns of evolution as(Kraev,2007): (a) completeness of parts of the system; (b) energy conductivity of a system; (c) harmonizing the rhythm of the system's parts; (d) increasing ideality;(e) uneven development of the system's parts; (f) transition to a super-system and dynamization; (g) transition from macro- to micro-level; (h) increasing the s-field development.

Altshuller named the above in three groups, which are called static trends (a-c), kinematical trends (d-f) and dynamic trends (g,h). Altshuller pointed out that the technical evolution analysis provides the forecast function in growth of a product. The development of glasses is now in the progress of dynamic trends. We can use the law of increasing flexibility which is in the dynamic trends to analyze the growth route of glasses and forecast its development.

In the course of evolution, technological systems develop from rigid structures to flexible and adaptive ones. A route of system evolution is shown in Figure 4, and the line of glasses development is shown in Figure 4 too. With the comparison, it is clear that the glasses are developing into a more flexible structure. The fluid-system and the field-system based development is in progress, thus it could give some forecasting proposals which are shown below:

(1) The nose pad and lens could be designed into air-filled or fluid-filled structures which can adjust the shape and degree to meet with different comfortable demands. Some solutions are like air cushioning nose pad (China Patent CN90217563.7) and stepless-adjustable degree glasses (China Patent CN91226398.9).

(2)The magnetic-rheological liquid could be filled to construct the artificial ciliary's body implantable system with a magnetic field controller being instead of the ill-worked human ciliary's muscle to adjust the lens and restore visual regulation.

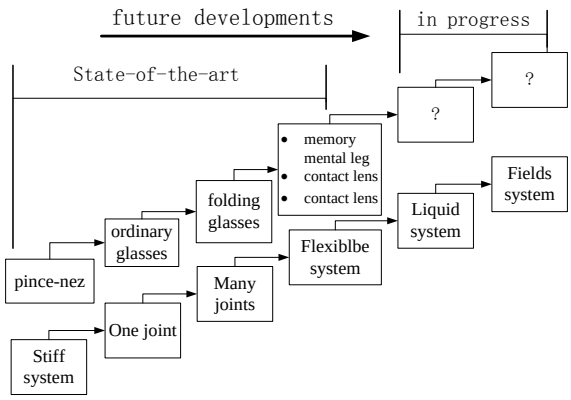

Figure 4. Evolution line of glasses development

7. Ideal solution based problem resolutions

The ideal solution has the following four characteristics: (1) the elimination of the deficiencies of the original system; (2) maintaining the advantages of the original system; (3) making the system no more complexity; (4) no introduction of new defects.

The ideal solution of glasses problem is no use of glasses, which the proposals are put forward such as the surgery to eliminate nearsightedness and drug to eliminate myopia. The two methods are accepted gradually popularly nowadays.

The ideal final resolution (IFR) is to control the occurrence of nearsightedness. The proposal has to resort to the control of DNA to prevent the occurrence of myopia, which means inhibition of the ciliary's body and lens aging and loss of activity.

8. Conclusions

In the process of solving Q5 problem, the TRIZ theory provides a series of problem analysis and resolution methods, which are effectively used to analyze the glasses oppression problem to the point from different angles and give the meaningful guide to solutions.

Furthermore, the development process of the glasses does follow the technical evolution law and therefore it can predict the future trends of the glasses. Based on the analysis of the ideal solution, we could jump out of the short-sighted problem solution just to decrease the weight of the glasses, and solutions can be found directly from the root of the problem of the human organic losing effectiveness. The use of TRIZ has proved to be right in the process of development of glasses and will be also right in the forecasting of development with its scientific method and theory.

Acknowledgements

We offer our thanks to the supports of the Innovation Methods Projects of Science and Technology Ministry of China (2011IM020300), the Industry-Academia-Research Cooperation project of Guangdong Province of China (2011A091000040), and Guangdong province technology plan project of innovation method (2011B061100001).

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Paper ID: 04

Experimental Study of Packaging Structure Design Based on TRIZ

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Abstract

TRIZ theory is introduced into the experimental teaching of packaging structure design. The experimental flow is changed and the experiment is changed from confirmatory experiment to innovation designing experiment. First the packaging structure is analysed by TRIZ theory and the function model of the system is established. Then the problem of the existing packaging structure is found and the innovation structure is designed by TRIZ conflict resolution theory. Finally the 2D carton drawing is created by BOX_Vellum soft and the carton is proofed. The innovation of the experiment can make the students find and solve problems on their own initiative, also make the students master the theory of TRIZ and cultivate students' innovative thinking and ability.

Keywords: packaging structure; TRIZ; experimental teaching; innovation design

1. Introduction

With the development of society the role of knowledge innovation and technology innovation has become more and more important [1]. Innovation ability is the most important ability of high quality talent and it has become the important issue of educational circles how to cultivate the innovation ability of college students[2]. People has put forward higher to product package, which demand puts forward higher demand to theory and experiment courses teaching of package. ‘Package Structure Design’ is an important major course of package engineering speciality. The purpose of teaching is to make the students have the ability of package structure design and master the production method of a series of package container. And the experiment of package structure design is an important practice course and is the complementarity to the theory course. The content of experiment is make the students design various paper package containers and use the proof press doing the paper containers material object. The experiment can make the students master the theory and method of paper containers design and cultivate the students’ ability of analyzing problem and solving problem.

TRIZ was put forward by Genrich S.Altshuler (1926-1998) and a series of researchers in 1946, based on analyzing and researching more than 250,000 patents all over the world[3]. The TRIZ theory is introduced into the experiment of package structure design in order to avoiding the deficiencies of traditional verification experiment[4], as well as to satisfy the needs of cultivating the students’ innovative practice ability. We reformed the experiment process and made the experiment

become to innovative design experiment, which can make the students master the solving problem process of TRIZ and cultivate the students' innovative thinking and ability.

2. Introduction of TRIZ

TRIZ theory is considered as a kind of innovative theory, whose main function is focused on solving invention problem. This theory system includes technical evolution models, theory of solving conflict, 39 general engineering parameters, 40 inventive principles, 39×39 solving contradiction matrix, 76 standard solutions, the algorithm of inventive problem solving (ARIZ), computer aided innovation and so on. TRIZ has become the study hotspot in the engineering field of Europe and America during these sixty years and many famous companies introduced TRIZ to solve technical innovation[3,5-10]. The process of solving problem is shown in Figure.1[3,5].

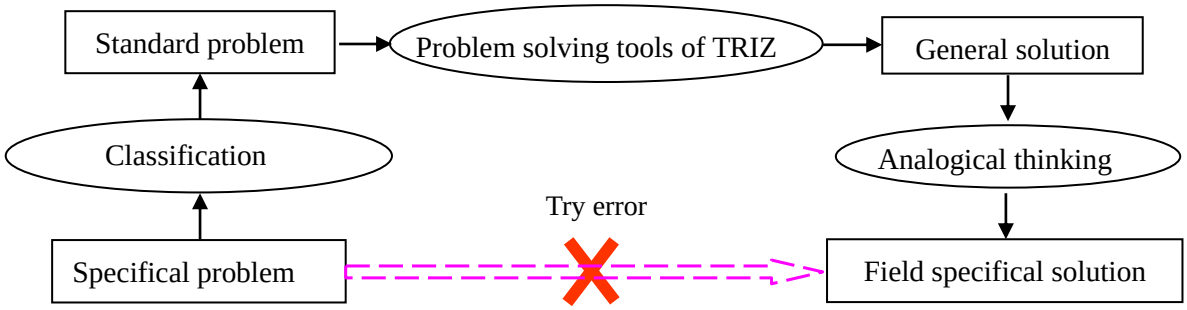

Figure 1. Process of solving problem on TRIZ

3 Experiment improvement of package structure design based on TRIZ

3.1 Improvement of experiment process

The original experiment is verification experiment and the content of experiment is that given a specific task and the students design the structure and proof them. For example, the experiment is that design a tube-folding carton whose cover is insertion type structure and bottom is bottom lock structure, meanwhile the outside size is 80*50*120mm and the paper thickness is 1mm, with the correction coefficient being 0. The students will design the manufacturing size and generate the 2D graphics of carton by using the software Box_Vellum and proof the carton. The experiment process is shown in Figure 2. The original experiment is a verification experiment and the students only need to finish one given task, but it is not contribute to the students discovering problem, putting forward the problem, solving the problem and it is not contribute to the cultivation of students' innovative thinking neither.

After the TRIZ theory is introduced into the experiment, the students are no longer passive to the experiment and they will design the innovate package structure on their own initiative by using TRIZ theory to analysis the existence question of current product. The new experiment process is shown in Figure 3. The detail process is introduced in section 3.2.

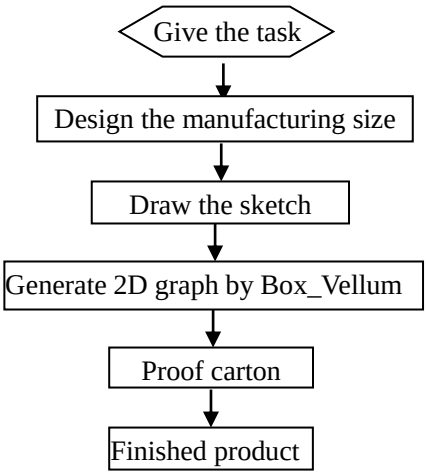

Figure 2. Original experiment process

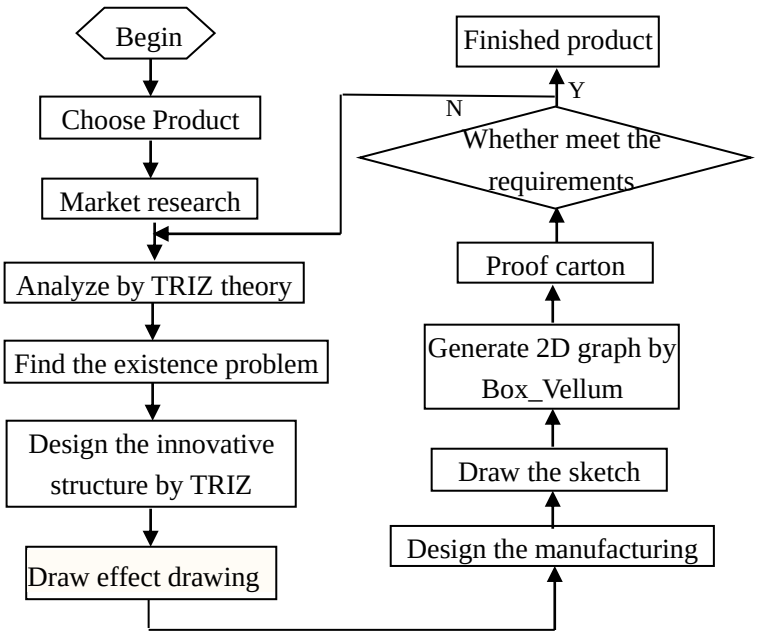

Figure 3. Improved experiment

3.2 The experiment of structure design based on TRIZ

3.2.1 Choose product Firstly, choose one product through market research, then establish the product function model[12] by applying TRIZ theory. For example, the students choose the package of oral liquid, because the current package of oral liquid mainly uses extra clapboard, which is made by plastic or cardboard and the carton is disc style carton, which cannot accomplish the automatic molding and cannot be folded and is not contribute to storage and transportation.

3.2.2 Found the function model of oral liquid Products are usually composed of many elements and the interactions between the components. The function analysis is to establish the connection between the product structure and the interaction of product [7]. The problem can be easily found by function analysis, then the methods for further improvement can be put forward. The function model of oral liquid package is established, and showed in Figure.4.

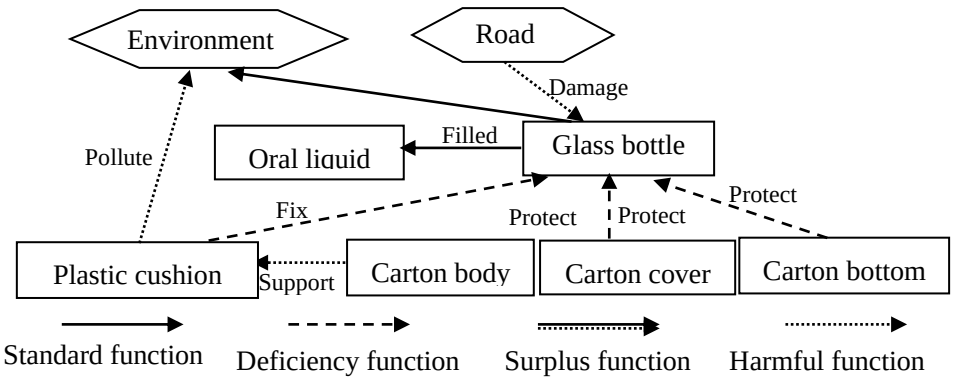

Figure 4. Function model of system

From this function model, we can know that plastic cushion have harmful function to super system and will pollute environment. The super system road will damage the product and it is harmful function to oral liquid. The carton has insufficient function to oral liquid bottle and it is not easily to fold. We should weaken the system's surplus function (if it has), and get rid of harmful function, and make up deficiency function.

3.2.3 Design the innovative package structure After analyze the package system, the students choose the conflict theory to solve this problem. We want the carton with clapboard can be open easily, so the improved parameter is NO.38 level of automation and the worsened parameter is No.36 complexity of device according to the table of engineering parameters. The corresponding principles of invention include No.1 division, No.15, dynamic, NO.24 medi-matter, No.10 pre operation. The No.15 can give us some help to design the innovative structure of oral liquid. The function of fixed and buffer can be realized by extending the body panels or bottom panels. The clapboard can be designed dynamic, which means the position can be changed to finish the automatic forming. The innovative structure is shown in figure.5.

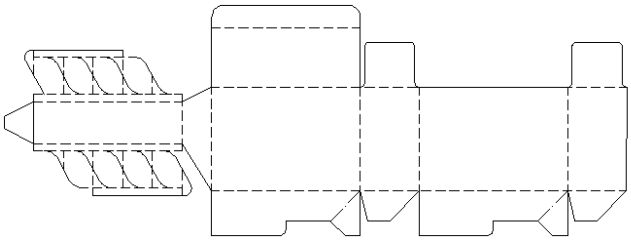

Figure 5. 2D carton drawing

3.2.4 Proof the carton The style of proofing machine is FC4210. The cutting pressure of this machine is 600 gram weight and can cut 350 GSM cardboard and the max size can be 600*860mm. The proofing machine can be controlled by setting proofing parameter. The line type can be set different colour to discriminate cutting line and creasing line. The proofing process is shown in figure 6.

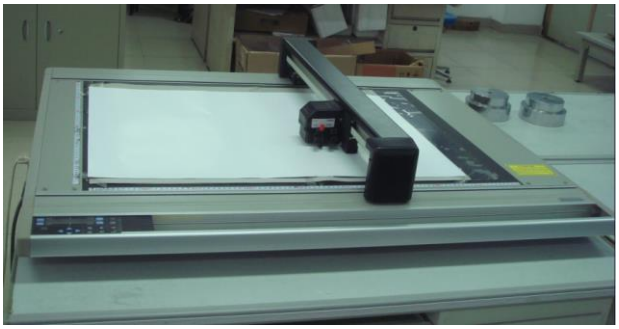

Figure 6. Proof carton

The opening carton picture is shown in Figure 7. The clapboard is extended by body plate and can be folded and adhered to one body plate. The structure of carton bottom is auto end-lock which can make the carton opening easily, which is convenient for manufactures to use.

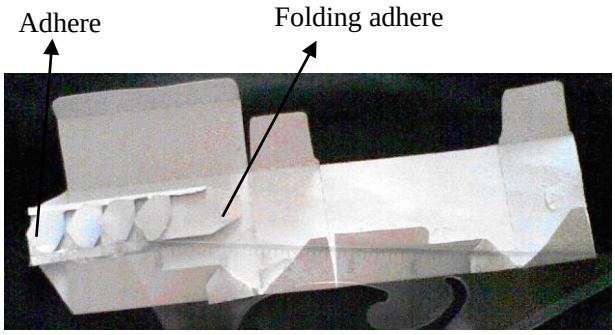

Figure 7. Process of folding carton

The innovative carton structure is shown in figure 8. The carton is made in one cardboard and the clapboard is made up of paper which is environment friendly. This carton removes the harmful factor plastic clapboard and the function of carton is fully implemented. This carton can be transport when they are folding and the cost of transport is very low. This structure has the advantages of convenient use, easy production and processing. This design shows that TRIZ theory has an effective guidance to the innovation design of package structure. The experiment of package structure design has become an innovative design experiment after the TRIZ theory is introduced into the experiment.

Figure 8. Carton effect drawing

4 Conclusion

A series of experiment courses had been formed after years of practice in Guangdong University of Technology, including experiment of package structure design, integrated experiment of package and printing material and so on. TRIZ theory is one innovation theory system easy to learn and use[13-14]. The traditional verification experiment has changed to innovative design experiment after the TRIZ theory is introduced into the package structure design. The tools of function model, theory of solving conflict can help the students discover problem, put forward problem, and solve problem, and then obtain the innovative package structure. The experiment can cultivate the students' innovation thinking and improve their practical ability. There has appeared apparent effect after introduced the TRIZ theory. The package structure designed by the students of Guangdong University of Technology has obtained many prizes in national packaging structure design competition, China packaging creative competition.

Acknowledgement

This work was financially supported by 2010 High Education Reform Project of Guangdong Province(BKZZ2011022), Guang-dong province and Ministry of Education Industry-University-Research integration project (2011A091000040), Guang-dong province technology plan project of innovation method (2011B061100001), technology plan project of innovation method of National Ministry of science and technology（2011IM020300）.

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Paper ID: 05

Design and Development of TRIZ Online Education Platform based on XML and ASP

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Abstract

According to the practical requirements of the Theory of inventive problem solving (TRIZ) for distance learning and outreach, TRIZ web education platform is developed based on XML and ASP, which helps users to take courses, analyze engineering cases, do homework and self-evaluation, and present on media, operate interactively, and search materials, etc. After applying this platform in practice, it improves the teaching performance, as well as promotes the popularization and the propagation of TRIZ distance learning.

Keywords: XML, TRIZ, Technology innovation, Online education platform.

1. Introduction

To realize the overall purpose of distance learning in China, i.e., “Implement modern distance learning project to form open education network, build life-time learning system, and make full use of and optimize national educational resources, spread and improve the knowledge among the people, reduce the cost for education, allow the people to enjoy opportunities of education”, to propagate the TRIZ theory national wide, and to solve the practical engineering problems more efficiently, TRIZ web education platform is developed based on XML and ASP with various functionalities, e.g., web courses, engineering cases analysis, exercises and self-evaluation, course media resources, interactive spaces, and materials searching, etc. This platform is able to present innovative knowledge to students, aid teachers to teach new knowledge effectively and efficiently, help students discover and review new knowledge, encourage students to think actively and to be self-motive. In addition, the platform offers a large amount of materials for both students and teachers, as well as the accurate, convenient, and fast indexing mechanism. Moreover, the platform provides an interactive learning space between students and teachers, which helps the students to solve problems encountered during the learning process. Thus, the platform is a useful tool for both web teaching and traditional classroom teaching.

2. The Architecture of Web Platform

The TRIZ web education platform consists of two major components: main page and courses. The main page module includes course introduction, curriculum, related materials, about, and help. The course module is composed of course learning, case analysis, exercise and exam, course resources, interactive interface, and resource searching, etc. among which the framework and implementation of course learning, case analysis, and exercise and exam are similar to each other since they all have directory frame and content frame. Furthermore, the directory frame is composed of toolbar of directory and directory, while the content frame is composed of toolbar of content and content. By clicking the chapter in the directory, students can read the corresponding content in the content frame, which are developed based on XML and XSL. On the other hand, as the interactive user interface, the frame of resource searching and interactive platform are dynamic pages, and are able to respond in real time and resource search based on ASP.NET and Access database.

3. The Development of Web Platform

3.1 The Main Page Module

The main page module includes course introduction (the brief introduction of course contents and application environment), syllabus (knowledge points, key pointes, difficulties and schedule), relevant resources (download services of related software needed to browse this website and links of related reference websites), about (copyrights and about us), help (user guide for this teaching website). Using DIV tag, the main page can show/hide introduction of courses, syllabus, relevant resources, about, and help through the control of navigation panel. User can start learning courses or leave this website by clicking corresponding buttons, while the excellent pictures that are relevant to courses are repeatedly displaying in the main page.

3.2 The Course Learning Module

The course learning module is composed of course learning, case analysis, exercise and exam, course resources, searching, and interactive platform. In addition, the frames of course, case analysis, and exercise and exam are similar since they are all composed of directory and content frame Moreover, the directory toolbar and director constitute the directory frame, while the content toolbar and content page form the content frame. The course learning module, as an introduction part, is mainly designed based on static pages, by applying JavaScript and XML. The following example illustrates how to design XML files.

The Design of XML files on the Web Platform: According to the requirements of web platform architecture, XML files' elements and associated properties in relevant course chapter, case, and exercise are designed as follows: the root element, "catalog", represents the whole course directory; "list" denotes heading 1, with "id" and "caption" property, among which "id" is the corresponding chapter number of heading 1 in the dictionary and "caption" is the chapter title. "list" embedded in the

first level of “list” indicates heading 2, which also has two properties of “id” and “caption”, in which “id” and “caption” refer to the corresponding chapter number and title of heading 2 respectively.

The Design of XSL files: XSLT (eXtensible Stylesheet Language Transformation) is the technique recommended by W3C for transforming XML documents. XSLT is used to query and read/write XML file. XSL file strictly follows the standard of XML, i.e., XSL file satisfies the grammar of XML. In XSLT, data element and associated properties are visited by using template-driven. When visiting the data, XPath 2.0 is used to define expressions and functions to exchange the data element of XML, such as looking up elements, defining display format, arithmetic operations, logic operations, and varies of function invoking. Finally, through embedding XSL into HTML, the elements and properties of XML are accessed to implement the transformation of XML. The XSLT processor can be installed on either client or server end so that XML data processed by XSLT can be displayed on the browser.

Since different types of texts need different format to display, XSL applies multiple templates in parallel to process different levels of documents in different format. In general, in XSL program there exists multiple templates, <xs:l template match="…">…</xs:l template>, each of which displays various levels of title by choosing corresponding properties, <xs:l value-of select="@ id" />. Then, connect the next level of template through <xs:l apply-templates select="…" /> to implement a full transforming program.

Such transformation utilizes the automatic generation of directory of course, exam and cases in the directory frame module, and links XML file to corresponding web pages, which allows users to read corresponding contents in the right-hand side content frame by clicking the chapter title in the left-hand side directory. In addition, the directory can expand/collapse quickly, at the same time when the GUI of course learning provides multiple functions, such as favorites, print, forward and backward, etc.

“The TRIZ theory and application” published by chemistry industry publisher is the core of the section of course learning, which delineates TRIZ and the key points in application course in detail, such as TRIZ theory, environment analysis and description of invention problems, physics collisions and associated solution theory, technical collisions and solutions, material-field analysis approach 76 standard solutions, analysis of technology evolution, prediction of technique maturity, procedure to handle invention problems, effects etc., together with large amount of pictures and cases making it easy to learn. Besides elaborately explaining existing cases in the text book, the section of cases analysis focuses on the key points of courses, i.e., 40 principles of invention and 11 kinds of technical evolution patterns, by collecting and analyzing innumerable new and advanced cases, which leads the nation compared with other courses, especially, in case of helping students grasp key knowledge. Exercises in the section of self-evaluation are designed based on needs of students, and corresponding answers are offered, which strengthens students’ ability of analysis, practice, understanding, and memory. Meanwhile, students are able to evaluate their performances by taking the exam of this course.

3.3 The Course Materials Module

Based on the key points and difficulties in the course, i.e., 40 principles of invention and 11 kinds of technical evolution patterns, a large amount of animations and multimedia are collected and made, each invention and technique evolution pattern are navigated by the links so that relevant multimedia resources will show up when clicking corresponding links, where users can control multimedia files in terms of play, pause, resume, and sound etc. These cases are very useful resources for students to understand key knowledge intuitively.

3.4 The Interactive and Searching Module based on ASP

The interactive module facilitates students to come with questions in the learning process. On the other hand, teachers can take advantage of this platform to answer questions, while platform administrators can publish information about exam information, arrangement of course, etc. Since interactive techniques are involved in this module, ASP is used to develop dynamic pages.

On this interactive platform, every student can ask questions. After setting up their name, gender, class, email, fonts and colors, they can leave messages. After teachers log into the platform, they can configure the message board, answer students' questions, delete duplicated questions, send emails to students, and changing their own passwords.

The searching engine in the website is developed by using ASP and Access database. On the left hand side of this searching page, users can search key words of the title in the module of learning, case analysis, and resources, as well as configuring how many items are displayed in the result page. On the right hand side of the panel, the list of files matching the searching condition is displayed, as well as relevant information, i.e., their titles, types, and chapters. By clicking the title, the corresponding page stored in the database is displayed.

4. Characteristics of the Website

4.1 What and How to Learn

The teaching platform contains every aspect of learning, which leads students to study courses from the following five perspectives: Fundamental Theory; contradiction analysis and their Solution; Substance-Field Analysis Approach; Technology Evolution Theory; ARIZ Approaches.

After students understand the fundamental theory, they can go ahead to make use of projects cases and multimedia resources to master theoretical knowledge further, while consolidating key points through exercises and self-evaluation which leads students in the right way to study this course.

4.2 Key Points and Difficulties of Teaching

The key points and difficulties of this course include collisions analysis, associated problem solving theory and technology evolution. The platform not only has a large amount of pages to elaborate them, but also provides many materials in case analysis module and course resource module for student to understand key points. Through theory introduction, case analysis, related pictures, animation and video etc., this platform ignites and improves the students' abilities to analyze and solve problems. Therefore, students strengthen their creative capabilities and master the creative methodology.

4.3 Novel Cases and Media Resources

Aiming at key points and difficulties of this course, i.e., collisions analysis, associated problem solving theory and technology evolution, a large number of project cases and multimedia resources are collect on the platform. There are 40 invention theory explained in the project cases, each of which includes up to 30 projects with total number of cases beyond 500. The multimedia resources take 11 kinds of technology evolution pattern for example, each of which contains up to 20 multimedia resources with total number of more than 200. These cases and media resources are derived from recent innovations around the world in the fields of industry, agriculture, military, energy, architecture, environment and life etc. Most of them are high-technology products. The novel cases such as future police robots and superconductivity cars are beneficial for students to understand contents and enhance their interests in this course.

4.4 Full Functionality

Besides course learning, case analysis, and exercises, etc., the web platform also provides interactive activities that facilitate students to ask questions encountered in the learning process. Additionally, teachers can answer students' questions, while website administrators can publish information of exam and course arrangement on the same platform. Due to the large amount of materials provided on the website, the search engine is developed, which builds indices on key terms of the titles contained in the module of learning, case analysis and resource. All information and links related to resources are stored in Access database which has up to 700 records. Furthermore, the website provides other functions, such as course introduction, syllabus, help, relevant resources, and references websites, etc.

4.5 User-friendly Interface

Besides the full functionalities, the user interface of the web platform is elaborated designed, e.g., a bulb is designed as the background of logo, to represent innovation together with TRIZ symbol, which make the logo special. Additionally, flash animation buttons make the user interface more vivid and elegant. Meanwhile, some flash animation pages are designed to strengthen the effects of the website as a whole.

5. Summary

Since the TRIZ Web Education Platform has been introduced, it has been trialed and widely used in colleges and large-scale companies. The feedback shows that the website is helpful for students in course learning, project cases analysis, exercise and self-evaluation, multimedia resources browse, interactive activities and search resources, etc. The website also has full functionalities, novel cases, user-friendly interface and good user feedback. After practices, the web platform is an excellent tool for distance learning and traditional classroom teaching so that it has a brilliant future to be widely applied and used. Along with the introduction and application of this platform, TRIZ theory must be widely applied and used in the nationwide range.

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Robust Inventive Solution Concept by Optimization

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Abstract:

This paper presents an approach and the software framework (RSC-Modeler) to generate the robust solution concepts from Inventive Design Method based on TRIZ (IDM-TRIZ) by using optimization techniques. It deals with reformulating the solution concept as an optimization problem in order to achieve the best possible design parameters of each solution concept and predict the approximate characteristics of final product in the criteria feasible or infeasible. The validating/ratting/selecting task will be done easily and will increase the level of confidence in using the results from optimization (in mathematical form). Nonetheless, presenting solution concepts as mathematical values it will speed up the embodiment and detail design phase. Finally, a case study is given to demonstrate the practicability and validity of the proposed approach and software framework.
Keywords: TRIZ, optimization, system modeling, Inventive Design Method

1. Introduction

Engineering design is a human activity where a set of frequently unclear objectives has to be balanced without violating another set of given constrains. There are many models of the engineering design process. A common model is phase type model – a top-down iterative process; see for instance Hubka and Eder, (1996), Pahl and Beitz, (2007) and Pugh (1991). Engineering design can be divided into three major phases: conceptual design, embodiment design and detailed design. Conceptual design can be further divided into *concept generation* and *concept selection*. The result of a conceptual design is a principle solution or *solution concept*.

Solution concept generation (also known as ideation) that is elaborating key specification such as functionality, physical structure, and performance expectations has been shown to be crucial to the success of new products as stated by Tassoul (2009). In the competitive world, the products must be multi-functional and more creative. But creativity is not an easily controllable process and it is difficult to force creativity and breakthroughs. A well-known way to manage this creativity process in design task is using TRIZ. (The Russian acronym for Theory of Inventive Problem Solving) developed in the middle of the 20th century by Althshuller (1984, 1999). *Solution concept selection* is a decision-making task – the measure about what is good, desirable possible or impossible to implement in the real world. For any given design, the designer has to give the different characteristics of the artifact. This is usually not done explicitly, but intuitively based on their past experience. Many times the creative solution concepts are considered as not reliable (or trustful) enough or impossible to

implement. Such situation is often due to the abstract description of a *solution concept*: often a rough graphical sketch and several sentences as written annotations. This information is not of a nature to provoke positive decisions as ***mathematical proofs***. During the concept selection, the designer must tradeoffs characteristics against each other. One purpose of conducting ***optimization*** is to make these tradeoffs visible. It would indeed be an interesting task to estimate what different ratings gave the final design before going into the next design phase.

Many researchers in the design community accept the earlier design decisions are made the better the final product quality and cost will be during the conceptual design phase. Not just concept selection but with all possible characteristics that have to be concerned. With this it seems particularly safer to make early design decision in the most possible optimal manner. In this paper we focus on reformulating the solution concept as an optimization problem **(Figure 1.)** in order to achieve/evaluate the design parameters of each solution concept then validating/rating/selecting later on. Moreover, when formulating the design problem as an optimization problem the answers have to be mathematically formalized. The decision-making task will be done easily and without any doubt with these answers. Nonetheless, having the characteristics of solution concepts as mathematical values or much more physical context will speed up the embodiment and detail design phase therefore give much more chance to have a competing R&D department in the innovation era.

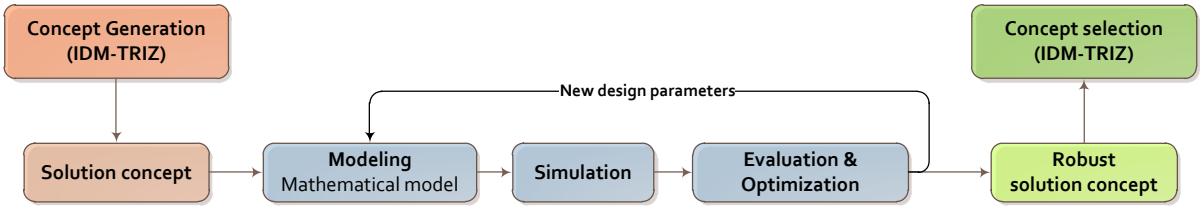


Figure 1. Proposal to generate a robust inventive solution concept

This paper describes how to reinforce the credibility of a solution concept with tradeoffs characteristics in term of mathematical values by using optimization in order to achieve targeted design parameters of each solution concept then validating/rating/selecting them under explicit condition. The overall structure of the paper is organized as follows: section 2 reviews the relevant state of art; section 3 details the methodology and demo software platform proposed by the authors. A case study is presented in section 4 while the paper ends with a conclusion and future work section.

2. Literature review

2.1 TRIZ & IDM TRIZ

TRIZ is now increasingly used during creative phases when attempting to solve problematic situations. The key to success in TRIZ is the fact that (technical) system evolve in similar ways, so by reducing any situation and its associated problems to an abstract level independent from the domain of the technical system (namely the contradiction), it is possible to apply standard solutions and problem solving techniques generalized from the observation of hundred thousands of patents from various field of technology.

From previous work of Zanni-Merk et al. (2009, 2011) and Rousselot et al. (2012) one of authors has been working in the formalization of the central notions used in TRIZ and has conceived an extension of the method, called inventive design method (IDM). The four major steps of it start with: 1) Analysis of the initial situation, 2) Contradiction formulation, 3) Synthesis of solution concepts and 4) Choice of the solution concepts to develop. At the third step, the key components of the contradictions will be uses as input to generate solution concepts assisted by computed TRIZ techniques. This framework has already been published and has been the object of an existing software prototype namely STEPS (Systematic Tool for Efficient Problem Solving, *http://www.time-to-innovate.com*). In STEPS, each solution concept present with roughly sketch image file and *xml* file (Extensible Markup Language, *http://www.w3.org/XML*) that consists in a description template that features an abstract description (phrase and context) and a fully described Technical Contradiction (TC). A TC is characterized by a set of three parameters. An Action Parameter (AP) is characterized by the fact that it has a positive or negative effect on another parameter: an Evaluation Parameter (EP) that can evolve under the influence of one or more AP. It allows measuring the degree of satisfaction or dissatisfaction. Furthermore, designers can define AP and EP using physical units. For example AP1 (action parameter1: area in m^2) and EP1 (evaluation parameter: stress in N/m^2) for the reason to present more physical context of the problem system.

2.2 Modeling / Simulation

Neelamkavil (1987) expressed the common definition of model as *"A model is a simplified representation of a system intended to enhance our ability to understand, predict and possibly control the behavior of the system"*. A model can be of a mental, verbal, physical or mathematical nature. It divided into three major categories: 1) descriptive model that explain the essential aspects of existing systems, 2) Constructive models that describe systems to be constructed, 3) Abstract models that are used for modeling a certain class of phenomena, but not (yet) applied to a specific systems. In engineering domain, they build formal models of physical systems to evaluate design parameters or to verify that it meets requirements. Typically, they build mathematical models that are amenable to automated analysis and simulation. A mathematical model is a representation of the essential aspects of an existing system (or a system to be constructed) which presents knowledge of that system in usable form.

Roozenburg and Eekels (1995) described the term simulation as *"The simulation refers to forming an image of the behavior and properties of a designed product by reasoning and/or testing models or the execution of a model in order to predict the properties of a design proposal"*. Here simulation always refers to the execution of a model in order to predict the properties of a design proposal.

One of the most basic requirements for simulations in the context of design is that the modeling language be *sufficiently expressive* to model. Another requirement is that *simulation models be easy to create and reuse*. Fishwick (1998) has been classified the simulation modeling paradigms and language according to the following criteria: graph-based versus language-based paradigms, procedural versus declarative models, multi-domain versus single-domain models, continuous versus discrete models, and functional versus object-oriented paradigms.

2.3 Optimization

Rao (1996) stated the Optimization as the act of obtaining the best result under given circumstances; it can be defined as the process of finding the conditions that give the maximum or minimum value of a function. Optimization problems can be classified based on

the type of constraints, nature of design variables, physical structure of the problem, separability of the function and number of objective functions. A growing number of optimization methods have been developed for solving different types of optimization problems. *Classical optimization techniques* are useful in finding the solution or unconstrained maxima or minima of continuous and differentiable functions. *Modern optimization techniques* also sometimes called nontraditional optimization methods, have emerged as powerful and popular methods for solving complex optimization problems.

3. Robust Solution Concept Modeler

In this work, IDM –TRIZ and STEPS will be considered as concept generation method and support tool respectively, which the result of this task is solution concepts. The physical units of each contradiction will be used as a secure key in our approach during the modeling task.
According to the objective, we start with some questions that always confront the designer during tradeoffs characteristics of solution concept. First we have to consider what properties the artifact should have, i.e. what are the values that we want to create, and how shall we be able to measure them? Secondly, which are the design variables, or system parameters that we could manipulate in order to achieve the best possible design? Finally, how do we articulate what is actually the best possible design characteristics? All of these questions guide to propose an approach to answer them, and define as workflow in **Figure 2**.

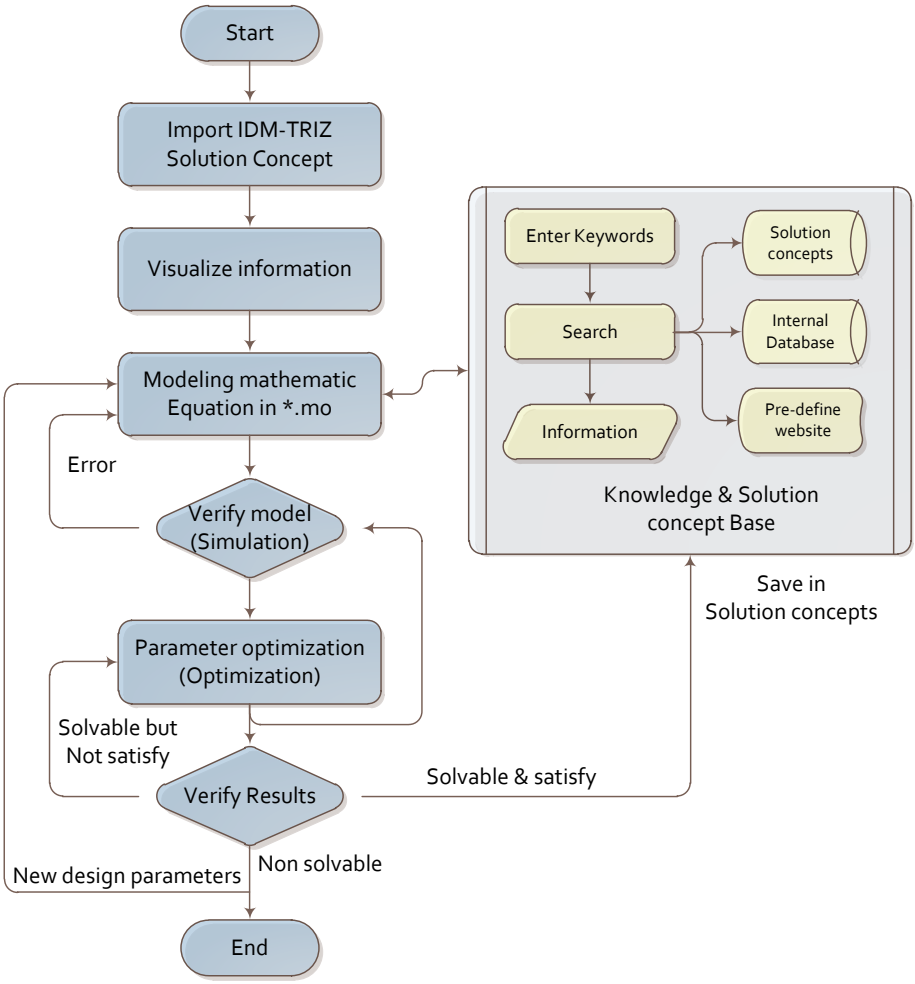


Figure 2. Flow chart of Robust Solution Concept Modeler (RSC-Modeler)

From the workflow in Figure 2, after importing and visualizing the solution concept from STEPS, the process starts with designers that will simplify and translate it into mathematic problem, and mathematic models. Each solution concept is obtained with the assistance of a knowledge base *(answer first and second question)*. Then the model is validated with eventual simulations. When the model is validated the optimization will be used to evaluate/generate the new design parameters in order to reach all best possible solution *(answer final question)*. Optimization as it is employed here is based on simulation results, possibly from a large number of different simulation environments. When the process is done, designers will have the pre-design characteristics in term of mathematical values. These results lead to the concept selection task under explicit conditions.

A prototype platform namly RSC-Modeler has been developed in JAVA language under integrated development environment Netbeans *(http://netbeans.org)* and can be clustered in to 6 modules: import, visualize, knowledge base, editor, simulator and optimizer. The mathematical model formulized in Modelica *(https://www.modelica.org)* syntax format. In this work Openmodelica *(https://www.modelica.org)* has been selected and used as simulator with Openmodelica optimization Editor (OMOptim) – a sub-system of the OpenModelica platform is used as an optimizer. The technology to realize the communication between ***the RSC-Modeler*** and Openmodelica is CORBA *(http://www.corba.org)* – the *Common Object Requesting Broker Architecture* is a standard defined by the OMG *(Object Management Group, http://www.omg.org)* which enable software component written in multiple computer languages to work together. One of a screen shot of RSC-Modeler is presented in **Figure 3**.

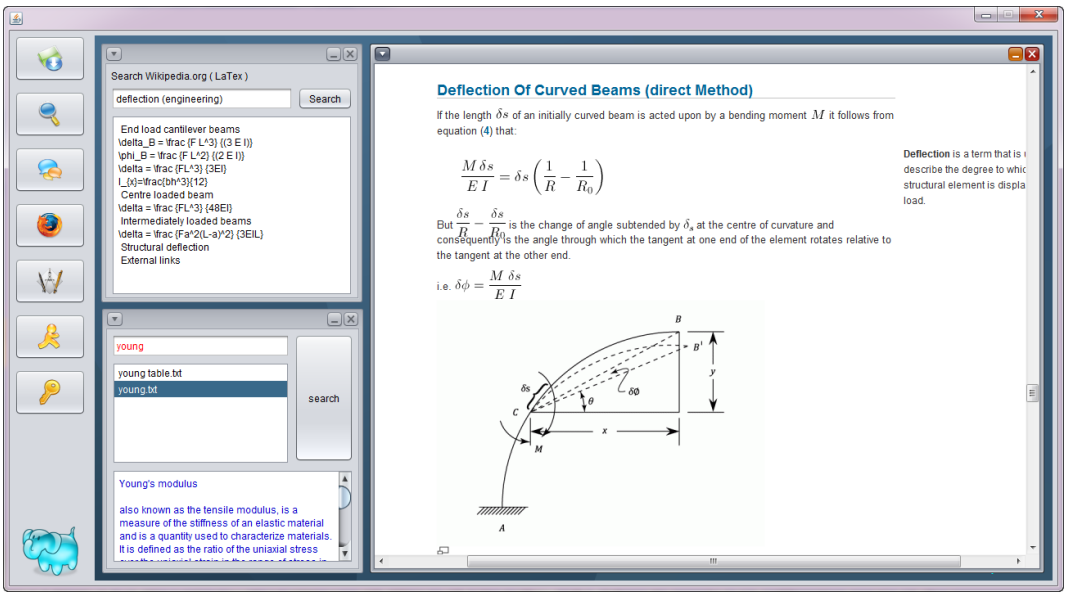


Figure 3. A screenshot of knowledge base searching module**.**

4. Case study

In order to validate our proposed approach and prototype platform, a simple case study will be presented. In this case study, the solution concept is considered as feasible so we will deal with the question how to tradeoff all best possible characteristics of the conceptual design solution in order to speed up the next embodiment and detail design phase.

The objective of the design project is new table lamp multi-functional with 2 objectives: 1) illuminate working area on the table *(with focus)*, 2) decorate *(without focus)*, after using

Inventive Design Method (IDM) and STEPS tool, contradictions of this project presented in **Figure 4**.

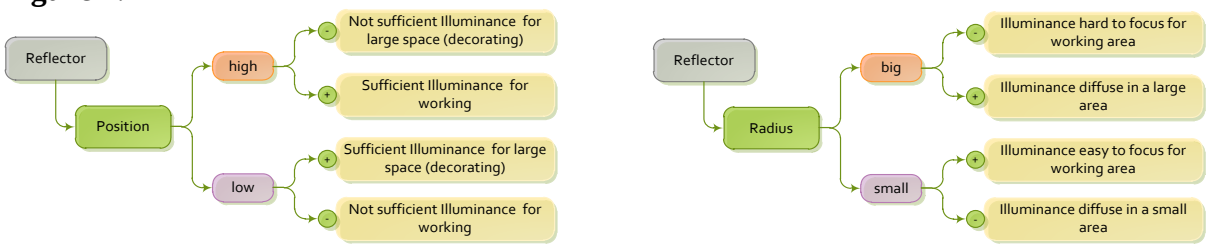
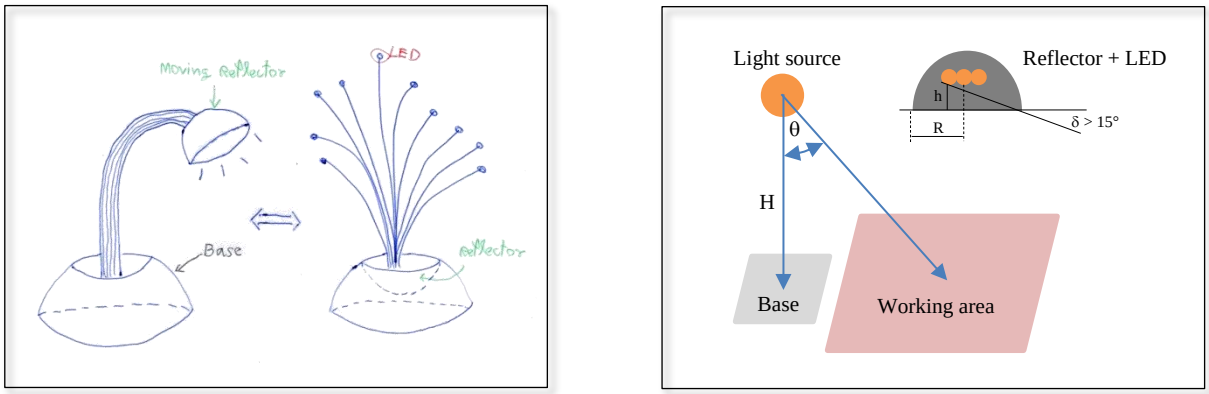


Figure 4. Contradictions of design project consider at reflector.

With the contradiction information, the key problems are the position and dimension of the reflector, then the *moveable reflector* is proposed to satisfy the objectives. The roughly sketch one of the solution concepts presented in **Figure 5a**. The *Description* of this solution concept: using LEDs as the light source with moveable reflector as switch between illuminating or decorating, stationery slot (pen, pencil, rubber and etc.), the dimension of base/support not over 20x20cm. and maximum height (H) around 35 – 50cm.

From the solution concept information (sketch and description), the dimension of base is depend on the dimension of the reflector and the dimension of reflector is depend on number of LED used. While the number of LED controlled by luminance requirement in difference working area. Then the analytic model of this solution concept is presented in **Figure 5b**.



a) b)

Figure 5. a) Rough sketch of a solution concept**,** b) simplified as analytic model

Refer to the approach in **Figure 2**, the designer model/reformulate the solution concept as optimization problem, guided by the solution concept information, the context and the assistance of a knowledge searching function. Then two necessary equations were found: 1) Illuminance on the surface 2) Reflector shielding angle. With the editor module, a mathematical equation model is automatically found on knowledge base and formed as mathematical model (Modelica format, *.mo). After that, We then verify and simulate with the initial values by interacting between ***the RSC-Modeler*** and Openmodelica via CORBA communication protocol. Finally, with the validated model we call and import the model into Openmodelica Optimization editor from ***the RSC-Modeler*** and set the objectives in Table 1, and range of each parameter with the value in Table 2.

Table 1. Setting the range of each objective.

Objective	*Min*	*Max*	*Unit*	*Comment*
NLed (N)	10	15	-	Number of LED (Minimize)
Illuminance (E)	500	700	lux.	Illuminance requirement (Maximize)
Shielding angle (δ)	15	25	deg.	Degree of shield of the light source by a reflector within luminaire (Maximize)

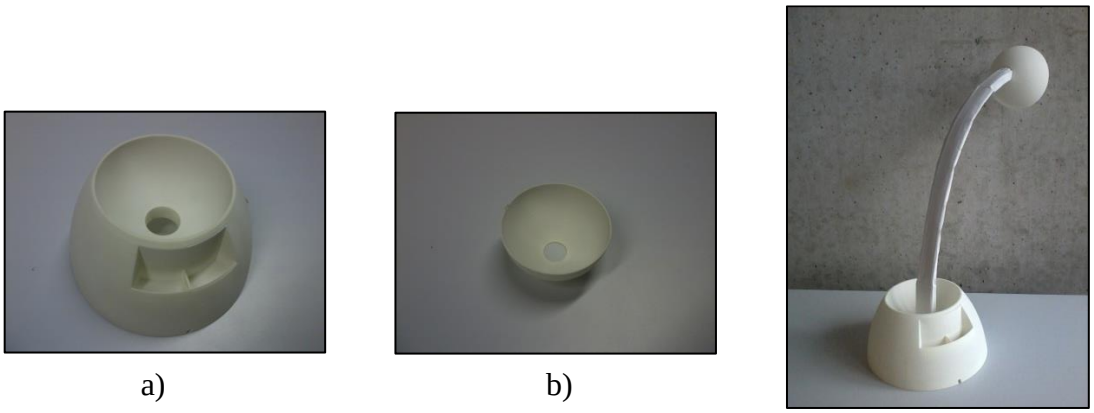
Table 2. Setting the range of each parameter.

Parameter	*Min*	*Max*	*Unit*	*Comment*
Projection angle (θ)	35	45	deg.	Angle from reflector to working area
LED position (hled)	0.01	0.03	m.	Install position of LED light source
Reflector radius (R)	0.03	0.07	m.	-
Height from base (H)	0.35	0.5	m.	Height maximum from base to reflector

After importing and setting parameters/objectives, for running the optimization process, the NSGAII is used as an algorithm, with the population size =50, and Max Iteration =450. The results are presented in Table 3. With all calculation results obtained, the solution concept has now gained credibility and robustness. It reached all admissible requirement such as base < 20x20 cm. because the radius of reflector (R) is < 10cm., illuminance > 500 lux for table in the office within optimal number of LED around 10 – 13 LEDs. (at the first time, design group decided for 25 LEDs), and reflector shielding angle > 15°. From the results, our platform gives us certain information and can help us speed up the design process for example in the CAD modeling (embodiment) until prototyping task as presented in **Figure 6**.

Table 3. Results from optimization.

Parameters , objectives	*ID.0*	*ID.1*	*ID.2*	*ID.3*	*ID.4*	*ID.5*
Projection angle (θ, deg)	36.973	46.332	44.496	36.892	42.235	41.319
LED position (hled, m.)	0.022	0.025	0.023	0.019	0.016	0.017
Reflector radius (R, m.)	0.045	0.063	0.058	0.041	0.040	0.040
Height from base (H, m.)	0.461	0.410	0.417	0.466	0.399	0.409
NLed (N)	11.516	13.985	12.759	11.732	10.335	10.518
Illuminance (E, lux.)	690.65	684.499	663.577	690.884	656.266	663.223
Shielding angle (δ, deg.)	20.100	24.094	24.298	20.223	23.761	22.951



a) b) c)

Figure 6. Prototype of case study, a) Base/Support, b) Reflector, c) New table lamp

5. Conclusion and future work

Through this paper, we proposed an approach to increase the robustness of a solution concept having tradeoff characteristics in terms of mathematical value by using optimization. The main purpose of our approach is to rapidly estimate feasibility of a given solution concept and speed up the validating/rating/selecting task in conceptual design phase. During this research investigation, a software prototype was built (RSC-Modeler) with an associated protocol of usage, aiming at rapidly basing decisions to further invest or abandon a solution concept not on intuitions, but on pre-estimated mathematical facts.

RSC-Modeler provides a searching module to obtain the matching information from knowledge base, a simulator and optimizer modules using existing open source tools to rapidly estimate feasibility and/or tradeoff characteristics of solution concepts. As reveled during the case study, our software prototype has found the satisfying values. These results are obviously filling the gap between an abstract solution to a much more robust and optimal one in quantifying for instance, the manner of number of LEDs and, the potential dimension of reflector. Our future work will mainly focus on two aspects. Firstly, we need to improve the current technique to translate abstract solution to optimization problem. Here, we want to reformulate the structure of the assistance provided and modify the way solution concept are first expressed in STEPS to better match a targeted knowledge base and instantiate, through its parameter, optimization directly (up to now there is still an important human manipulation, therefore a risk of error). Finally, we would like to investigate new knowledge bases (web-based one) to support multidisciplinary design domains as their complexity will more obviously benefit from computer-based assistance.

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Study on Radical Innovation Technology Prediction Based on TRIZ Final Ideal Solutions and Technology Evolution

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Abstract

Radical innovation (RI) is a high efficient technology innovation for modern enterprises to participate in market competitions. It's the great significance to upgrade technology and enhance the capability of the independent innovations for enterprises. For the mature period product, the radical innovation inherent basic law is revealed after further studying on product technology system evolution process. After the product technology system was decomposed, we can summarize the core functions and core technical subsystems and analyze the current technology evolution state of the product core technical subsystems. The direction of technology evolution is constrained by changing principle and updating system of the TRIZ final ideal solutions in order to select the direction of technology evolution and technology evolution route. The technology prediction model of product technology system for RI is established. As a case study, the belt conveyor technology system is investigated. The study shows that the adoption of TRIZ final ideal solutions and technology evolution theory in forecasting radical technologies of product is feasible.

Keywords: Radical innovation, Technology system decomposition, Technology evolution, Technology prediction model for radical innovation

1. Introduction

Since technological innovation theory has been put forward by Schumpeter, according to the difference of the innovation strength, the technological innovation is divided into the Incremental Innovation (II) and Radical Innovation (RI).Incremental innovation is the gradual and continuous innovation caused by improving and perfecting of the existing technology. Radical innovation is the major technological breakthrough and discontinuous innovation. The radical technology is the specific measures for implementing radical innovation. It is not adjusted or improved for existing technology in accordance with the market needs of the mainstream users, but there is the new technology of the inflection point in the industry's core technology track, exceeding

the original technical performance and generating the new technology to replace the original technology, which open up a new the direction of technology development and meet the market needs for potential users. As with the other technologies, radical technology is the result of technology evolution and is the special node in the technology evolution route. It can be predicted by using technology evolution theory.

In the field of technological innovation management, radical innovation is defined to meet the following two conditions[1]: the brand new product concept and the significant changes of the connection between the product core components by Henderson and Clark. Richard[2]considers that meeting one of the following conditions can be called radical innovation: the brand new product features, improving the existing performance index five times at least, reduction of 30% for the cost of the product at least. Zhang[3]thinks that radical innovation results in the product performance index dramatically changed or has a significant impact on the rules of the market and competitive situation. Richard[4]establishes the process model for the radical innovation based on a large number of engineering projects for radical innovation from the life cycle perspective. Zhang[5]discriminates the concept of radical innovation in the stage of product fuzzy front end (FFE) and systematically elaborates the contents and steps of FFE management. The above studies are based on the definition and macro model of radical innovation and this kind of models is not suitable for the actual product development process.

This paper argues that radical innovation happen in the mature stage of the product life cycle. The technology prediction model of product technology system for radical innovation is established based on TRIZ final ideal solutions and technology evolution make it possible for product practical application development.

2. Methodology

2.1 Product technology system performance limit

As is shown in Figure 1, the historical data shows that technical performance appears S-shaped curve with variation of the time. With the time passed, the S-shaped curve is significantly close to a straight line, which is the technical performance limit determined by the natural properties of the technology system. The technical performance limit determines the level of the idealization of product technology system.

In the evolution process of the product technology system, Incremental innovation is the continuing innovation evolving from a to b along the current technology

track in the same S-shaped curve. Besides, the continuing innovation transits A curve to B curve is the racial innovation from the current technology to the more advanced technology.

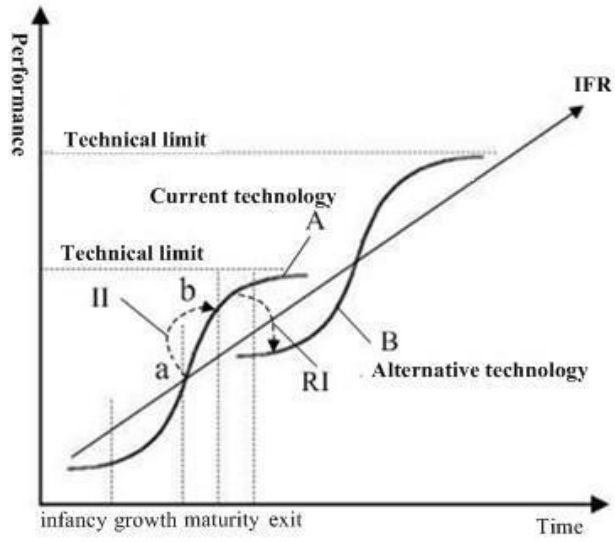

Figure 1. Product technology system performance limit.

The S-shaped curve of the product technology system is made up of the infancy, growth, maturity and exit period. In the growth stage of the product evolution, enterprises continue to improve and perfect the technology to improve product performance continuously, but radical technology is far from perfect at this stage. With the maturity stage of the product evolution, the product is profitable. On the one hand, enterprise has further improved the existing technology, on the other hand, reduced the cost of product in order to make more profits and compete with other enterprises. With the maturity later stage of the product evolution, product technical performance has basically reached the technical performance limit which appears that profits fell sharply and benefits reduce significantly. The existing product replaced by the new product is the inexorable law. So, the paper argues that the time of racial innovation happen in the mature stage of the product life cycle, the best time for mature later stage.

2.2 The radical innovation of the product technology system

As is shown in Figure 2, a complete product technology system mainly consists of four parts of the power system, transmission system, execution system, control system[6]. There are two main methods for radical innovation of product technology system[7]: one is the working principle of innovating technical subsystem from the perspective of the execution system, and the other is the power system and control system of innovating technical subsystem from the perspective of the other three technical subsystems. Changing the technology principle of the technical subsystems create the brand new technologies and working principle of products replacing the working principle of the existing products to achieve radical innovation of the products.

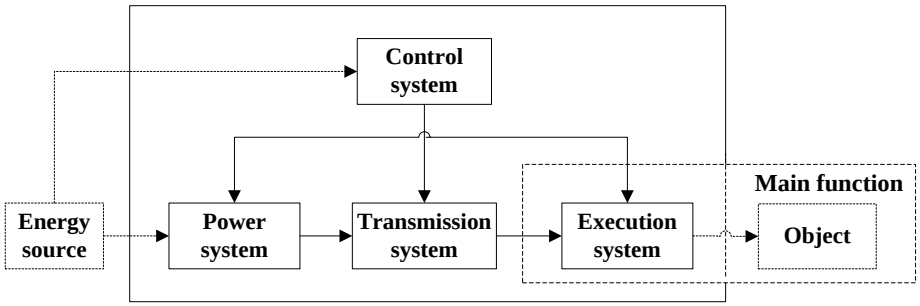

Figure 2. The composition of the product technology systems.

The product is realization of the function. According to the use of the function, the function of the product can be divided into the drive function, transmission function, executive function, and control functions[8], which can describe the basic functions of the product technology system[9]. The important significance of the existence for the system is to realize the executive function which directly achieves the main function of the system. The other function are consider as auxiliary functions, play a supportive role in realizing the main function of the product in order to better achieve the main function of the product technology system. The product technology system contains a number of subsystems can achieve a certain function. These subsystems respectively achieve each of the sub-functions integrating to achieve the total function of the system.

2.3 Product technology system decomposition

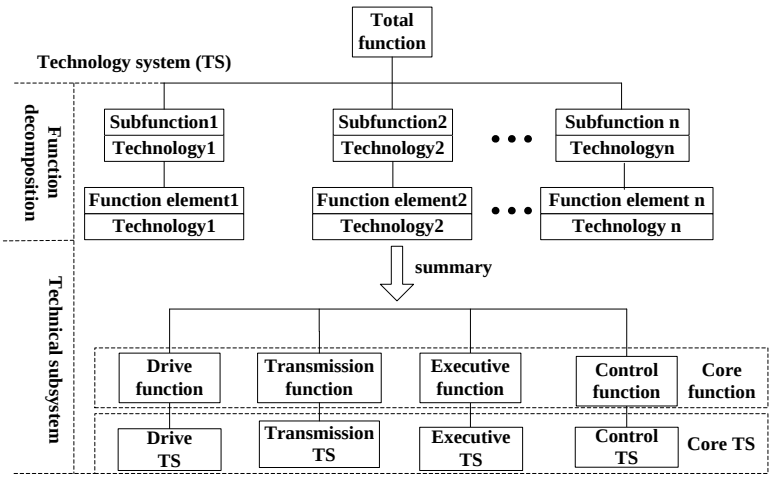

Figure 3. The decomposition model of the product technology system.

For the technology can realize the function, the function tree method

can be used to decompose function and the process of product function decomposition accompanies with the product technology system decomposition. Figure 3 shows the decomposition model of product technology system based on function tree. In the decomposition process of product technology

system, product total function can be decomposed into function elements step by step, and then each function element is mapped to the technology.

Then we can summarize the decomposed function elements by using the vocabulary of the Stone function base[10] and conclude the drive function, transmission function, executive function, control function and the corresponding drive technical subsystem, transmission technical subsystem, executive technical subsystem and control technical subsystem. Because these functions and the corresponding technical subsystems play the necessary role in the constitution of the whole product technology system, this paper summarize them as core functions and core technical subsystems.

2.4 Evolution analysis of the product technology system for RI

The technology opportunities for RI come from product core technology subsystem emerge two states of performance lead state(PLS)and performance deficiency state(PLS), while product core technology subsystem performance approaches the technical performance limit. Therefore, the technology opportunities for RI have close relationship with technology system evolution state.

2.4.1 Evolution state of the product technology system

As is shown in Figure 4, we use radar charts for expressing the technology system. Supposing a whole technology evolution system E_t is made up of 4 core technical subsystems named drive technical subsystem, transmission technical subsystem, executive technical subsystem and control technical subsystem, $E_t = \{E_{t1}, E_{t2}, E_{t3}, E_{t4}\}$.The real line areas represent for technical performance and broken line areas represent for user needs. There are 5 kinds of typical state in the technical system process:

(1) Optimal Performance state, OPS. The performance of each technical subsystem can meet user needs (Fig.4 a).Systemic performance could already meet user needs at this time.

(2) Performance lead state, PLS. While the performance of product core technical subsystem approach the technical performance limit, the performance of some core technical subsystem significantly exceed the user needs (Fig.4 b).In order to cope with the brutal competition in the market, enterprises need to farthest improve the performance of some product core technical subsystem departing from the user needs to reach a new technical performance limit beyond the original performance limits. So, PLS is regarded as the opportunity for

produce Radical Innovation.

(3) Performance deficiency state, PDS. While the performance of product core technical subsystem approach the technical performance limit, because of the highly increasing of user needs or the evolution deficiency of product core technical subsystem (Fig.4 c), user needs exceed the original

technical performance limit and the performance of some product core technical subsystem significantly lower than the user needs. Therefore, improving the technical performance of core technical subsystem reach a new technical performance limit in order to meet user needs, beyond the original technical system performance limit. So, PDS is also regarded as the opportunity for produce Radical Innovation.

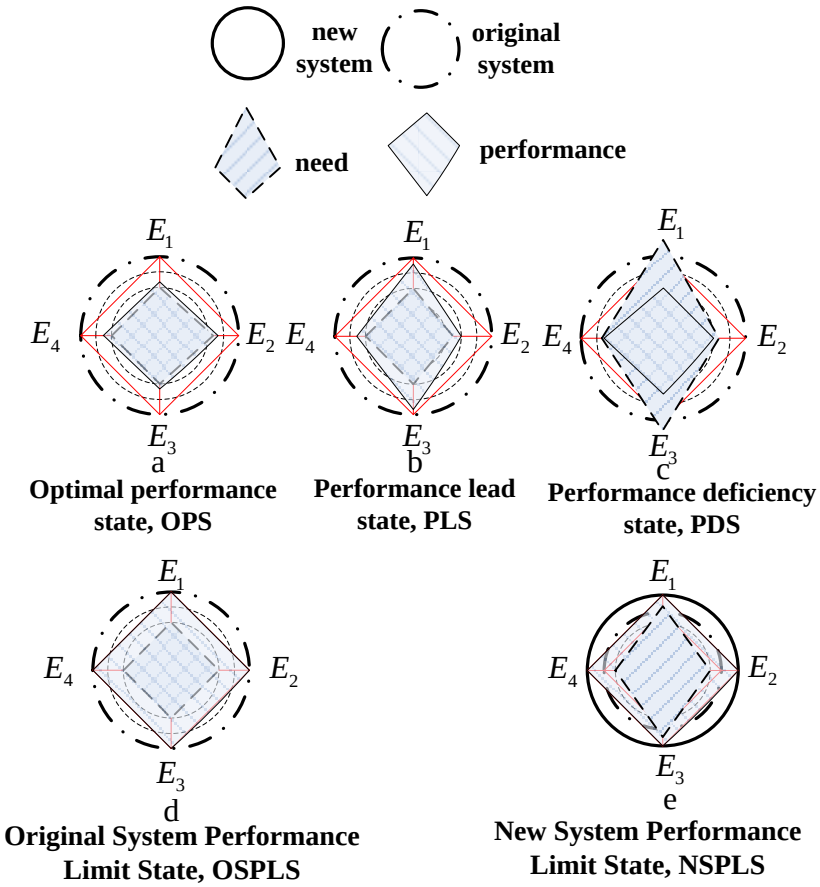

Figure 4. The evolution state of product technology system.

(4) Original system performances limit state, OSPLS. The performance of each core technical subsystem meets the original system performance limit (Fig.4 d). When the product core technical subsystem performance approaches the technical performance limit, Enterprises should further continue to perfect the existing technology in order that the performance of product technical system has basically reached technical performance limits. OSPLS is the goal for Incremental innovation.

(5) New system performances limit state, NSPLS. The performance of each core technical subsystem reaches a new technical performance limit beyond the original technical system performance limit(Fig.4 e).While product core technical subsystem performance approach the technical performance limit, enterprises should actively research and develop or select a new core technology to replace existing core technology in order that launching a new generation of products enable enterprises to win in the future market competition. NSPLS is the goal for Radical Innovation.

2.4.2 The process model of the product technology system for RI

Technology system evolution appears as the resultant force of each subsystem evolution and the process of technology system evolution is just the process of product innovation. Product continuous innovation is made up of incremental innovation (II) and radical innovation (RI). In the process of technical system evolution, both innovations always run through of them.

As is shown in Figure 5,in the process of incremental innovation, product technology system evolve from S_{n-2}, S_{n-1} to current state of S_n which is located in the mature later period and $E_3 > E_{n3}$ which we can conclude from S_n .Therefore, E_3 is the hotspots in the market competition of the process for incremental innovation. PLS has already appeared in the evolution process of product mature period. Moreover, user needs to E_{n1}, which is the need to subsystem E_1, is always increasing. However, E_1 isn't increasing accordingly and this result in $E_{n1} > E_1$ when the evolution comes to the current state of S_n .So PDS also appears in technical system evolution.

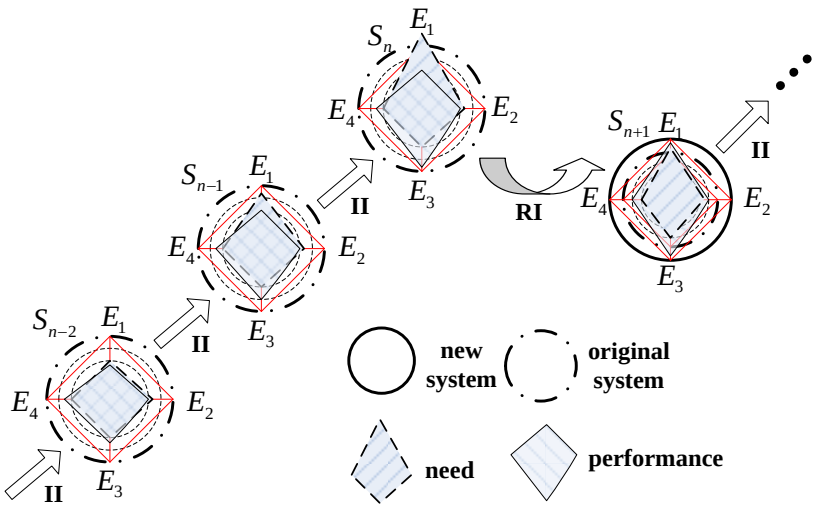

Figure 5. The process model of product technology system evolution for RI.

S_n has the two evolution processes for radical innovation which are as follows, according to the definition of S_n state above:

(1)To PLS: enterprises need to farthest improve the performance of E_3 technical subsystem departing from the user needs to reach a new technical performance limit beyond the original performance limits. At this moment, in the potential state S_{n+1}, $E_3 > E_{n3}$.

(2) To PDS: enterprises need to farthest improve the performance of E_1 technical subsystem, reaching a new technical performance limit beyond the original performance limit to meet user needs. At this moment, in the potential state S_{n+1}, $E_1 > E_{n1}$.

3. Technology forecasting model of the product technology system for RI

Idealization is the essence for improving the product technology system. The goal of the product innovation is to constantly improve the level of the idealization of the product technology system. The TRIZ final ideal solutions (IFR) will significantly improve the useful function of the product technical subsystem, while reducing the cost and hazards of the technology system, to break through the limit of the level of the idealization of the original technology system. The Law of technology evolution in TRIZ is the tool to break through the limit for the level of the current idealization.

As is shown in Figure 6, P_s is a technology evolution route of the incremental innovation and P_d is a selected technology evolution route of carrying out the radical innovation. The current status a is located in the mature period and the highest state a+1 is located in the exit period which product evolve along P_s. The current state is closed to the technical performance limit, so it is necessary to look for or select the new alternative technologies.

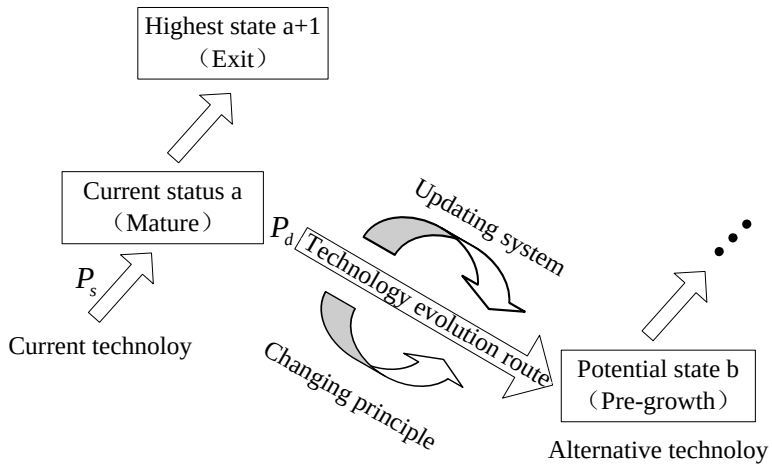

Figure 6.The technology prediction of the product technology system evolution for RI.

If the current status a in the mature period carry out the radical innovation to look for the new alternative technologies, the potential state b of the alternative technology in the pre-growth period which product evolve along the technology evolution path. In order to calculate the potential state b of the alternative technology, first of all, the direction of technology evolution is constrained by changing principle and updating system of TRIZ final ideal solutions to select the technical evolution direction and technical evolution route. And then after the product technology system was decomposed, we can summarize the core functions and core technical subsystems and analyze the current technology evolution state of the product core technical subsystems. The enhanced core technology system selected from products core technology systems is carried out technology evolution prediction. In this process, we can predict the potential state b of the alternative technology after carrying out radical innovation through this state is integrated into the product technology systems.

According to the previously described the process of the product technology system evolution for RI, Figure 7 shows that technology prediction model of the product technology system for RI.

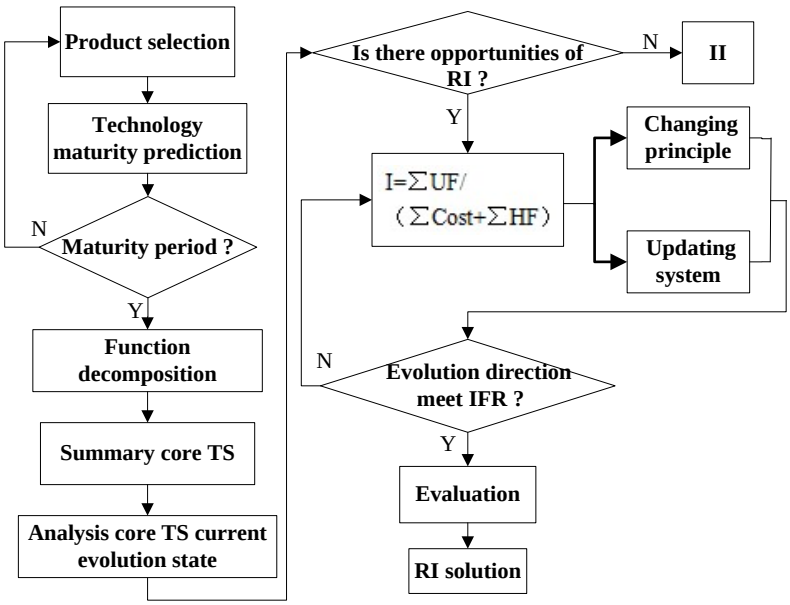

Figure 7. The technology prediction model based on TRIZ final ideal solutions and technology evolution for RI.

Firstly, select a target product according to the enterprise self-condition and the situation of market. If the target product is not in maturity, re-select products.

Secondly, summarize the core functions and core technical subsystems (TS) and analyze the current technology evolution state of the product core technical subsystems to determine whether there are the technological opportunities for RI or not. If not having the technological opportunities for RI, the product can be performed incremental innovation or reselected.

Thirdly, the direction of technology evolution is constrained by changing principle and updating system of the TRIZ final ideal solutions in order to select the direction of technology evolution and technology evolution route. If the direction of the technology system evolution does not meet the requirements of the final ideal solutions, reselect the direction of the technology system evolution and technology evolution route.

Fourthly, the achieved the technical subsystem evolution state is evaluated as the selected program, that is, the radical innovation solutions of product.

4. Case study—the magnetic floating belt conveyor

The belt conveyor is the continuous equipment for transporting materials through the movement of the conveyor for carrying material. The structural principle is shown in Figure8. Conveyor forms the endless belt around the transmission drum and rear drum. The upper and

lower conveyor supported by idler to limit the deflection sag of the conveyor. Tensioning device provide the desired tension for the conveyor running normally. When it works, drive equipment drive the transmission drum and the conveyor is run through the frictional force between the transmission drum and the conveyor. The material is on the conveyor with the conveyor moving together.

Since the ordinary belt conveyor directly contact with the idlers, on one hand, wear increase accordingly maintenance costs increase, on the other hand, friction resistance also increases the power consumption. Therefore, the bearer of the conveyor and its supporting components is the main direction for the improved belt conveyor at present. This paper proposes a new type of belt conveyor innovative idea by using technology prediction model for RI.

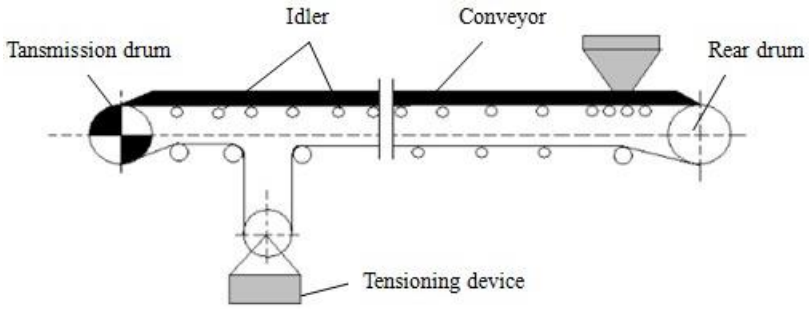

Figure 8. The structural principle of the magnetic floating belt conveyor.

Firstly, Judging by the level of the technology and the situation of the markets of belt conveyor, technology evolution of the belt conveyor has entered the stage of the maturity. Therefore, belt conveyor is selected as the target product for RI.

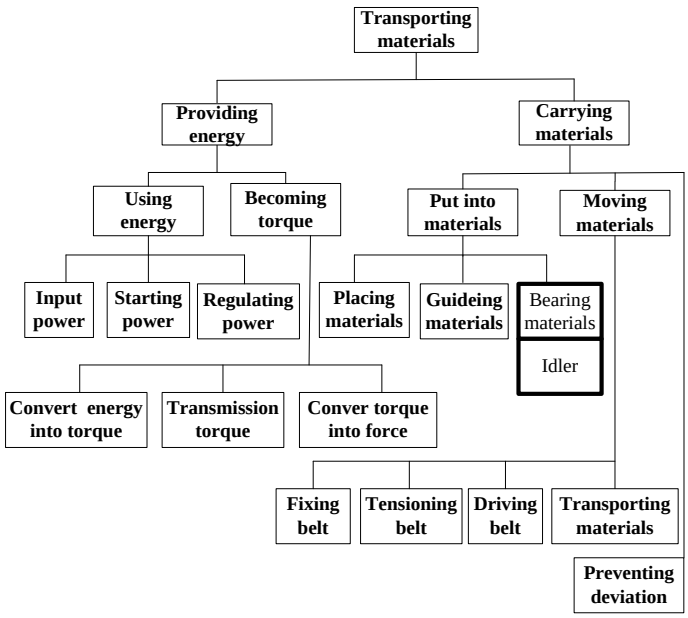

Figure 9. The technology system decomposition of the belt conveyor.

Secondly, the core functions and core technical subsystems are summarized after function decomposition of the belt conveyor. The bearer between the idlers and conveyor is the main direction for improving the belt conveyor to carry out RI, so, this article only lists the corresponding idler technical system of bearing materials. The belt conveyor technology system decomposition is shown in Figure 9.

Thirdly, the technical performance of the idler technical subsystem of the belt conveyor has been close to the technical performance limit after researching and analyzing the technical subsystem current evolution state. The urgent need of reducing the friction and wear for belt conveyor has been far beyond the technology performance limit of the traditional belt conveyor. So there appears the state of PDS in the belt conveyor technology system and exists the opportunity for RI.

The selected technology evolution route of "to the fluid or field evolution" can become technology prediction for RI based on the TRIZ final ideal solutions. The magnetic floating belt conveyor can be designed in order to reduce contact and friction consumption based on the ordinary rubber material belt conveyor. The structural principle of the magnetic floating belt conveyor is shown in Figure10.The corresponding metal powder can be dissolved into the rubber make the conveyor, and then be magnetized so that it became a magnetic elastomer. Moreover, the permanent magnet with the same magnetic of the supported surface is installed on the surface of the supporting conveyor. There will generate the repulsive force between the conveyor belt and the magnet. So, the conveyor can be suspended in the bearing seat in order to achieve a non-contact supporting.

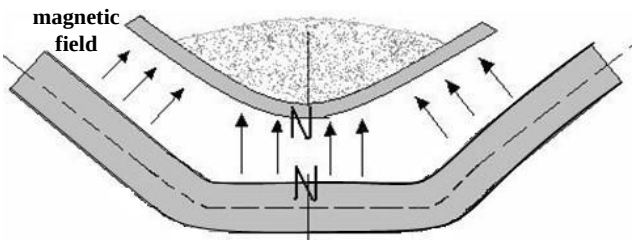

Figure 10. The structural principle of the magnetic floating belt conveyor.

Fourthly, the technology prediction can be realized after evaluating the possibility of achieving the magnetic floating belt conveyor in accordance with the actual situation of the enterprise.

5. Conclusion

The technology prediction for RI is an important reference for enterprises to draw up product development strategy. The technology opportunities for RI come from product core technical subsystem emerge two states of performance lead state and performance deficiency state, while product core technical subsystem performance approach the technology performance limit. After the product technology system was decomposed, we can summarize the core functions and core technical subsystems and analyze the current technology evolution state of the product core

technical subsystems. The direction of technology evolution is constrained by TRIZ final ideal solutions. Finally, the technology prediction model of product technology system for RI is established, providing an effective method for product radical innovation.

6. Acknowledgment

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Research on Extracting the Laws of Product Function Evolution based on Patent Knowledge Mining

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Abstract

The laws of function evolution reflect the interaction among the function units, functional structures and the environment which is significant, stable and repeatable. The method of extracting of the laws of function of product based on patent knowledge mining was proposed based on patent. Firstly, the system components and their interaction are extracted from lots of patents, and then the time series of the functional structures are gotten easily after the functional structures constructed, at last, the laws of function evolution of the products can be found from the changes of the inner functional structures. At the end of the essay the process of the functional evolution of the electric shaver was studied on the basic of the method, and several rules were extracted.

Keywords: The laws of function evolution, patent knowledge mining, functional structure, electric shaver.

1. Introduction

There are three important words in the process of the product design which are demand, function and technology. And close relationships exists among them. All designs exist for satisfying some functions after all , technology is corresponding to function, so technology was the supporter of the functional implementation; however, realizing function is the process of the satisfying the demand of design.

Lin Hai (2008) had proposed that one of the main principles of modern technology philosophy is all the systems were developed as objective rules. Altshuller G S, (1999) had put forward that the system of technology was evolved to the ideal orientation as a predictable pattern. The evolution of the technology system includes demand evolution (Papazoglou and Ionanis A, 1988), function evolution and system evolution (Petrov V, 2002).With the developing of demand evolution and system evolution, the driving of the market and the technology, the function is in the status of evolution. For these reasons, it can be concluded that the changes process of the functions must be followed some rules. But how to find the rules of the function evolutions has not been proposed in existing literatures, so, this question becomes the core aspect of this paper.

According to the systematic design theory, the design process was begin with extracting the total function from the custom demands, and the total function can be divided into several sub-functions and function units. And then asking for the principle answers and getting the corresponding technology structures. In the process, patent was found the effective tool. Patent, a kind of literatures, is regard as the phylogeny of the technology. Details represent of the technology, the technology elements and their composition is included in it. So, the technology elements and their composition can be extracted in patent, and then make the construction of the function structure based on the method of bottom-up, in addition, the laws of function evolution can be extracted followed the rules of the function structure changes.

2. The Laws of Function Evolution

The process of the product design is also a process of design based on function (Li Jian and Deng Jiadi, 2002). Function, the essence of the demand of the custom, is the abstract represent of the relationship between input and output which is to achieve the intent of design. The achievement of the function should be built on the relationship of the exchanging with environment, material and signal, and changing with the development of the system of demand and technology. The laws of technical system evolution must have three levels: demands, functions and systems (Petrov V, 2006). With the demand evolution and system evolution and in the driving of market and technology, function is in the status of evolution. Petrov considered that the evolution of the function should be governed by objective rules and including four evolution laws of function: idealization of functions, growth of the degree of function dynamics, coordination of functions, transition to mono or poly-functionality. And later, someone proposed that the function evolution should be divided to two groups:

- Laws of function organization (those which describe the rules of forming of the new static functions) and
- Laws of function improvement (those which refer to the dynamic development rules of the function).

3. Patent Knowledge Mining

There is a close relationship between technology innovations and patent which is a kind of special literature. It reflects not only the effect between the institution of patent and technology innovation, but the important information output from technology innovation. There are rich contents in patent, which is including technical information, inventor, territorial, legal and time information and so on. The process of studying the functional evolution of the product should be including the evolution of demand and the evolution of technology. The technology information in patent mainly includes the composition of the technical structures and their relationships. Therefore, patent is one of the best tools of studying product innovation.

Patent knowledge mining is a kind of method of patent research, which researches the relevance and the objective rules from a large number of messy patents. On the basis of that, some predicts of trend can be made for the specific technology or its field. In addition, it also can get the important decision information to guide the manufacture and management of a country, an industry or an enterprise.

Patent knowledge mining can make the analysis of the trend of the number of patent application and the developmental information in its field taking advantage of the classical patent analysis, such as IPC (International Patent Classification) analysis, which can give the technical composition of the specific field; Technical efficiency matrix analysis can make a reclassification of all the technical fields and efficiencies, which is good for the research staff to make their purposeful studies. It can make a deep mining with some information mining soft wares, for instance, the participle software can be used to make a deep mining to the abstract and the full text of the patent, and finally find the purposeful information. This paper mainly digs the composition relationships of the system and the relationship of their functional structures in use of the method of patent analysis and the relevance software.

4. Process of Extracting of the Laws of Function of Product Based on Patent Knowledge Mining

The process of extracting of the laws of function of product based on patent knowledge mining includes four stages: Data Preparation, Data Cleaning, Patent Knowledge Discovery and Extracting of laws of function evolution. The process can be described as the Figure 1.

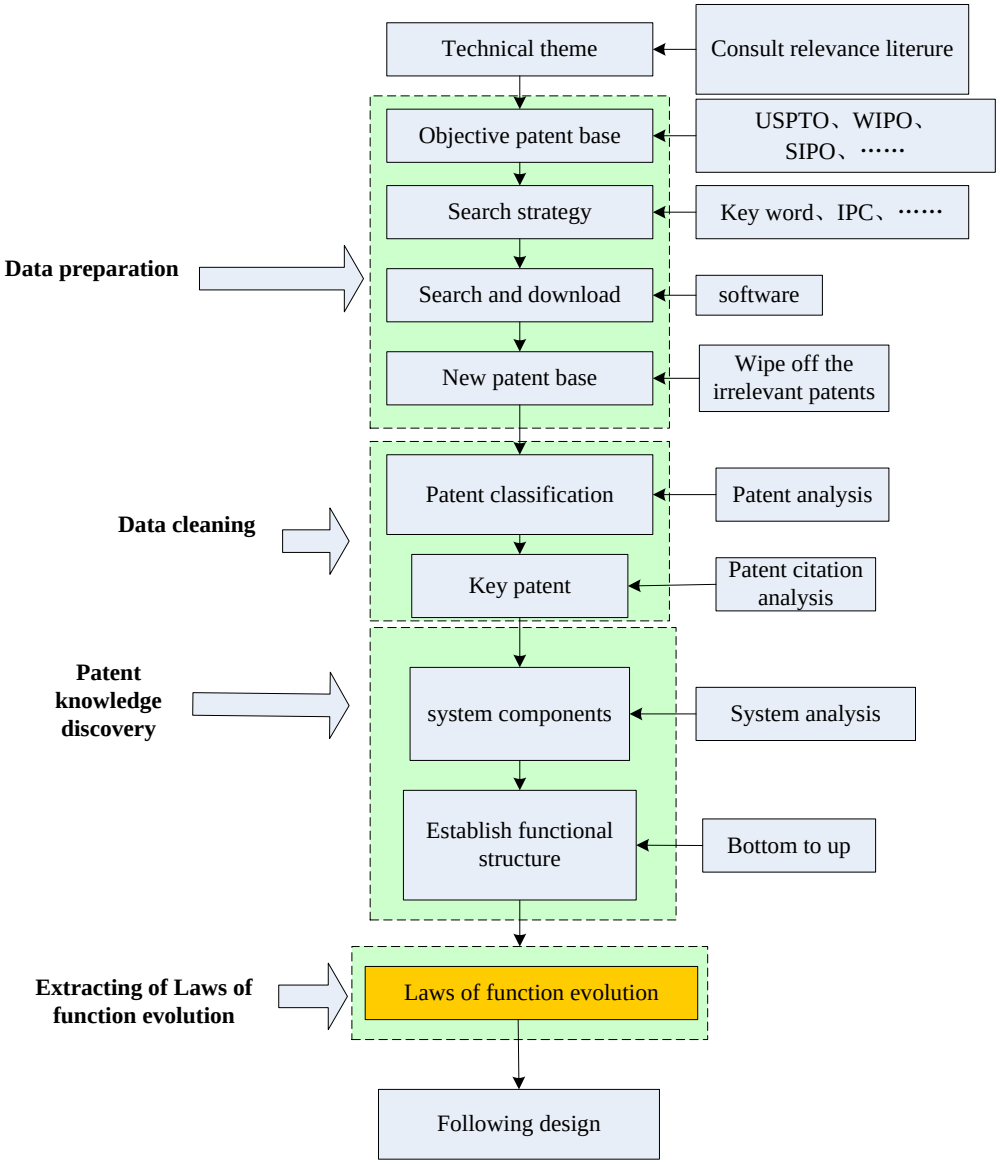


Figure 1. The process of extracting of the laws of product function evolution based on patent knowledge miming.

4.1 Data preparation

The data source is the basic of patent knowledge analysis, the larger the source is, and the messier the information is. So, it is more important to make a corresponding method of the data preparation.

Firstly, determine the research topic according to the design demand and understand the relevance background and aspects. Then choose a suitable patent server, such as USPTO, EPO and SIPO and so on. Define the patent search strategy and approach, several strategies can be

used together to make the search more accurate. At last wipe off the repeated and irrelevant patents, and set up a patent data base.

4.2 Data cleaning

A lot of patents can be got in the phase of 4.1, but those which are messy and chaotic, which is not benefit for the subsequent work, so the phase of data cleaning is needed to make the patent set well-organized. This phase includes two steps: one is the patent classification; the other is the determination of the key patent. The method of patent analysis can be used to the patent classification and based on which the key patent can be found.

1) Patent classification

In this part, the technology-effect matrix patent List, shown as Table 1, should be built on the patent set. The y-axis is the technology structure and the x-axis is the achieved effect after the improvement of the some technical structure, the cross of the y-axis and the x-axis is the list of some patents which can realize the some function effect after improving some technical structure. The construction of the list can realize the classification of the technical structure and function effect, and get the patents in every relevance fields.

Table 1. Technology-effect matrix patent list

Effect Technology	Effect1	Effect2	……
Technical structure1	Patent1, patent2, ……		
Technical structure2		patent3,patent4, ……	……
……			
……	patent5,patent6, ……		patent7,patent8, ……

2) Key patent confirming

A key patent is valuable and its technology that used in products manufacturing has a great impact to the other patents'.

There are many methods to confirm the key patent, such as cites per patent, the number of the patent families and the information of the lawsuit of a patent and so on. This paper adopts cites per patent method to confirm the key patent, for the reason that it is one of the simplest and most effective methods. As is known for all, there are several basic patents or key patents

in every stage of the technical development. The method of cites per patent is an effective method of finding key patent in the massive amounts of patents. A patent must be including important technology when it was cited (5 times, 10 times, 20 times or more), and many subsequent relevant patents are created by it. Usually, every patent's citation quantity is used for the relevant important criterion. Therefore, the analysis of cites per patent provide the proof of the key patent and basic patent.

4.3 Patent knowledge discovery

1) System analysis

The main technical system components and their relationships can be extracted in the method of system analysis. The name of the components, number, and interactional relationship is presented in the specification of the patent, so it is convenience to extract them.

Lexical analysis and natural language processing (NLP) is a mature method that often be used to extract words and sentences automatically. Based on that, we can extract technical system components and their relationships intellectively, and then establish the functional relationship matrix which is shown as Table 2. Write down all the technical components to the x-axis and y-axis, and the relationship between two components to the blank cross of them. The functional relationship matrix can express the effect relationship of every two components. And which will lay a foundation to the construction of the function model which is in the next step.

Table 2. Functional relationship matrix of components.

From To	M1	M2	Pipes	Hangers	Mantle	Pipe-walls
M1	X		Heats(in) Vibrates Elongates			
M2		X				
Pipes		Heats	X			Moves
Hangers	Impedes(ex)		Supports	X		
Mantle	Conducts				X	Holds
Pipe-walls			Supports			X

2) The construction of the functional model

In TRIZ, the functional model analysis is the common method to decompose the complicated system for simple system, which can be used in many aspects, such as finding the functions of the components, expressing the relationship of the composition, So this kind of

analysis method are widely used. In this paper, the construction of functional model can provide a method of ascertaining the standard function. The functional model of the system is shown in the Figure 2.

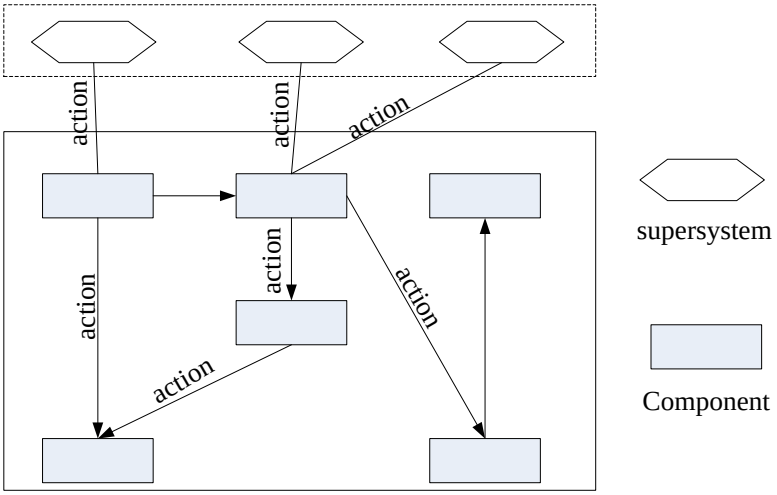


Figure 2. Function model for system.

The simplest functional model is the smallest system that can work, which consists of three aspects: two kinds of materials (S1, S2) and one kind of field (F). It shows that in the field F, S2 acts on S1 and changing S1. The system functional model reflects the function achieved by the components the most, which is system function.

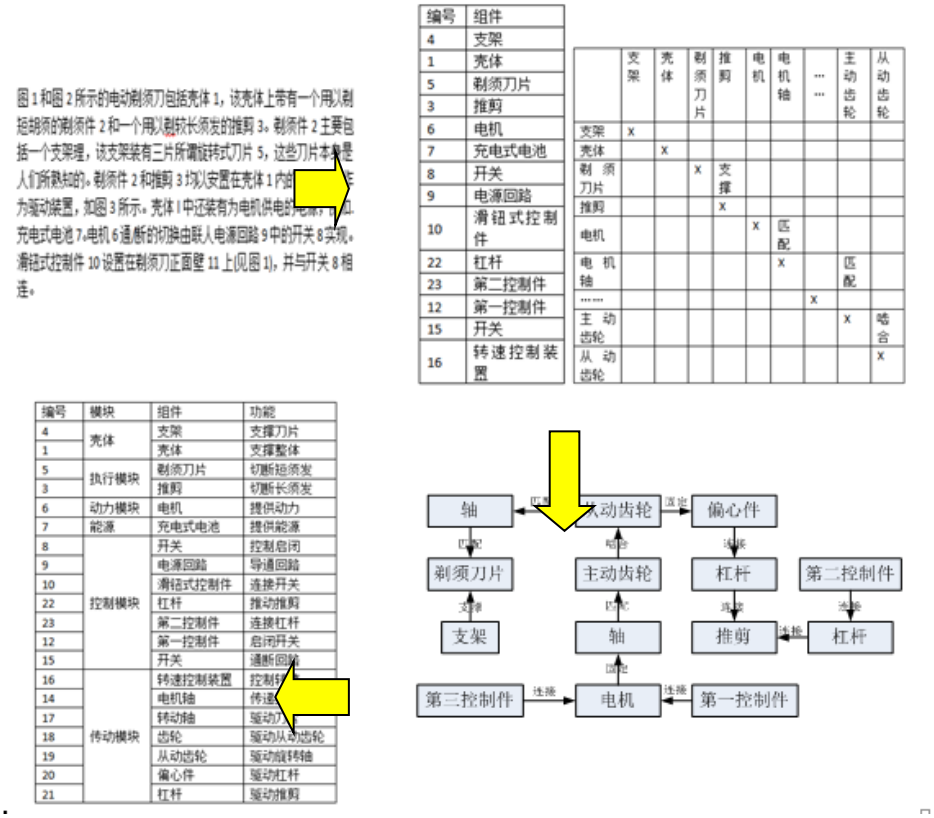


Figure 3. The patent specific description and the process of extracting of technological components.

According to the system components and their relationship shown in Table 2, the system functional model can be established rapidly, and then confirming the standard function of all the components according to the function set (Cao Guozhong, 2006). Figure 3 shows the whole process of extracting components from patents.

3) The construction of the system functional structures

The conceptual design phase is a design process based on the function and principle, and usually the total function of the product should be divided into relative independent sub-functions, and the sub-functions can be divided into several function units which can formed a layer structure. And then all the sub-functions and function units that in the same level can be linked by the input and output flow forming a chain structure. The layer structure and the chain structure constitute the functional structure of the product. However, the functional structure will mutate in the purpose of realizing the function, so the laws of function evolution can be studied by the variation of the functional structure. In this paper, all the standard functions are extracted. According to the system composition, assembly all the function units to sub-functions and assembly all the sub-functions to the total function of the system using the method that from bottom to up, and then establish the functional structure.

4.4 Extracting of the laws of function evolution

The laws of function evolution present the changes rules of the combinations relationship of the sub-functions and function units that inner functional structure, which means that we can extract the change rules of functions from the changing of the functional structures. Based on that, it is obvious that through the analysis of the changing of the sub-functions and the function units, the laws of function evolution can be found.

5. The study of the function evolution of the shaver

5.1 Data preparation

The shaver is the necessity in humans` daily life. It has developed over one hundred years. Through the technical maturity prediction we forecast that it belongs to mature product. Generally speaking, the mature product has a integrated process of evolution, the study of the laws of function evolution should consider the whole development stages of the product, so the shaver is the ideal object of study.

A shaver is mainly consist of shell, motor, tool bit structure and transmission structure and so on. There are several methods for its classification, as the way of the blade action, which can be classified into rotary and reciprocating. The rotary shaver system operates as the way of central rotating, which can cut beard continuously in one orientation. The advantages is Not only make shaving more clean thoroughly and comfortable, but also produce less noises; the reciprocating one cutting beard by the left and right movements of the blade, due to the continuous acceleration, deceleration of the movements, which makes much noises and shock.

Search and download the patent for invention with the key word” shaver” relevance topic and get 140 patents, then wipe off the repeated and irrelevant patents, set up the patent data base, which is shown as Table 3.

Table 3. List of yearly patent application.

Year of application	1990	1996	1997	1998	2000	2001	2002	2003
Number of application	1	3	2	3	2	4	3	8
Year of application	2004	2005	2006	2007	2008	2009	2010	
Number of application	12	8	13	19	6	7	15	
Total	106							

5.2 Data cleaning

1）Patent classification

The Table 4 shows the partial patent list of technology-efficiency matrix:

Table 4. Patent list of technology-efficiency Matrix（partial）.

Effect / Technology	High efficiency	High Reliability	Simple structure
Transmit structure	CN200310102784.0 CN03158514.0 CN200580025403.0	CN200610007046.1 CN200610111465.X CN200710068317.9 CN200810059741.1 CN200810162954.7 CN201010196202.X	CN01805383.1 CN03123951.X CN200510109748.6 CN200710069835.2 CN200710069835.2 CN201010179079.0 CN200580020205.5 CN200710166225.4
Control structure		CN200410006679.1	CN98103907.3
Guidance structure	CN01800072.X	CN97111130.8 CN97117498.9	

2）Confirm of the key patents

As what mentioned before, the several key patents can be determined as follow:

(1) CN90103611 shaver;

(2) CN200310102784.0 shaver;

(3) CN200710166225.4 buncher and shaver.

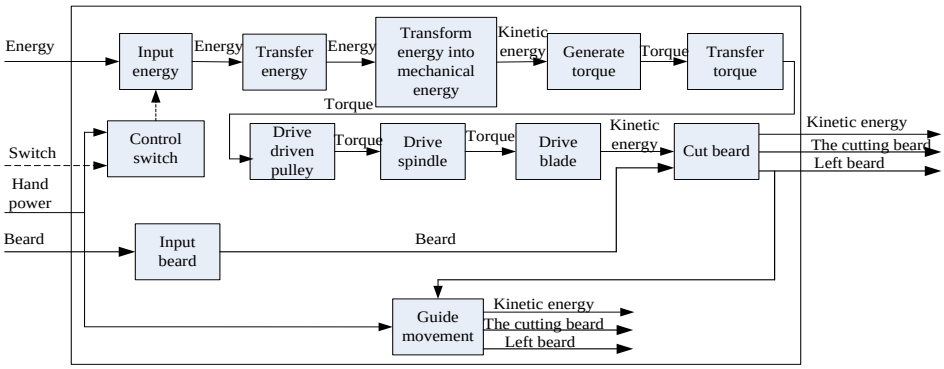
Table 5 shows the partial patent reference quantity analysis:

Table 5. Patent reference quantity analysis（partial）.

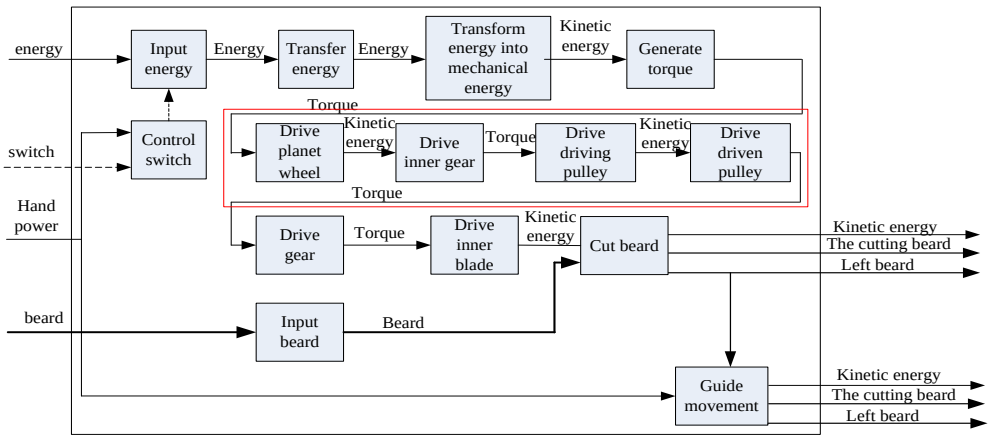
Number	Patent number	Cited number	Citing number	Patent family number
1	CN88103017	1	5	16
2	CN88103231.X	0	0	0
3	CN90103611.0	6	14	16
4	CN96106656.3	13	12	17
5	CN96121421.X	0	0	0
6	CN96123953.0	0	3	14

5.3 Patent knowledge discovery

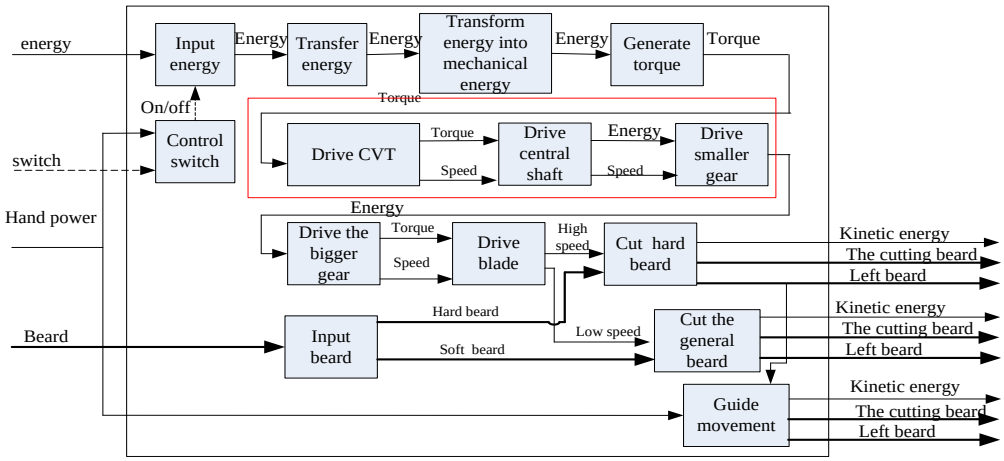
With the preparation of the above steps, the key patents were determined, and then make a detail analysis of the key patents to dig the rules of the inner functional structures changing. After the steps of extracting system components, the construction of the list of the standard functions and the construction of the functional models, the functional structures can be obtained which is shown as Figure 4.



（4a）



（4b）



（4c）

Figure 4. The functional structure of the electric shaver of the three key patents.

5.4 Extracting of the laws of function evolution of the shaver

Through the digging of the content in the key patents, the design requirements, the technical structures that satisfy the function, function structures can be listed, the results was shown as Table 6:

Table 6. The result of the mining the key patents.

	Design requirement	Changing of the functional structure	Changing of technical structure
patentA	Can meet the basic requirements and convenient shaving	The most direct and the simplest functional structure to realize the function of the torque	Fixed gear
patentB	Specified reduction ratio and reduce noise	Realize the transmission torque in use of a series of new functional structures and improve the performance	Planetary gear train and tape drive
patentC	Simple structure, miniaturization, modular/smooth shaving	Realize the transmission torque in use of a few new functional structures and improve the performance	Continuously Variable Transmission

1 The functional structure of the product in the first patent is the simplest. To realize the transmit of the speed/torque using the constant gear technology;

2 To the second patent, the function "Transfer torque" was divided into several sub-functions. Generally speaking, this kind of functional decomposition symmetry "Feng Peien et al. (2012)" will improve the performance of the system. In this performance, it shows the obtaining of reduction ratio, and reduces the noises. Therefore, the corresponding technical structures are the planets wheel drive and belt drive;

3 The third patent, the functional structures present the emerging of new structures in realizing the function "Transfer torque". Make an analysis of the design requirements, when encountering the hard beard, the system will output a high speed, and when coming across the soft beard it will output a low speed.

Functional evolution can make useful function strengthen, harmful function weaken. The working principle of the shaver and the integrity of the system tell that the main function of the shaver is cutting beard. Function evaluated towards the idealized direction. The idealization of functions evolution is a basic law of function evolution, which is also the foundation of the other laws, so the rules of the product function change must conform to it. Considering all of the above, the process of the function evolution of the shaver belongs to the category of functional improvement, so it satisfies the law of function evolution: function controlled.

6. Conclusion

This paper mainly introduces the method of extracting of the laws of function evolution of product based on patent knowledge mining. The main idea is extracting the variation trend of the functional structures from lots of patents. The laws of function evolution reflect the interaction among the function units, functional structures and the environment which is significant, stable and repeatable. So, the corresponding laws of function evolution in the process of function evolution can be deduced from the trend of the functional structures` change. There is little literature about the study on extracting of the laws of function evolution, so this paper is an exploration for this part of aspects, and also provides a method to extracting the laws of function evolution from the patent base. Due to the limited time, lots of product can not be provided to the extracting of the laws of function evolution at my Master graduate student period. But in the future research, some examples are able to be provided to complete the base of the laws of function evolution of the product.

Acknowledgments

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Forecasting Process of Disruptive Technology Based On Function Innovation

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Abstract

Disruptive innovation (DI) is an effective process of product innovation, the technology applied in DI process is called disruptive technology (DT). DI can help enterprises meet the demands of potential customers, customers' needs drive the innovation of product, function innovation essentially. Function innovation is a process of reconstructing function structure through recombining and optimizing functions. It can guide engineers forecast the disruptive technology, and complete the product disruptive innovation effectively. The paper proposes one process of disruptive technology forecasting based on function innovation. Finally, we take electric stew cup for example to forecast its disruptive technology, and get a new smart stew cup.

Keywords: Disruptive innovation, disruptive technology, function innovation, technology forecasting

1. Introduction

Disruptive innovation (DI) was first officially proposed by Christensen in 1997"The work(Christensen C M., 1997)". Christensen holds that DI aims at low-end market or new market, not the existing market. With the progress of technology and the improvement of product property, new product may gradually erode the existing market, even replace the market in existence. Disruptive technology (DT) is the technology applied during the process of DI, so the forecasting of DT is critical for the process of DI "The work (Steven T. W. et al.,2002; Sun J.G. et al.,2011; Chen J.X. Wang M.,2009)".

DI can meet the needs of potential customers and threaten the existing market, because for customers the requirement of a product is essentially the demand for its function, so how to conduct function innovation is critical. Function innovation means the process of recombining and optimizing function "The work (Cao G.Z. et al.2012)". Function-tree is an effective way of decomposing function in TRIZ. We first apply it to

analyze the function of the existing product, and convert new demands into one new function or some design constraints "The work (Guo J. et al. 2012)". DI includes low-end disruptive innovation (LDI) and new market disruption (NDI) "The work (Sun J.G., Tan R.H.2011)". Seen as Figure.1 "The work (Christensen C M. Raynor M E.,2004)" solid line (a) shows the property change of the existing product over time. The changing process from (a) to (b) is the LDI process for the existing product, solid line (b) shows the property change of new product with time going on, this new product is usually got by reducing property index or cost. LDI is effective for the products whose properties are over-satisfied for customers. On the other side, the changing process from (a) to (c) is the process of NDI, solid line (c) shows the property change of the new product over time, this new product is usually got by adding one new function, this function attracts new customers, so a new market space appears.

From the two aspects, we propose a model of forecasting DT according to the way of function innovation, which contains detailed LDI and NDI process.

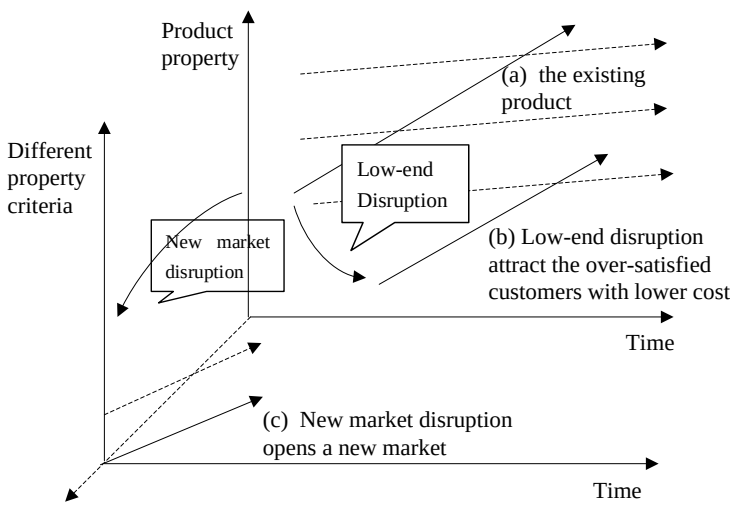

Figure.1 The third dimension of disruptive innovation model "The work (Christensen C M. Raynor M E., 2004)"

2. The Forecast of Disruptive Technology Based On Function Innovation

Customers' needs drive product innovation. The process of satisfying the customer needs continuously is the process of product innovation. LDI is mainly for low-end customers, they always think the product's price is too high, if we can weaken the existing properties of product which are over-satisfied, then the new product may attract these customers. We define these needs as low-performance needs. NDI is mainly for new market customers, these customers have not bought the product before, but if we

add a certain new function to the existing product, the new product may attract them. Because the new function are usually not offered by customer themselves, but found by engineers, so it can bring some surprise to them, we define them as excitement needs.

2.1 The analysis and transformation of new needs

(1) Judge the classification of the new needs

When faced with new needs, we first judge which classification they belong to, whether the needs are over-satisfied. If the needs come from the customers who think the product is expensive or over-satisfied, then the needs belong to low-performance needs. If the existing product can not satisfy the customers' needs, we deem this kind of needs as high performance needs. As shown in Figure.2.

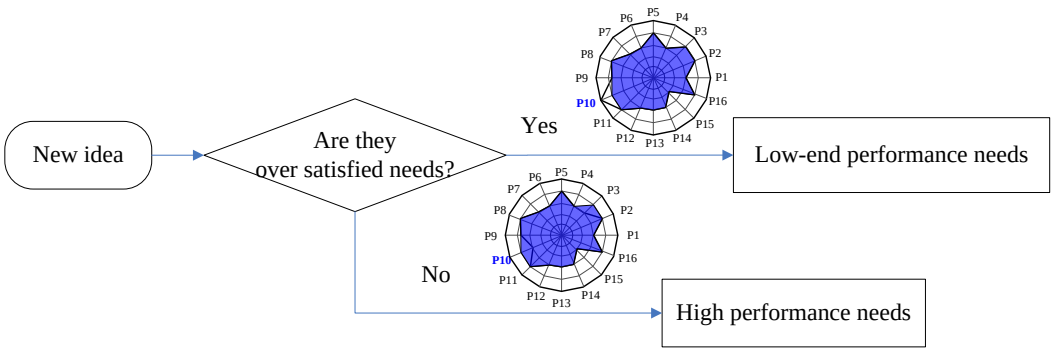

Figure.2 The classification of new needs

(2) The transformation of needs

a. The transformation of new needs in LDI

Faced with low-performance needs, designers need to take the property index into consideration, in the point of low-end customers' view. During the process of LDI, in order to reduce the cost, this category of performance needs are transformed into design constraints (Cs), they act on one or some functions of this product, and they will affect the degree of function realization. As shown in Figure.3.

Figure.3 The transformation of new needs in LDI

b. The transformation of new needs in NDI

Why the high performance needs exist, the current product can not satisfy the society needs well. Faced with this kind of needs, designers think that it is necessary or not to add a new auxiliary function, in order to satisfy the high performance needs. If the answer is "Yes", then the new needs are transformed into new function (FRr), on the other hand, the needs are transformed into some design range(Dr). As shown in Figure.4.

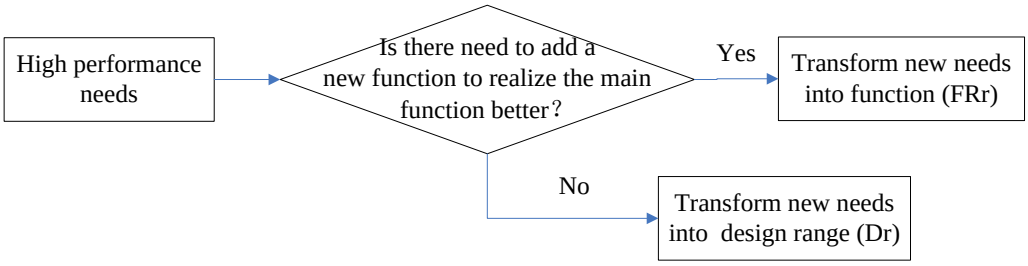

Figure.4 The transformation of new needs in NDI

2.2 The process of function innovation

Function innovation is a process of reconstructing function structure. TRIZ (Theory of inventive problem solving) provides several ways of analyzing function of products, such as substance-field analysis "The work (Darrell L. M. et.al.2008) " .

Here we apply the function-tree analysis (as shown in Figure.5). FR is the total function of the product, FR1, FR2 etc. are the first level decomposition result. FR11,FR12,FR21 etc. are the second level, the function is decomposed level by level until the sub-function can not be decomposed "The work (Tan R.H.,2010)". We fuse the Cs, Dr or FRr into function-tree structure of the existing product, which are transformed from the new needs, and forecast disruptive technology (DT) in LDI and NDI.

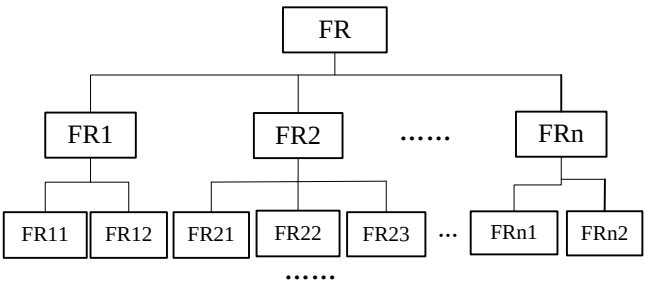

Figure.5 function-tree structure in TRIZ

(1) The process of function innovation in LDI

During the process of LDI, we fuse the Cs into the function analysis of the existing product, the Cs act on one or some sub-function (FR1, FR2, etc.). Suppose the Cs restrict the sub-function FRn, so the result of new function analysis is as shown in Figure. 6.

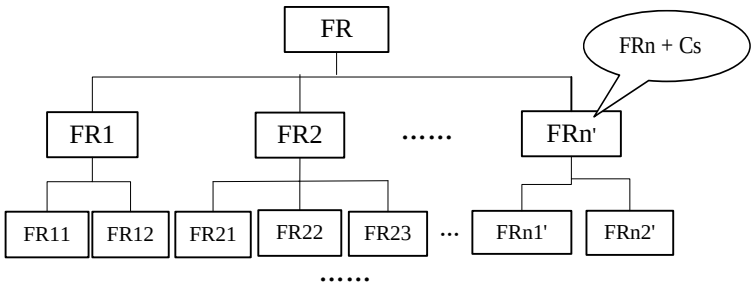

Figure.6 Function innovation in LDI

(2) The process of function innovation in NDI

During the process of NDI, one situation, the new function (FRr) which is transformed from high performance needs should be added at the first level of function decomposition. FRr is auxiliary function "The work (Guo J. et al. 2012)", and it is a sub-function of the new product. The function-tree structure of the new product is as shown in Figure.7.

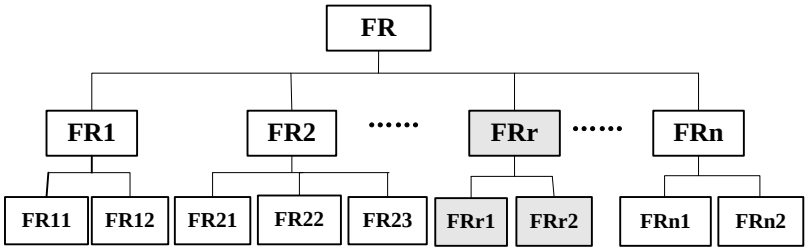

Figure.7 Function innovation in NDI

The other situation, in order to satisfy the high performance needs, designers only improve some performance of the product , and there is no need to add a new function. The design range can affect one or some functions of the product. The model is similar to the LDI model, as shown in Figure.6. The difference is that one is reducing the performance, and the other is improving the performance of the product.

2.3 The forecasting of DT based on function innovation

The model of DT forecasting process based on function innovation is as shown in Figure.8

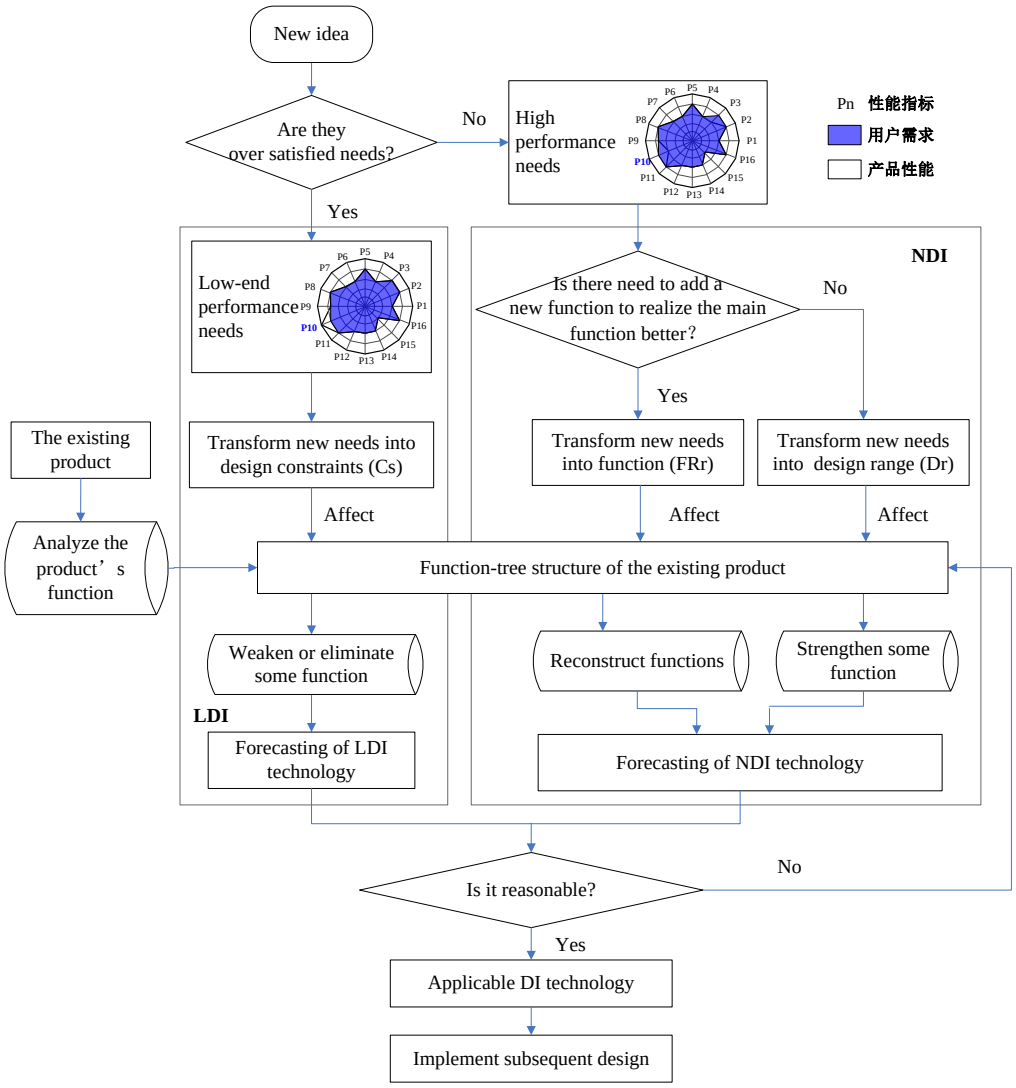

Figure.8 Forecasting Process of Disruptive Technology Based On Function Innovation

Step1: Analyze and transform the new needs. New needs mainly come from customers or engineers, judge the needs belong to low-performance needs or high performance needs. The low-performance needs can be transformed into design constraints, and the excitement needs are transformed into one or some new functions or design range.

Step2: Function innovation process. The Cs or Dr acts on one or some function of the existing product, according to the limit of the Cs or Dr, functions are optimized. The new function FRr is an auxiliary function, and we need to confuse it when analyzing

the function of the product, and structure the new function-tree, the function of the product is reconstructed.

Step3: The forecasting of DT based on function innovation. The process of function innovation is the process of forecasting the disruptive technology. We forecast the LDI technology by optimizing functions, and we forecast NDI technology by reconstructing function, so we will get a new function-tree structure. Faced with the new function-tree, we find the way to innovate the product, it guides us to design new products and occupies new market space.

3. Case Study-----the design of smart electric stew cup

We take electric stew cup for example. As shown in Figure.9, it is an electric stew cup suitable for a single person. It has an inner magnetic cup, when you want to stew congee, first you need to pour water into the space between the inner stew and outer pot. And you put rice and water into the inner magnetic cup, what you need to do next is to press the power. Besides, the stew cup has timing function, if you just prepare to go out, you can choose 1.5 hours, 2.5 hours or 3.5 hours, so it has high security. As for its price, it only cost about RMB100, so it is good for consumers.

Figure.9 The stew cup in the existing market

3.1 Analyze and transform the new need.

According to the market survey, this stew cup sells well, customers are satisfied with it. Now customers have not other requirements, but engineers excavate new needs, engineers come up with a new demand for customers, it is that if you are not at home, you can also have porridge when you reach your home. Because it does not come from customers directly, so it belongs to excitement need, and should be transformed into

new function, which is "set the starting time in advance", so we will forecast its NDI technology.

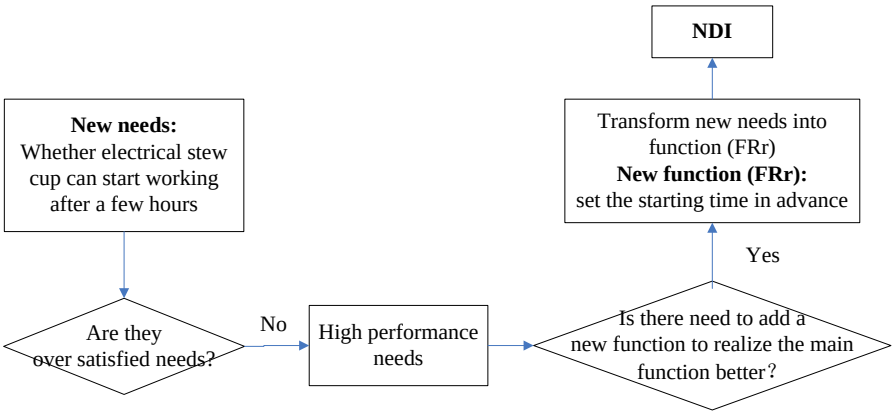

Figure.10 The need analysis and transformation of the electric stew cup

3.2 Process of function innovation.

First we analyze the function of the stew cup in existence, the result is just like the light color part in Figure.9. The new demand of setting the starting time in advance is an auxiliary function of the product. We confuse the new function FRr (as shown in Figure.9) into the original function structure. After analyzing it, we find it will not influence other functions, so it is an independent function and should be added at the first level of the function-tree structure, and decompose the new function level by level. The new function-tree structure is as shown in Figure.10.

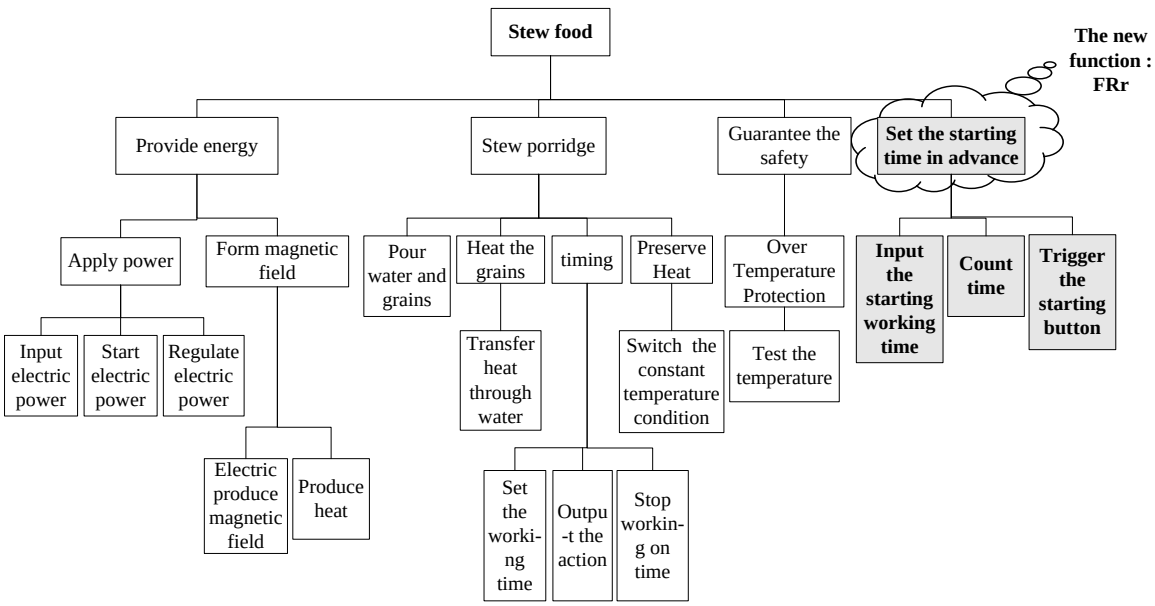

Figure.10 The new function-tree structure of stew cup

3.3 The forecasting of DT based on function innovation.

Faced with the new function-tree structure, we can ascertain the innovative scheme easily. The process of reconstructing function-tree can guide engineers conduct DI. As to the new function "set the starting time in advance", timer can realize the new function easily, so we only need to add a timer. The result of DT forecasting of the smart stew cup is as shown in Figure.11, timing2 is the button of choosing when the stew cup will begin to work. The time interval from now to the setting time is displayed on the Screen2. This is our forecasting result.

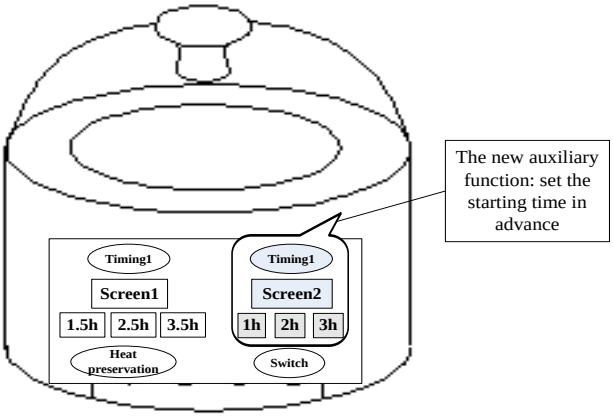

Figure.11 A smart stew cup

4. Conclusion

DI includes LDI and NDI. LDI is mainly for the low-end customers, most of these customers think that the existing product is expensive. We can reduce cost by weakening the product properties. During the process of LDI, we first transform the new needs from customers into Cs, here we apply the restrictions of design constraints (Cs) acting on function to realize it.

NDI is mainly for new market customers, we need to supply a new product of having new function or higher performance to attract them. During the process of NDI, we first transform the new needs into one or some new functions or design range, analyze its relation with other functions, and reconstruct the function-tree structure to forecast the DI technology.

Seen from above, the process of function innovation is just the process of forecasting the DI technology. The generation of NDI technology verifies the feasibility of this way.

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Research on Multi Biological Effects Modeling Method Based on Symbols

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Abstract

At present, the application of biological knowledge largely depends on the biological knowledge and the ability of engineering transformation that the engineers have. This paper proposes a multi biological effects modeling method that based on symbols in order to solve the difficulties that the engineers meet when they use the biological knowledge. This method has a complete system of symbols and complete modeling principles and process, so it can be easily handled and used by ordinary engineers. This method can provide richer, more comprehensive and intuitive knowledge of biology than traditional methods, and it also can be widely used in the product innovation combined with the multiple coupling bionics design. Finally, the proposed modeling method is further discussed and verified with a specific biological example.

Keywords: Multi biological effects, Modeling method, Symbolic

0. Introduction

Benyus (2002) had proposed lives of nature have been on the earth for billions years, through the long-term natural selection the biology have had the high adaptability to the natural environment and ability of strong self-adjustment, which are what the artificial systems always lack . Vincent(2002) had proposed the biosphere that has a huge amount of information is the source for the all sorts of innovation produced by human beings. However, there are only about 10 percent of biological principles applied in the engineering technology. The principles that have largely potential for further application, so these needs to be further developed and utilized. TRIZ has pointed out that the solutions of any invention may already exist; the only thing we

need to do is searching and comprehensively using the knowledge. The principle solution of product innovative design can be figured out through the constructing analogy design using the known knowledge and combinations of them. Biological knowledge is a huge amount of information which is an analog source for designers to generate ideas for high-level innovations and inventions. Apte(1999) had proposed effect based on knowledge is a high-level innovation method of TRIZ , which can change the scientific principles form the tacit knowledge classified by the subjects to the explicit knowledge problem oriented and classified by functions, and help the researchers make a high level innovation solution by utilizing the design knowledge from the scientific perspectives not the engineering perspectives. The work(Ijspeert et al.2005a, Barron and Srinivasan, 2006b, Ferris et al. 2005c) had marked in recent years, scholars who research innovation methods have transformed the biological information into biological effects and established the biological effects database according to the function classification. It is an effective way to systematically use the biological knowledge in product innovation design that selects the biological effects or chain of biological effects to realize the demand function from biological effects database through the searching, analysis, integration and optimization of biological effects. Asknature website built by the joint efforts of Autodesk and Biomimicry Guild is a kind of such biological effects database, and this database has classified more than 1500 biological effects according to the biological functions, which provides the engineers and technicians with an open searching tool based on website. Engineers and technicians can retrieval the most matching biological effect from the database that contains eight upper classes and 165 subclasses. In addition, Golden(2005) from University of Maryland had put forward a modeling method for biological effect called function template description.This method convert the biological effect into the combination of entities, actions, attributes and other language elements as the way the function base does in the description of the function, which can be easily used by the engineers and technicians. But the frame of existing biological effect database is still only for single bionic, and the biological effect only contains the information of single bionic to realize the function. Although the chain of biological effects formed by the rules of combination in the subsequent step achieves the multiple bionic, it is the only artificial combination of the information of single biological effects. The advantages of natural biological system reflect not only in the realization of a single biological function, but also in the natural combination rules formed in the long time of evolution. The phenomenon of biological coupling widespread in the biosphere is the inherent nature of biological.Ren and Liang(2011) had proposed the phenomenon of biological coupling needs to be processed by the multi biological effects so the biological knowledge can be systematically used in the innovation of product design. The concept of multi biological effects is the improvement and expansion of effect in TRIZ, it is a systematic multivariate bionic method helps engineers create principle results of innovative design. The accurate description of rich information of multi biological effects is the foundation of product innovation design used by engineering technical personnel. This paper

presents a modeling method of multi biological effects to help the engineering and technical personnel use the rich information of multi biological effect. This method has a complete system of symbols and complete modeling principles and the process, so it can be easily handled and used by ordinary engineers.

1. The basic theories of symbolic method

EMS model (energy - material - signal) and material - field (SFA) model and its variation are two kinds of the most typical modeling method applied in the product design process which are used by engineering and technical personnel. Both of the methods are symbolic can intuitively reflect technical information of system components and avoid misunderstanding of users who have different professional background. There are some certain differences in the technical background and professional knowledge among the engineers and technicians the users of multi biological effects models, so it should avoid the error message that caused by the limitation of the modeling method. So making multi biological effects based on the symbol is very necessary. Multi biological effects model has a large amount of information, which uses the graphic model based on the symbols so information contained in the biological effect can be directly expressed.

▪1.1 EMS model

Pahl and Beitz (1996) had put forward the EMS model or function black box model. An analysis of engineering systems reveals that they essentially channel or convert energy, material or signals to achieve desired outcome. Energy is manifested in various forms, including optical, nuclear, mechanical, electrical, etc. Materials represent matter. Signals represent the physical form in which information is channeled. An engineering system can therefore be initially modeled as a black-box “Figure 1” with energy, material and signal inputs and outputs from the system.

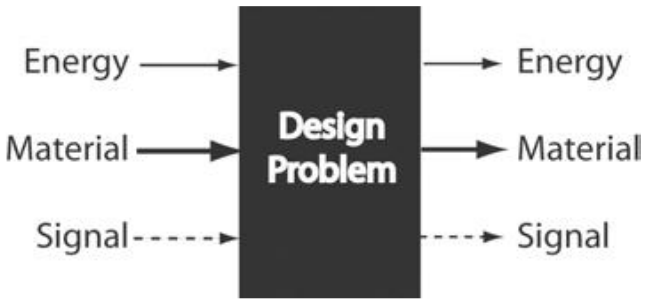

Figure 1. Energy, material and signal flows through a generic `black box' design.

Engineers and technicians who use this method in analysis product system can clearly know that the function of the product designed. Hirtz et al.(2002)had marked the method has a flexible expansibility. With this method the engineers and technicians can decompose an abstract general function into several subfunctions.It is more specific for the technical personnel to achieve the subfunctions and more facilities for technicians to find the corresponding technical solutions to settle the designing problems. The advantage of this modeling method lies in the description of different attribute flow in the model. The transformation of flow reflects the products' function and the continuity of the flow ensure the separability and consistency of the whole system.

▪1.2 Substance-Field Analysis and Variants

A key concept in TRIZ is the modeling of all material objects (visible or invisible) as substances, and sources of energy (mechanical, chemical, nuclear, thermal, acoustic, etc.) as fields. A function can therefore be defined as a substance, S1, acted upon by a field, F1, created by a second substance, S2. The substance-field for a complete system can be represented with the notation "Figure 2" shows the structure of SFA model.

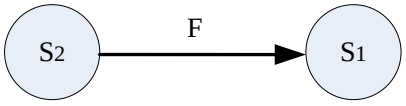

Figure 2. The structure of SFA model.

The parameters S1 and S2 are often referred to as object and tool, respectively, where the tool is acting on the object to create the desired effect. Models that do not have all three components (tool, object and field) are referred to as incomplete. By adding the missing element, a problem that may have been present in the system can be solved. Royzen(1999) had proposed the use the Tool-Object-Product (TOP) analysis("Figure 3"), a variant of SFA, as the next generation modeling approach. In TOP analysis a complete system has four elements: tool, object, field and product. The latter is defined either as a useful product (UP) or a harmful product (HP). Ogot(2005) had marked the TOP analysis for a complete system can be represented with the notation.

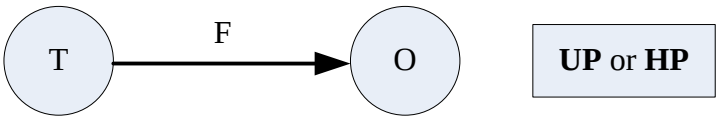

Figure 3. The structure of TOP model.

Both SFA model and TOP model are important tools for engineers and technicians in the construction of product system and analyzing the relationship among the components in the system. These models can be easily converted into technical system model. SFA model has good expansibility and high flexibility of combination. The goal of product innovation can be achieved by the combination and extension of the SFA models.

This article proposed a modeling method of multi biological effects based on utilizing and the improving of basic thought of EMS model and SFA model. This modeling method can convert biological knowledge into model of multi biological effects. This graphical model constituted of various kinds of symbols can directly express rich information including the transformation of the flow of different attributes, the relationship between compositions of biological systems and so on. This method can be conveniently handled and utilized by engineers and technicians; it is a fundamental solution to error in the description of information. .

2. The elements and symbol system of symbolic multi biological effects model

▪2.1 Elements of multi biological effects model

The purpose of establishing multip biological effects model is to process knowledge and information existed in the biological phenomena efficiently and integrate an intellectual tool that contains information related to multi biological effects. Engineers and technicians utilize this intellectual tool in the innovative design of products. Multi biological effects model is an iconic indication of biological knowledge in systematic level, so multi biological effects model should contains all information about the biological system. The information forms the elements of multi biological effects model. These elements contain several following aspects.

Effect and chain of effects: the core content of multi biological effects model is the effect and chain of effects and this part of information reflects the flow changes in the system, which is an important link in the conversion form multi biological effects model to product function.

Flow and node: Flow and nodes are the basic units of multi biological effects model. Flow contains material flow, energy flow and trigger signal flow. There are two kinds of nodes material node and function node, and material node is the material basis of flow, function node is the main site where the conversion of flow happens.

The table of state transition: It is used to indicate the changing conditions of flow when passing through the function node in multi biological effects model, it reflects the conversion effect of function nodes.

The information about the interaction with the environment: it indicates the interaction between flow in multi biological effects model deemed as a complete system and control factors existing in the environment, and it indicates characteristics of whole biological system.

▪2.2 symbolic system of multi biological effects model

Multi biological effects model should contain the information about the conversion of material or energy and the trigger or control signal and the chain of effects and the structure of biological system. In order to describe the whole information of multi biological effects model, to create the symbolic system of multi biological effects model by integrating and extending the EMS model and SFA model. The symbolic system showed in the “Table 1”.

Table 1. The symbolic system of multi biological effects model.

Graphics	Name	Implication
	Material node	Material node refers to the visible or invisible material or elements
	Function node	Function node includes fields of mechanical, chemical, nuclear, thermal, acoustic etc.
	Material flow	Material flow indicates the direction and path of material flow in the system.
	Energy flow	Energy flow indicates the direction and path of energy flow in the system.
	Trigger signal	Trigger signal indicates the interaction between the signal and the function nod.
	Factor of trigger /control	It indicates an auxiliary factor that triggers or controls the function node to operate.
	Super system resource	Super system resource mainly refers to the substance or energy out of biological system.
	Transition of energy	It indicates the transition of energy of the process in the function node.
	Change of physical state	It indicates the change of physical state of substance after the effect of function nod.
	Control and feedback	It values the result of signal acting on the effect of function nod.
	The link of effect	It is a collection of substances nodes and function nodes that based on a certain function.
	Biological base	It is a collection of substances nodes and function nodes that based on biological tissue.

3. The strategy and process of symbolic multi biological effects model

▪3.1Modeling rules of symbolic multi biological effects model

The process of modeling the multi biological effects model is to utilize the elements of symbolic system to represent composing and information of biological systems. The modeling process needs support of modeling rules to guarantee correctness and rationality of model established and the information of model can be correctly interpreted by the technicians. The modeling rules including:

(1) The rules of confirming the order of biological bases in biological system

Biological bases are the basic compositions of biological system and the first stage to analyze the biological system, which indicates the information of multi biological effects on the biological composition level. The main structure of multi biological effects is determined by the order of biological bases. The order of biological bases has the dual nature of spatiality and timeliness. But for a single biological system, its order mainly concentrated on spatiality or timeliness. There are two kinds of rules confirming the order of biological bases:

Rule of spatiality: If the order of biological bases in the biological system has obvious spatial hierarchy, ranking the biological bases in multi biological effects model by the rule of spatiality. For example, in the biological process of plants' absorption and utilization of the water from the soil, many tissues of plants have obvious spatial hierarchy so the biological bases in this model should be ordered by the rule of spatiality.

Rule of timeliness: If the order of biological bases in the biological system has obvious succession, ranking the biological bases in multi biological effects model by rule of timeliness. For example, in the process of photosynthesis, the spatial hierarchy of biological bases is not easy to confirm, so rank biological bases by the time succession.

(2) The rules of confirming the connections between nodes and flow

The flow and nodes are the basic elements of the multi biological effects model. They are also the key to the conversion from biological information to intellectual tool that the engineers and technicians can utilize. It depends on the order of biological bases and the analysis of super system resource to confirm the flow and nodes of multi biological effects model.

Firstly confirming and using the super system resource symbol to represent the resource the input resource from environment to the biological system and the interactive information between the multi biological effects model and environment. Secondly connect the super system resource symbol and the corresponded biological base with the symbol of the flow

according to the corresponded attribute. Then marking the flow that has obviously transition when it passing functional node with the corresponded symbol. Lastly verification the integrity of the flow of different attributes.

(3) The rules of confirming the chain of multi biological effects

Multi biological effects as well as the chain of multi biological effects formed naturally is the core of multi biological effects model, which is the application template used directly by the technicians in the multi bionic innovation of the products' system as well. It depends on the connection of the flow and nodes to determine the relationship between biological effects in the chain of multi biological effects. The extraction of the chain of multi biological effects is the final summary of establishing the multi biological effects model, and it includes two main steps the division of biological effects and extractions in the chain of effects. A group of the nodes that have obvious function can be integrated as a biological effect or a biological base which can be defined as a biological effect. According to the interaction of the biological effects and the relationship between biological effects can be divided into four kinds: previous effect, follow-up effect and trigger effect, passive effect ("Figure 4"). The chain of biological effects can be determined by the interaction between the biological effects.

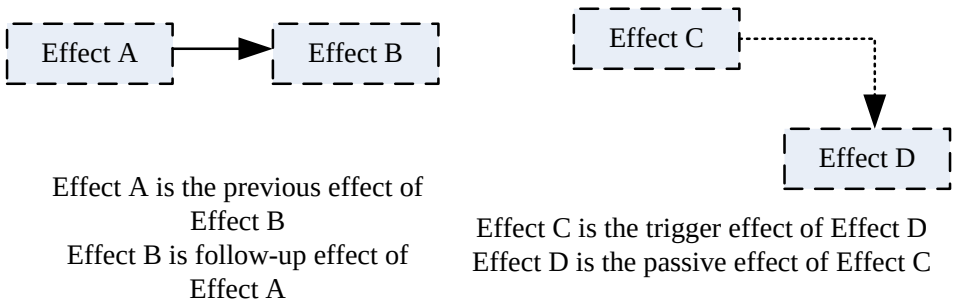

Figure 4. Four kinds of the relationship between the biological effects.

▪3.2 Procedure of establishing the symbolic multi biological effects model

According to the modeling principles listed above the procedure of establishing the symbolic multi biological effects model from biological prototype can be roughly divided into the following several steps:

Step 1: Analyze the biological prototype selected, and confirm the biological base that formed the biological prototype system.

Step 2: Analyze the characteristics of biological function and confirm the rule of the order of the biological bases.

Step 3: Confirm the order of biological bases.

Step 4: Identify the super system resource nodes of multi biological effects.

Step 5: Classify the super system resource nodes according to the different attributes.

Step 6: Confirm the connection between the flow and nodes of different attributes in the multi biological effect.

Step 7: Label the state symbols in multi biological effect model.

Step 8: Inspect the integrity of flow of different attributes in the multi biological effects model.

Step 9: Divide biological effect in the multi biological effects model.

Step 10: Analyze the relationship between the biological effects.

Step 11: Extract the chain of multi biological effect and completing the work of modeling multi biological effects. (the procedure showed in “Figure 5”).

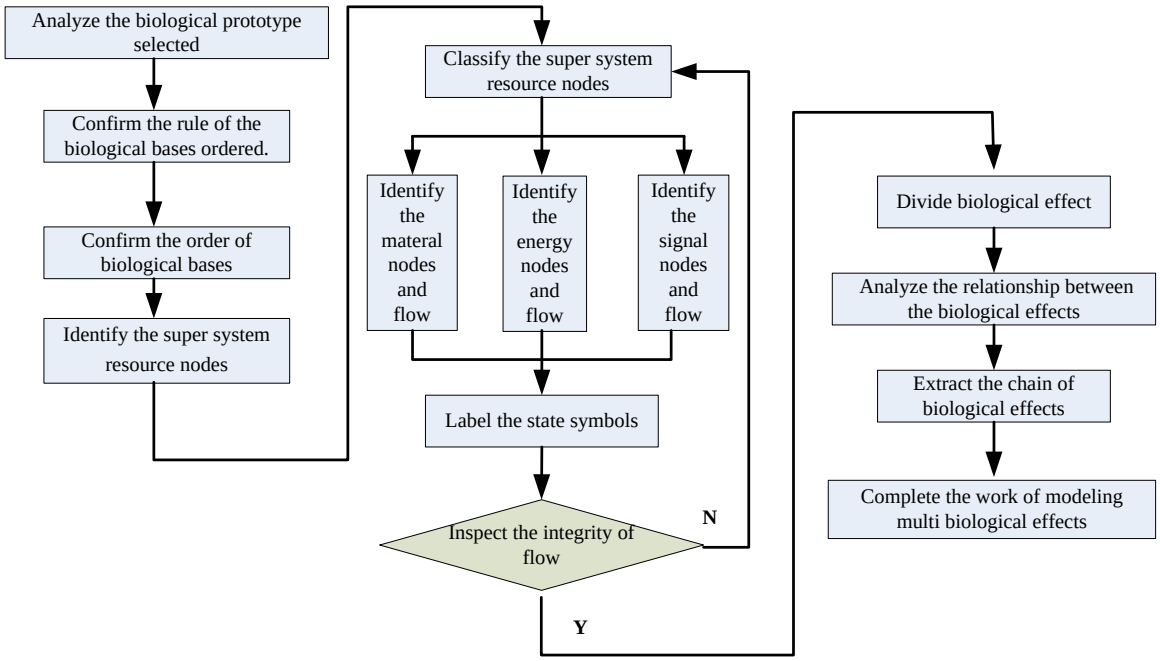

Figure 5. Procedure of establishing the symbolic multi biological effects model.

4. The analysis of the example model

Modeling the process of photosynthesis used the symbolic multi biological effects modeling method.

▪4.1Modeling rules of symbolic multi biological effects model

Photosynthesis is a biochemical process that the plants algae and some bacteria in the irradiation of visible light using photosynthetic pigment to convert carbon dioxide and water to organics and oxygen through the two steps of photosynthesis the photoreaction and dark reaction. Photosynthesis process can be expressed as follows:

$H_2O \rightarrow 2H + 1/2O_2$（The photo- dissociation of water）

$NADP^+ + 2e^- + H^+ \rightarrow NADPH$（Hydrogen delivery）

$ADP + Pi \rightarrow ATP$（Energy delivery ）

$CO_2 + C5 \rightarrow 2C3$（Carbon dioxide's fixation）

$2C3 + 4NADPH \rightarrow (CH_2O)n + C5 + H_2O$

$ATP \rightarrow ADP + Pi$（Energy consumption）

It is hard for the technicians to extract the information utilized in the innovation of product from traditional methods, so the multi biological effects model of photosynthesis need to be established.

▪4.2Establishing the symbolic multi biological effects model of photosynthesis

(1) Divide the composition of biological system and confirm the order of biological bases

In the process of photosynthesis, the order of biological bases is determined by the time sequence, so rank the biological bases of photosynthesis by the rule of timeliness (Figure 6).

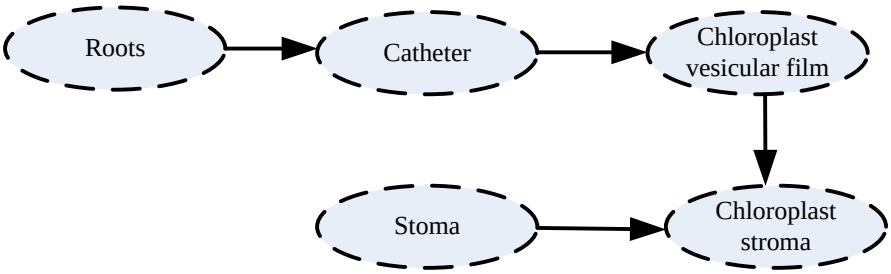

Figure 6. The order of biological bases in the photosynthesis.

(2) Identify and classify the super system resource nodes of photosynthesis

The super system resource involved in the photosynthesis includes water from soil , carbon dioxide from air and the optical energy from environment. According to the analysis the water and carbon dioxide are the material nodes the optical energy is the energy node. Then connect the super system resource nodes and the corresponded biological bases.

(3) Complete the connection between the flow and the nodes in the model of photosynthesis.

Indentifying the material and functional nodes that connected by the flow of different attributes depending on the biological composition and functions, then finishing the connection of the same attribute.

(4) Label the state symbols in the model of photosynthesis.

Labeling the flow that has obviously change in the physical or energy state with the state symbols by tracking its path.

(5) Inspect the integrity of the flow in the model of photosynthesis.

Inspecting the integrity of the flow in the model of photosynthesis following the conservation of mass and energy.

(6) Dividing the biological effects and determining the relationship between biological effects.

Identifying the biological effect by dividing the flow and nodes of the model depends on the analyzing the function of nodes in the biological base. A group of the nodes that having obvious function can be integrated as a biological effect or a biological base can be defined as a biological effect. After analyzing the relationship between the biological effects the work of modeling multi biological effects is finished. The symbolic model of photosynthesis showed in “Figure 7”.

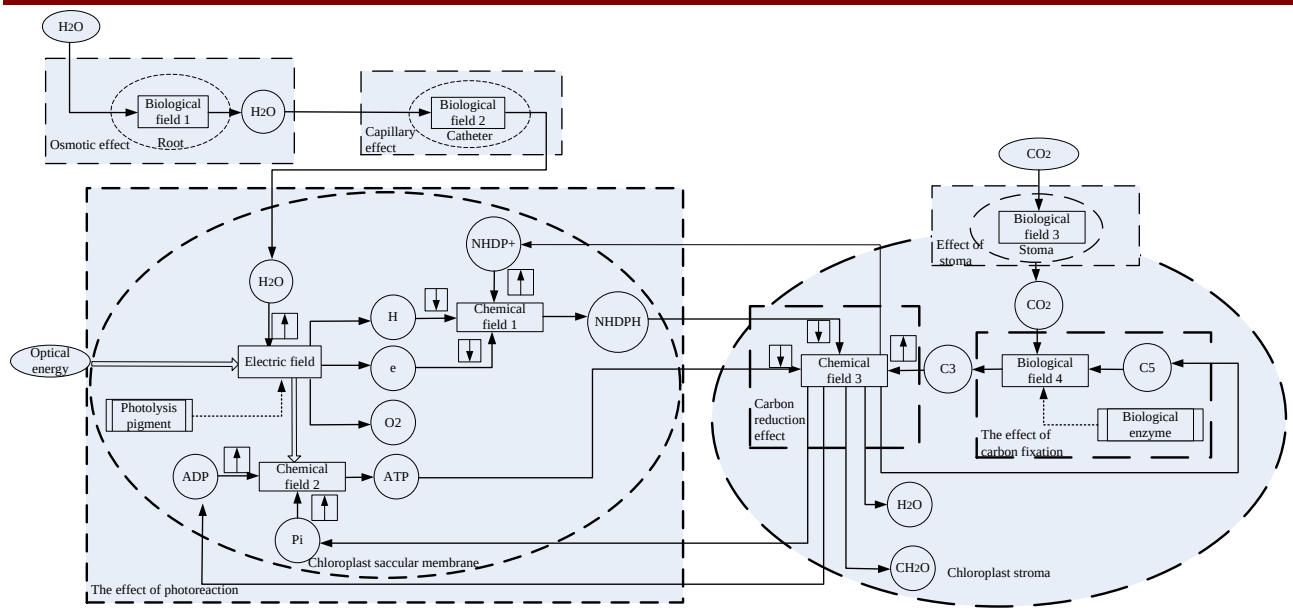

Figure 7. The symbolic model of photosynthesis.

(7) Extract the chain of multi biological effects in the photosynthesis and finishing the work of modeling.

The chain of multi biological effects in the photosynthesis showed in the “Figure 8”.

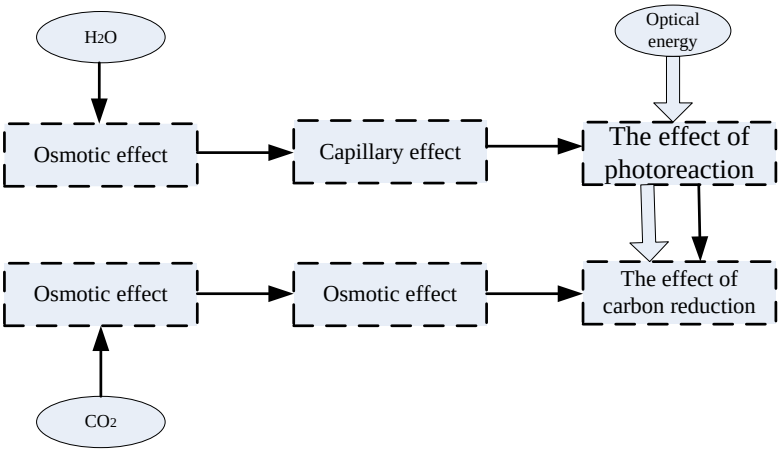

Figure 8. The chain of multi biological effects in the photosynthesis.

The technicians can utilize the information of the multi biological effect model that established by the method of symbolic multi biological effects model modeling in the process of innovation of real products. The result of the chain of multi biological effects is formed naturally not artificially. When the technicians utilize the multi biological effects model of the photosynthesis in the process of multi-coupled bionics the only thing they need to do is to replace the biological effect of the chain of multi biological effects model with the technical effect totally or partly and then they can get the principle solution of the technical system. So

the process of the bionic design especially the multi-coupled bionics is largely simplified, therefore it can be easily utilized by the normal technicians.

5. Conclusion

The method of establishing the symbolic multi biological effects model can describe the information about the biological system from many aspects. The final result of analyzing the relationship between multi biological effects is the graphic model and the chain of multi biological effects. This method has advantage over the traditional methods which are based on the analysis of semantics on containing more information and reflecting the relationship of the effects in the multi biological effects. Moreover, this method can directly express the relationship between biological effects that formed the multi biological effects model and avoid misunderstanding of information caused by differences between users. This method also can be utilized in the process of products' design to improve the utilization rate of biological knowledge at the same time. Research on the multi biological effects modeling method provides fundamental tool for the research and development of multi-bionics and create the conditions for the biological knowledge widely utilized in the innovation of product.

Acknowledgments

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Research on the Extraction Method of Sustainable Design Criteria Based on Patent Knowledge Mining

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Abstract

As guidance and restraint for sustainable design methods, sustainable design criteria is essential for meeting sustainable requirements. Through patent analysis, retrieval and knowledge mining, this article combines sustainable requirements and characteristics, task of each stage in product life cycle, putting forward the sustainable design criteria extraction process model, which can extract sustainable design criteria for product design, so as to provide a theoretical basis for designers.

Keywords: Patent mining; Sustainable design; Sustainable design criteria; Extraction model

1. Introduction

In the product design process ,it needs to follow some design principles to ensure the quality and function of the products , so in the process of sustainable design for the products , sustainable design criterion is the rules which designers need to follow in solving product elements , through the guidance of sustainable design criteria to make products meet sustainability requirements. Because of the importance of design criteria, scholars do research into product design criteria from different angles, including some green design criteria(Liu,1999a, Lin et al.2001b, Cui et al.2003c, Liu et al.2003d), sustainable design criteria(Cao and Tan,2008a, Liu et al.2010b, Hou and Ren,2009c, Justel et al.2006d, Chen and Chen ,2007e), and some design criteria(Liu and Gao,2009) which is specially used to cope with a law. But these sustainable design criteria were mainly faced to one or several links in the product life cycle, and they basically are summarized according to laws and regulations, so they cannot fully reflect sustainable requirements of the product in the actual production and life. So how to put forward accurate and applicable sustainable design criteria will become the focus of

research. And at present there is almost no research on sustainable design criterion extraction method, so finding a way which can extract sustainable information from real product extraction and eventually form the sustainable design criteria become the focus of research.

This paper Starts with the patent, combining product sustainable requirements and characteristics, task of each stage in life cycle, puts forward a extraction process model of sustainable design criteria based on patent mining. We can extract sustainable design criteria for guiding product design by using this model, so as to provide a theoretical basis for designers.

2. Sustainable design criterion related concepts

▪2.1 The generation and concepts of sustainable design criteria

With China's accession to the WTO, enterprises are faced with more intense competition, because of its leading advantage in the design technology, foreign enterprise set "green barrier"(Li, 2004) to our country enterprise. The enterprise wants to survive, it must change the original design strategy, in response to related environmental directives and they derived on all kinds of the high standard test requirements, at the same time meeting the growing environmental needs. In this kind of economic background, the enterprise urgent need to the guidance of sustainable design method, thus improve overall enterprise innovation ability, strengthen the enterprise market competition ability. Design criteria is the design constraint factors, it is also need to be followed at any design moment, so putting forward sustainable design criteria to guide sustainable design of product.

Sustainable design criteria（Desimone and Popoff, 1997） is used to reduce consumption of resources, reduce the environmental hazards and improve product value, it connects the sustainable development indicator with environment, economy, social influence each of stage of the products life cycle. According to the market demand of sustainability, enterprises urgent need sustainable design criteria to guide the sustainable design of product, to make property of the whole life cycle that includes product materials, processing, manufacturing, transportation, use, remove, maintenance until recovery and reuse meet sustainable design requirements.

▪2.2 Sustainable design indicators system

Because the sustainable design indicators system is the basis of sustainable design criteria, so the study on sustainable design indicators system is very important to accuracy of sustainable design criterion. At present, the scholars at home and abroad do a lot of research on sustainable development indicators system, but from the point of view of product design doing research into sustainable indicator system is little and little, only literature（Li,2011）firstly mentioned the sustainability indicator system from a design standpoint, it stresses the sustainable

development indicators contains environment, society and economy three aspects, and sustainable design is the reflection of sustainable development thought in the area of design, therefore it follows the inheritance relationship, so sustainable design indicators system also include environmental, social and economic this three key factors. But the literature only makes a simple introduction to sustainable design indicators system, and the specific indicators information of the economic, environmental and social three aspects is limited, not perfect, so we perfect the sustainable design indicators system through the analysis of environmental protection laws and regulations, and combining with the related literature of sustainability, green and ecological. Specific sustainable design indicators system show as follows table 1:

Table1. Sustainable design indicators system

Environmental indicators	
high material utilization	material easy recovery
high level of material utilization	identifiable material
biodegradable material	material of low pollution
disabled toxic and hazardous substances	material recyclability
small amount waste emissions	non-polluting waste
end-of-life product recycling convenience	recyclable waste utilization
energy and resource conservation	resources and energy high reserves
high utilization resources and energy	resources and energy using convenience
resources and energy security	resources and energy clean renewable
Economic Indicators	
low production costs	low maintenance costs
low transportation costs	low using costs
low recovery costs	high economic benefits
high working efficiency	long service life
structure simple and versatility	high qualified products
the economy material	materials for easy storage
easy maintenance	high parts recycling utilization
savings raw	less component types and quantities
avoid secondary processing to decoration	optional economic resources and energy
low waste disposal costs	materials life similar and compatibility
Social indicators	
practicability	high reliability
high degree of intelligence	ease of use
security	high capacity utilization
high social value	good human-computer interaction
product easy to upgrade	space savings

3. Patent and Patent mining

▪3.1 Patent

Patent information is the crystallization of the human wisdom, it almost include all applications technical achievements, such as the most important information resources in economic development, technology innovation and strategic decision. World intellectual property organization (WIPO) statistics (Liu, 1992) show that patent information contains 90% ~ 95% of the technical information in the world, using patent information effectively can shorten an average 60% development time, save 40% development costs. Patent economic value in research and development of the world output ratio is more than 90%, so in the current knowledge economy era, patent information play a vital role for the state, enterprises , the greatest degree developing and using of patent information also become the important guarantee of getting competitive advantage in the countries and the enterprises.

▪3.2 Patent mining

The patent mining especially directs at the patent information mining, it is a discovery process which searches out the hidden special related knowledge from a large number of patents. On the patent information mining is helpful to support product innovation design with the latest research results, so through the patent information mining, searching out the hidden sustainability information, and putting forward a kind of sustainable design criterion based on patent mining to guide designers for sustainable design is more significance. At present this aspect of research has not started. In this paper the methods and means of patent mining are as follows: first of all, searching out the target patent through the patent retrieval analysis software; secondly, downloading and exporting the characteristics information of patent, such as patent literature patent name, application number, date of application, the applicant, the inventor, agents, summary and so on; finally, Finally, Clause processing derived information on the basis of the data mining software and collecting the patent information according to the clustering algorithm.

4. Extraction of sustainable design criteria based on patent mining

It is based on the understanding of the above, starting from the concept of front Prevention, through the method of patent mining, and combining the requirements of sustainable development in the whole life cycle, forming the extraction process model of sustainable design criteria based on patent mining, as shown in Figure 1. It can extract the sustainable design criteria of each stage in product life cycle by using this model to guide the sustainable design of products, to ensure low cost, low consumption and low pollution in every link, make the product realize sustainable requirements in the concept design phase.

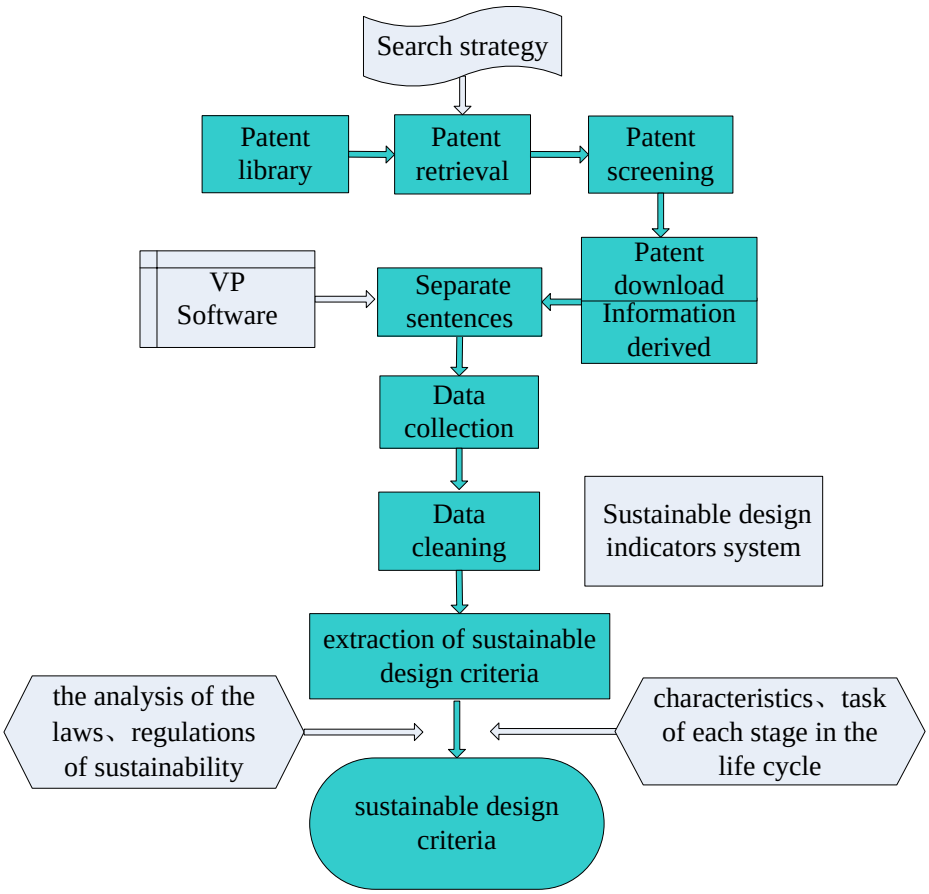

Figure1. The extraction process model of sustainable design criteria

Step1. Patent retrieval, screening, download and information derived

This paper takes all patent data from the Chinese state intellectual property office as the patent retrieval and screening's data sources, with the keywords retrieval as the main retrieval, name keywords retrieval as auxiliary , it need to export patent name, the application date, the applicant, the inventor, agents and patent abstract from all the patent document with the same name to excel after retrieval, then screen and remove the same patent(A patent may also apply for invention patent and the utility model patent). All the patents after screening and removing need to be exported to excel, specific content include patent name , application number, date, the applicant for a patent, the inventor, agent and the patent abstract and so on, to get ready for Separating sentences and semantic relation analysis.

Step2. Separate sentences

In this article, using the Vantage Point (VP)software to divide into sentences. Because the description about sustainable information in patents is not the gerund, it is usually a word, so

extraction of sustainable information should extract sustainable statement. It may cut the text into the single statement information according to punctuations by using VP.

Step3. Data collection

Through artificial recognition on the patent abstract after separating sentences, we may extract sustainable information from it. Artificial recognition to sustainable information is for semantic expand based on the sustainable indicators system, the extracting the sentences of sustainable information which are the direct expression and the indirect expression, to ensure integrity of extracting sustainable information.

Step4. Data cleaning

Data cleaning also called data standards, its main function is that regulating and screening and eliminating the information of the same concept but different expression. Summarizing the sustainable information after Data collection, counting out the total of expressing the same meaning statement and phrases, then screening and eliminating the same statement and phrases, and taking sustainable design indicators system as a benchmark to standard sustainable information after screening, forming standard sustainable statements or phrases.

Step5. The extraction of sustainable design criteria

Making the sustainable information after standardization form sustainable semantic related information database, then through the analysis of the laws、regulations of sustainability and characteristics、task of each stage in the product life cycle, we can extract sustainable design criteria of each stage in the product life cycle from sustainable semantic related information database .

5. Engineering example

Because extracting sustainable design criteria of any stage in the product life cycle should be a engineering example, therefore this paper takes extraction of material selection design criteria for example to check out the extraction model of sustainable design criteria. In recent years, the refrigerator is a product which reflects sustainability obviously, so this paper will take the refrigerator as the engineering case object.

Step1. Patent retrieval, screening, download and information derived

With DaWei Patent software as patent retrieval platform, with “material” as the main retrieval, “refrigerator “as the auxiliary search for data retrieval, Searching to a total of 157 patents including inventions, utility models and appearance, as shown in Figure 2.Through

screening and not found the patent literature of the same name, that is not the same patent, so need not eliminate the same patent. Then exporting the patent abstracts to excel.

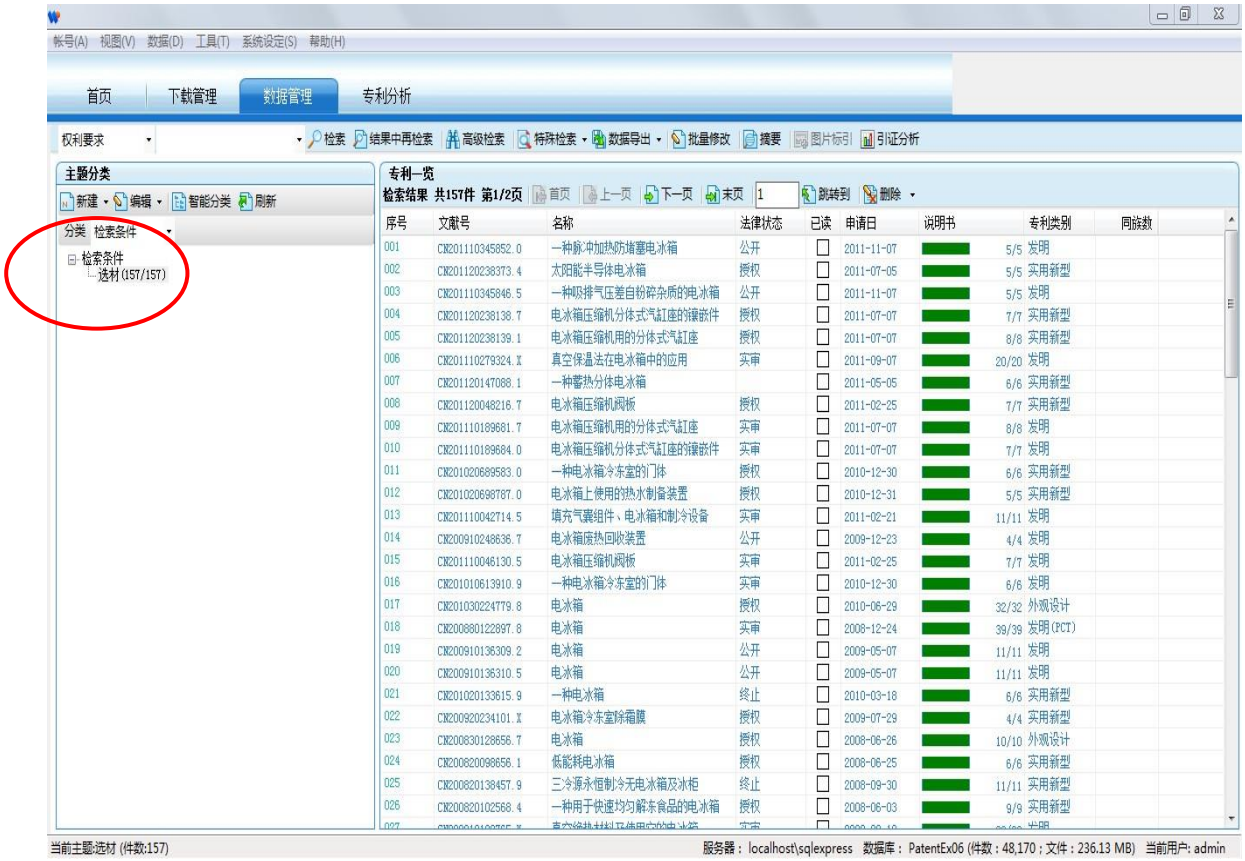

Figure2. Patent retrieval results

Step2. Separate sentences

Because the VP software can only identify English, so it needs to change Chinese punctuation for English format before applying VP, then import the contents in excel into the VP software, then VP software will cut the imported content based on punctuation, it cuts 157 patents into 1776 independent sentences as shown in Figure 3, then outputs the independent sentences.

List::摘要: Divide at/Comma

	#Records	#Instances	摘要: Divide at/Co
1753	1	1	隔热材料
1754	1	1	隔热材料在外壳的后壁面上
1755	1	1	集管
1756	1	1	集管间自然对流
1757	1	1	雪冷源内壁冷传板
1758	1	1	雪冷源层
1759	1	1	需要把门框接触面的上部做成台阶形
1760	1	1	靠磁力将其吸附在电冰箱表面
1761	1	1	音响
1762	1	1	顶面及底面
1763	1	1	预先安装一体地带有V室用返回管的绝热分隔壁１１
1764	1	1	风扇
1765	1	1	食品冷冻与冷藏
1766	1	1	食品取放方便
1767	1	1	食品支架
1768	1	1	食品支架放置在积水盆内
1769	1	1	饮料柜门的缓转构件下方的侧面上形成有注入发泡材料用的注
1770	1	1	驱动器用于控制电冰箱电源的通断
1771	1	1	高效节能的对开门冰箱
1772	1	1	鱼
1773	1	1	麦饭石
1774	1	1	３ｂ
1775	1	1	ＰＴＣ加热板
1776	1	1	Ｕ型体位于电冰箱的左

List::摘要 List::摘要: Divide at/Comma

VantageP... VantageP...

Figure3. Separate sentences results

Step3. Data collection

Firstly making semantic expand based on the sustainable indicators system, secondly it needs to recognize the directly and indirectly sustainable information from VP exporting into excel, and eliminate the Non sustainable information, and collect 275 pieces of sustainable information, and in turn Numbers for x1 ~ x275.

Step4. Data cleaning

Classifying and summarizing the same or similar semantic information in the 275 pieces of information based on the K - means algorithm of fuzzy clustering algorithm. According to the calculation process of K - means algorithm, using c + + language programming the calculation process and form program code to support the classification and summary. The specific process is as follows: first of all, according to the statement of expression giving a mark to the 275 pieces of information, the marking result is as shown in figure 4.

x1	0.55	x36	0.46	x71	0.255	x106	0.59	x141	0.81	x176	0.94	x211	0.94	x246	0.053
x2	0.05	x37	0.68	x72	0.545	x107	0.56	x142	0.465	x177	0.945	x212	0.66	x247	0.62
x3	0.35	x38	0.41	x73	0.435	x108	0.935	x143	0.67	x178	0.745	x213	0.051	x248	0.935
x4	0.15	x39	0.77	x74	0.35	x109	0.565	x144	0.635	x179	0.67	x214	0.965	x249	0.675
x5	0.25	x40	0.58	x75	0.56	x110	0.94	x145	0.26	x180	0.94	x215	0.74	x250	0.39
x6	0.45	x41	0.62	x76	0.27	x111	0.75	x146	0.64	x181	0.35	x216	0.56	x251	0.925
x7	0.85	x42	0.73	x77	0.375	x112	0.66	x147	0.635	x182	0.66	x217	0.66	x252	0.975
x8	0.75	x43	0.36	x78	0.56	x113	0.84	x148	0.55	x183	0.665	x218	0.745	x253	0.48
x9	0.65	x44	0.558	x79	0.46	x114	0.76	x149	0.92	x184	0.645	x219	0.73	x254	0.73
x10	0.96	x45	0.94	x80	0.56	x115	0.26	x150	0.835	x185	0.465	x220	0.725	x255	0.36
x11	0.58	x46	0.945	x81	0.665	x116	0.62	x151	0.475	x186	0.735	x221	0.56	x256	0.73
x12	0.56	x47	0.56	x82	0.69	x117	0.52	x152	0.935	x187	0.635	x222	0.355	x257	0.66
x13	0.551	x48	0.67	x83	0.37	x118	0.66	x153	0.945	x188	0.255	x223	0.25	x258	0.645
x14	0.551	x49	0.87	x84	0.57	x119	0.66	x154	0.47	x189	0.43	x224	0.25	x259	0.62
x15	0.552	x50	0.53	x85	0.575	x120	0.36	x155	0.84	x190	0.23	x225	0.25	x260	0.365
x16	0.553	x51	0.69	x86	0.265	x121	0.56	x156	0.83	x191	0.745	x226	0.745	x261	0.46
x17	0.35	x52	0.68	x87	0.945	x122	0.64	x157	0.3	x192	0.05	x227	0.935	x262	0.28
x18	0.97	x53	0.44	x88	0.565	x123	0.08	x158	0.94	x193	0.83	x228	0.63	x263	0.35
x19	0.971	x54	0.46	x89	0.12	x124	0.34	x159	0.935	x194	0.94	x229	0.925	x264	0.26
x20	0.43	x55	0.05	x90	0.67	x125	0.36	x160	0.56	x195	0.475	x230	0.29	x265	0.265
x21	0.973	x56	0.47	x91	0.86	x126	0.97	x161	0.74	x196	0.36	x231	0.26	x266	0.261
x22	0.1	x57	0.69	x92	0.47	x127	0.55	x162	0.7	x197	0.44	x232	0.925	x267	0.57
x23	0.3	x58	0.675	x93	0.16	x128	0.88	x163	0.66	x198	0.68	x233	0.935	x268	0.263
x24	0.451	x59	0.56	x94	0.86	x129	0.57	x164	0.64	x199	0.845	x234	0.936	x269	0.84
x25	0.45	x60	0.68	x95	0.26	x130	0.465	x165	0.935	x200	0.64	x235	0.937	x270	0.73
x26	0.46	x61	0.93	x96	0.635	x131	0.46	x166	0.95	x201	0.66	x236	0.938	x271	0.15
x27	0.964	x62	0.935	x97	0.41	x132	0.455	x167	0.96	x202	0.56	x237	0.938	x272	0.9
x28	0.6	x63	0.49	x98	0.95	x133	0.925	x168	0.46	x203	0.64	x238	0.94	x273	0.745
x29	0.37	x64	0.585	x99	0.835	x134	0.68	x169	0.47	x204	0.635	x239	0.941	x274	0.55
x30	0.88	x65	0.28	x100	0.45	x135	0.355	x170	0.56	x205	0.945	x240	0.962	x275	0.635
x31	0.15	x66	0.27	x101	0.36	x136	0.56	x171	0.28	x206	0.37	x241	0.958		
x32	0.34	x67	0.68	x102	0.94	x137	0.55	x172	0.635	x207	0.74	x242	0.56		
x33	0.91	x68	0.965	x103	0.965	x138	0.68	x173	0.64	x208	0.56	x243	0.63		
x34	0.56	x69	0.56	x104	0.29	x139	0.69	x174	0.93	x209	0.94	x244	0.48		
x35	0.46	x70	0.935	x105	0.945	x140	0.42	x175	0.36	x210	0.845	x245	0.64		

Figure4. The marking result of Statement information

Secondly, inputting the marking result into the written program and then classifying and summarizing the 275 pieces of information, the specific clustering results as shown in figure 5.

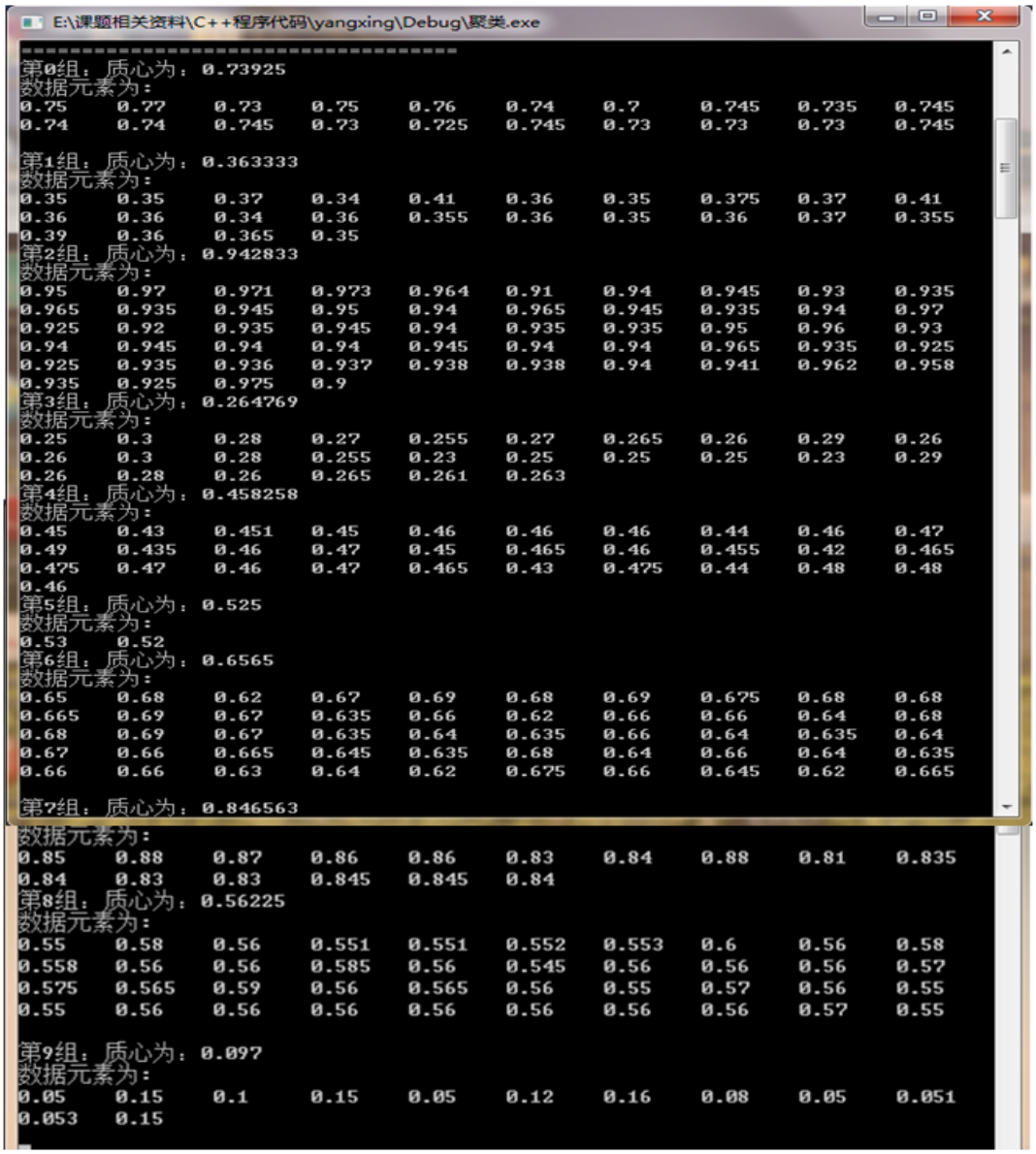

Figure5. Clustering results

Again, Classifying and summarizing the statement, counting of all the statements in each class based on the various data corresponding statement in the clustering result. Due to the accuracy of the clustering algorithm cannot reach 100%, so it needs to review check on the above clustering results to correct the error in the clustering results, mistakenly classified statements will be selected and placed in its corresponding semantic class, the final classification result of the statement is as shown in Table 2.

Table2. The statement information classification results

x2， x55，x123，x192，x213，x246	x4， x22，x31， x89，x93， x271
x7，x30，x49，x91，x94，x99，x113，x128，x141，x150，x155，x156，x193，x199，x210，x269	x8，x39，x42，x111，x114，x161，x162，x178，x186，x191，x207，x215，x218，x219，x220，x226，x254，x256，x270，x273
x3，x17，x29，x32，x43，x74，x77，x83， x101，x120，x124，x125，x135，x175，x181，x196，x206，x222，x250，x255，x260，x263	x5，x23，x65，x66，x71，x76，x86，x95，x104，x115，x145，x157，x171，x188，x190，x223，x224，x225， x230，x231，x262， x264，x265，x266，x268
x6，x20，x24，x25，x26，x35，x36，x38，x53，x54，x56，x63，x73，x79，x92，x97，x100，x130，x131，x132，x140，x142，x151，x154，x168，x169，x185，x189，x195，x197，x244，x253，x261	x1，x11，x12，x13，x14，x15，x16，x28，x34，x40，x44，x47，x50，x59，x64，x69，x72，x75，x78，x80，x84，x85，x88，x106，x107，x109，x117，x121，x127，x129，x136，x137，x148，x160，x170，x202，x208，x216，x221，x242，x267，x274
x9，x37，x41，x48，x51，x52，x57，x58，x60，x67，x81，x82，x90，x96，x112，x116，x118，x119，x122，x134，x138，x139，x143，x144，x146，x147，x163，x164，x172，x173，x179，x182，x183，x184，x187，x198，x200，x201，x203，x204，x212，x217，x228，x243，x245，x247，x249，x257，x258，x259，x275	x10，x18，x19，x21，x27，x33，x45，x46，x61，x62，x68，x70，x87，x98，x102，x103，x105，x108，x110，x126，x133，x149，x152，x153，x158，x159，x165，x166，x167，x174，x176，x177，x180，x194，x205，x209，x211，x214，x227，x229，x232，x233，x234，x235，x236，x237，x238，x239，x240，x241，x248，x251，x252，x272

Delete the duplicate information in the subtotals, then unified treatment of retained sustainable information based on sustainable design indicators system and forming a unified standard of sustainable statement. For example in this category reflects “the material life”, rollup out a total of six sentences: x2 meeting the cylinder bore and the rubbing of the shaft hole, x55 long life, x123 reducing the incidence of failure, x192 long life, x213 extend the

overall life, x246 extending protective life. It can be seen x55, x192, x213, x246 are the direct expression of the long life; x123 reducing the incidence of failure and the implied meaning is to extend the life, x2 also increase the life expectancy due to rubbing, so x2 and x123 indirectly expressed the meaning of long life, so these six words express the same meaning, therefore it is to retain only a sentence, the remaining five can be deleted, then retained sentences will be unified treatment and get: materials long service life.

Step5. The extraction of sustainable design criteria

According to step 4 methods, going heavy and unified treatment of the All Categories statement information, summarizing all statements after unified treatment and sustainable semantic related information database as shown in figure 6.

G	H
economy material	materials long service life
material easy availability	good physical properties of materials
material easy to transport	good material compatibility
material easy to save	good use properties of the material
material easy workability	material practical
material recyclability	high reliability material
energy economy	high level material utilization
material non-polluting	high material utilization
good social value	singularity type of material
material savings in space	material waste low
low materials recycling costs	energy ordinary
non-polluting waste	biodegradable material
recyclability waste	material without coating
renewable energy	material no effect on the environmen
non-polluting energy	material Safety and no effect on human body
high energy utilization	low Material processing maintenance costs
energy recyclability	

Figure6. Sustainable semantic related information database

Through the analysis of the laws、regulations of sustainability and characteristics、task of each stage in the product life cycle, we can extract sustainable design criteria of product selection stage from sustainable semantic related information database as follows:

- **Select material design criteria**
  - Resources and Energy：
  - (1) select economics energy
  - (2) select renewable, recycling energy

(3) select non-polluting energy

(4) select high energy utilization

(5) select rich reserves of energy

- Economy：

(1) select economy materials

(2) select processing, maintenance, recycling material with a low cost

(3) select abundant and readily available materials

(4) select ease storage, transportation, processing and maintenance materials

- Using Performance：

(1) select safe materials

(2) select long life materials

(3) select good using performance materials

(4) select practicability, and high reliability materials

(5) select high level of utilization and utilization materials

- Properties：

(1) select good physical properties and good material compatibility

(2) select a single kind of material, to avoid mixing use a variety of materials

- Environmental Protection：

(1) select waste non-polluting materials

(2) select less waste material

(3) select recyclable materials

(4) select renewable materials

(5) select pollution-free, biodegradable materials

- Security：

(1) select non plus coating, coating materials

(2) select non-toxic and non-hazardous materials

(3) select no effect on human materials

As a result, we can be drawn: The sustainable design criteria extraction model can extracted sustainability information hidden in patent, and form sustainable design criteria, which verifies that the sustainable design criteria extraction model is accurate feasible.

6. Summary

Based on patent mining as the means, This article connects the characteristics of the design process and the characteristics of each phase in the life cycle, forms the sustainable design criteria extraction process model, the model can extract sustainable design criteria for product design, and eventually get the economic, environmental and social win-win for meeting sustainable requirements in the phase of concept design. But along with the social innovation, and at the same time it also can produce a series of new environmental problems, this needs new criteria to guide the product design to overcome these environmental problems, therefore the perfection of sustainable design criteria is a long process, we need to efforts to complete.

Acknowledgments

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Paper ID: 12

The Computer Aided Innovation System Based on the Wide Area Network and Mobile Terminal

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Abstract

This paper proposed an innovative Computer Aided Innovation(CAI) system based on the Wide Area Network(WAN) and Mobile Terminal(MT). We apply all sectors of various types of computer terminals to realize the sharing of innovation database. At the same time, the application of multiple terminal WAN makes innovation knowledge base self-expanded possible. We propose an innovation software based on a portable equipment and center server doing core operations. In order to solve the problems efficiently, and meanwhile realize the self-expansion function, a win-win concept between user and software is presented. Besides, we elaborate the working principle of the system, and list three cases. Finally, according to the structure analysis of the system, we show the initial development of the CAI software based on the Advanced RISC Machines(ARM) mobile terminal.

Keywords: Wide Area Network(WAN), Computer Aided Innovation(CAI), Mobile Terminal(MT), Advanced RISC Machines(ARM), self-expansion.

1. Introduction

Computer Aided Innovation(CAI) plays a key and fundamental role in the new product development“ The work(Ma J.H.2004)”, which is a comprehensive technology by means of computer, mainly based on TRIZ, and includes other advanced design theory and methods “The work (Tan R.H.2000)”. CAI combines professional design theory which is characterized by different functions and advantages with design knowledge. With the help of high-speed and high-capacity computer, CAI can assist designer to do the innovation activities. Its effect lies in helping engineers extend their thoughts, get rid of the bondage to utilize knowledge of different fields and put forward practicable innovation idea “The work (Dong J.Q. Wang K.S, 2008)”. The typical tools are Tech Optimizer (Goldfire Innovator) developed by Invention

Machine company, Innovation Workbench(IWB) by Ideation International, Trisolver2.1 by Germany , Invention Tool by Hebei university of technology and so on.

There have been over ten years on the research of CAI "The work (Fey V S et.al.1994)". So far, many companies have applied CAI to solve engineering problems successfully "The work (Ma J.H., Tan R.H.2003; Shi g.,2008)" .Such as Ford, GM, Motorola, IBM, HP. Actually, the key to popularize an advanced technology is the universalization of software tool. But now, CAI has a serious problem that how well the users understand TRIZ limits its application. If you know little about TRIZ, you will get little help from CAI, that is to say, CAI has been an expert tool and assist experts to innovate rather than computer assistant innovation. However, major users hope that CAI would be an innovation tool to learn easily and use conveniently. Besides, the CAI is expensive and generally there is only one constant computer installed a software in a lab, a company or a research center. Faced with the high cost, inferior portability, low popularization and other problems, the market of CAI is competitive seriously, no matter the entrance of a new software or the update of the existing tool encounters enormous challenge. Therefore, how to make CAI popularity is a problem to be solved instantly.

This paper provides a CAI project based on WAN and Mobile Terminal. We make use of many kinds of computer terminals to realize the sharing and self-extended of innovation knowledge database. This MT can solve the above problems with the advantages of low cost, low power consumption, good portability and more simple operation interface "The work (Alberto S. V.2001)". Apparently, it is the research trend of CAI.

2. System construction

2.1 System Composition and Division of Labor

This paper provides two solutions: one based on mobile terminal, which can use its own database to solve the problem. One based on the Wide Area Network and Mobile Terminal, when the database of mobile terminal can't meet the requirements, we can make remote call from the database of the center server to help users to solve the problem.

As shown in Figure 1, the computers of many fields embedded in innovation software terminal. When the industry encountered with innovation problems, in order to achieve creative problem solving, it can through connections between this terminal and the center server and requesting the auxiliary information from the industry innovative system. Once the certain innovation problem of the industry has been solved through the terminal, it can be requested to upload. Once approved, the standardized innovation scheme will be expanded to the center server, and the server is available to all connected users to download.

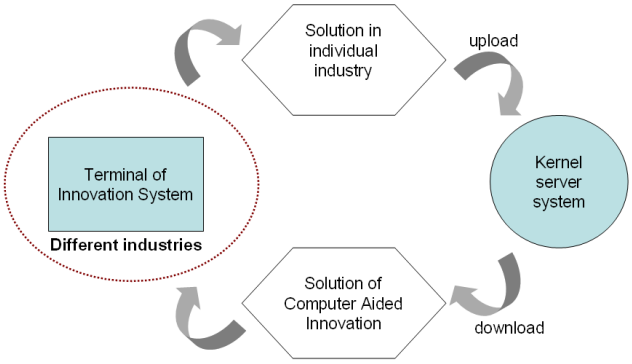

Fig.1.The data exchange principle of computer aided innovation system based on the wide area network.

As shown in figure 2, center server is the root to solve all problems. All applications in various fields of embedded system can be connected with the central server. When encountered with the problems, the user only need through the portable device to issue remote input to the center server corresponding to the call center server database. After calculation, processing, and then answering feedback to the user, this original and complex man-machine communication process can be transformed into a portable device to exchange with a central server. Then what it needs for users is only to perform simple operations in the portable device.

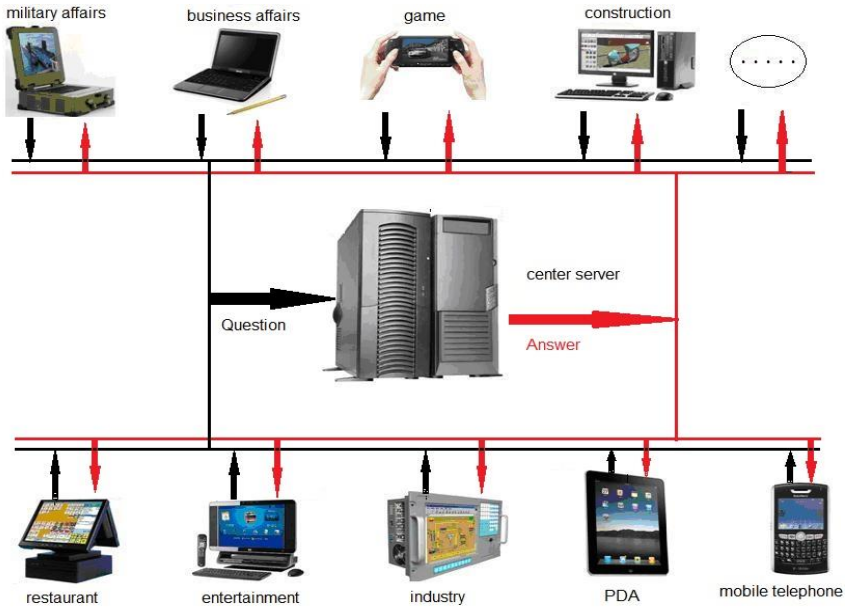

Fig.2 .The structure of computer aided innovation system based on the wide area network and multimedia terminal.

2.2. A win-win process between user and software

This software can provide users with free solutions, but the perfection of this software itself and the expansion of the database need the users' help in return. Before using this software, users will need to sign an agreement. When this system successfully provides users with a solution to the problem, the users can also upload free solutions back to the central server database. Thus, to provide convenience to others, at the same time to achieve its own database software's perfection and rich. It is a process of win-win.

2.3. The Work flow

As shown in figure 3, figure 4, the work flow of this system can be divided into the following several steps:

1) Users complete the description of the problem in the portable equipment, and upload them to the central server.

2) Center server will receive the issue of classification and retrieval.

If it is already in the database, then directly output the answer to the question.

If it is not found in the database, using innovative methods, such as TRIZ tool, for problem solving method.

3) Send back the answer to the user's client.

4) Evaluate: the answers to the users is satisfaction or not.

If not satisfied, add additional requirements or redefine the problem, and then return to the above steps, until the problem gets the satisfied answer, then feeds back a satisfied solution to the center server.

If satisfied, return the plan to the center server.

5） Center server receives a satisfied solution, and produces the relevant audit. If it is not already in the database and the content is very practical and legal, stores them in the database, complete the database's extension.

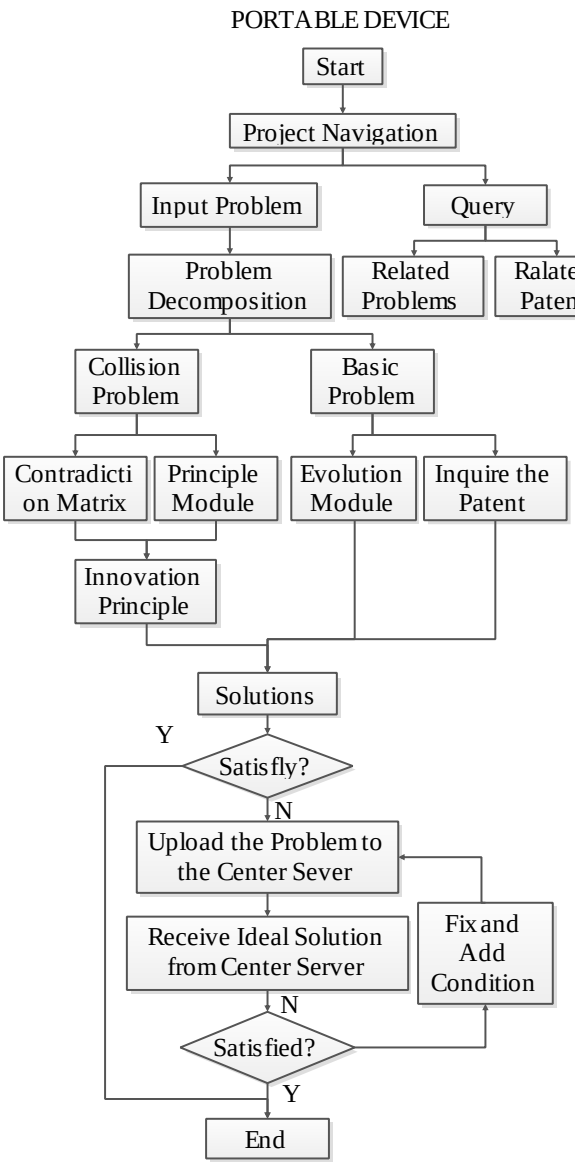

Fig.3.The work flow of client

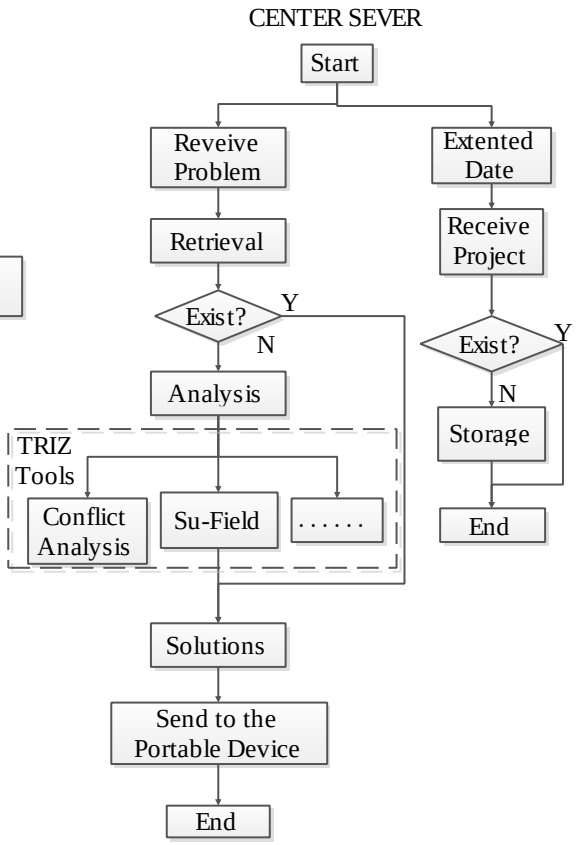

Fig.4.The work flow of center server

3. Software development

As shown in figure 5, here we use SinoSys-EA2440a as a multimedia terminal research, and use VS2005 C + + for software development. SinoSys-EA2440a based on Samsung's ARM processor S3C2440A as the main processor; hardware design of the core plate and bottom plate design ideas, core board adopts 6 layers design, and the base plate adopts 4 layers design. S3C2440A using ARM920T nuclear, with internal performance MMU (memory management unit). It is applied to the design of mobile handheld devices products with high performance, low power consumption, rich interface and small volume. As the picture below:

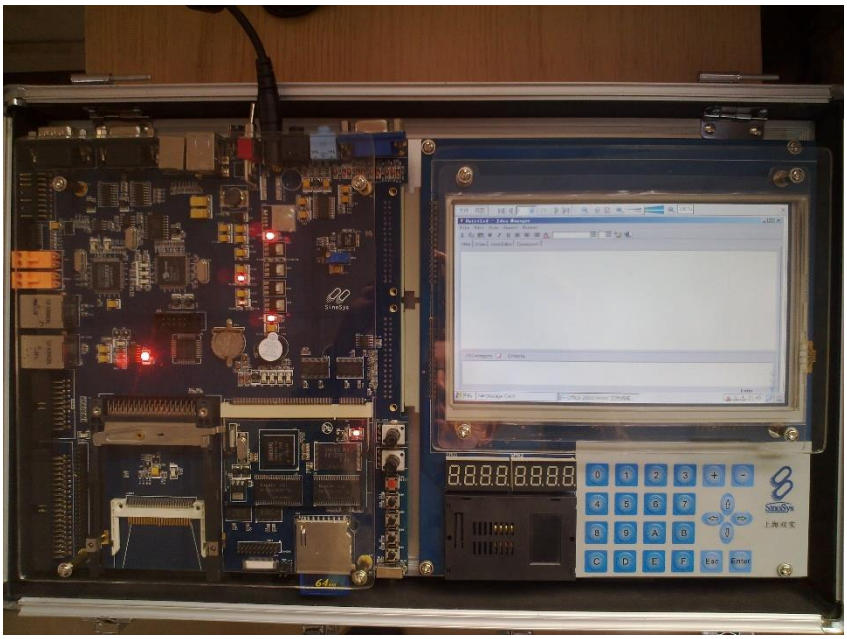

Fig.5. SinoSys-EA2440a multimedia terminal

As shown in figure 6, this is the primary interface of this software, which mainly includes the establishment of project, the input and edit of the problem and add additional conditions on problem.

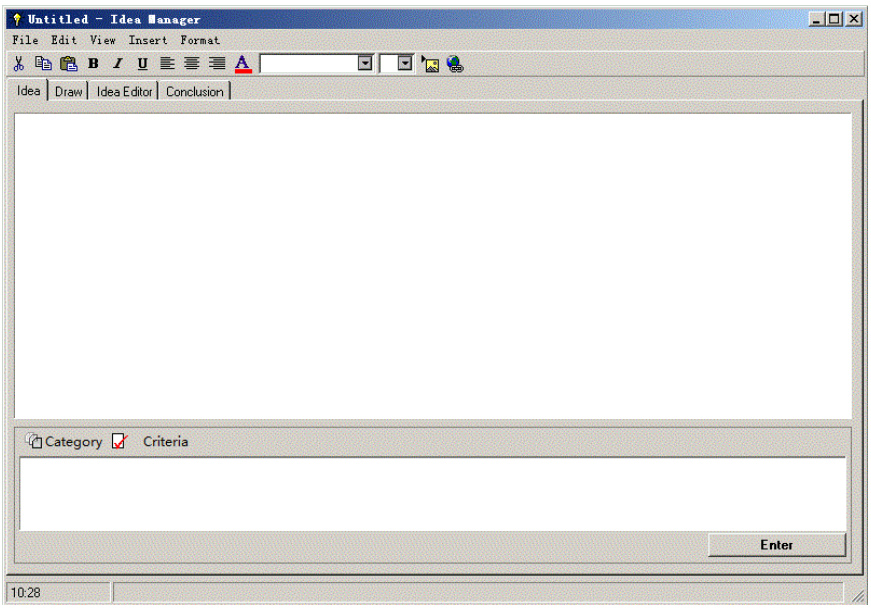

Fig.6.The primary interface of this software

As shown in figure 7. The user must first establish the project. Define names and properties of the problem.

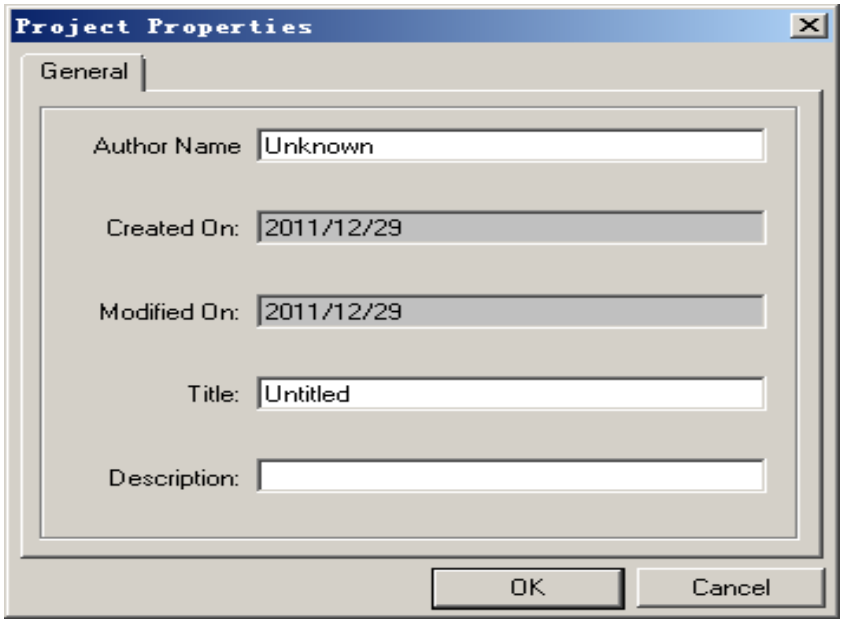

Fig.7. Project Properties

As shown in figure 8, input the question's type and detailed attributes. This can better facilitate problems for rapid retrieval.

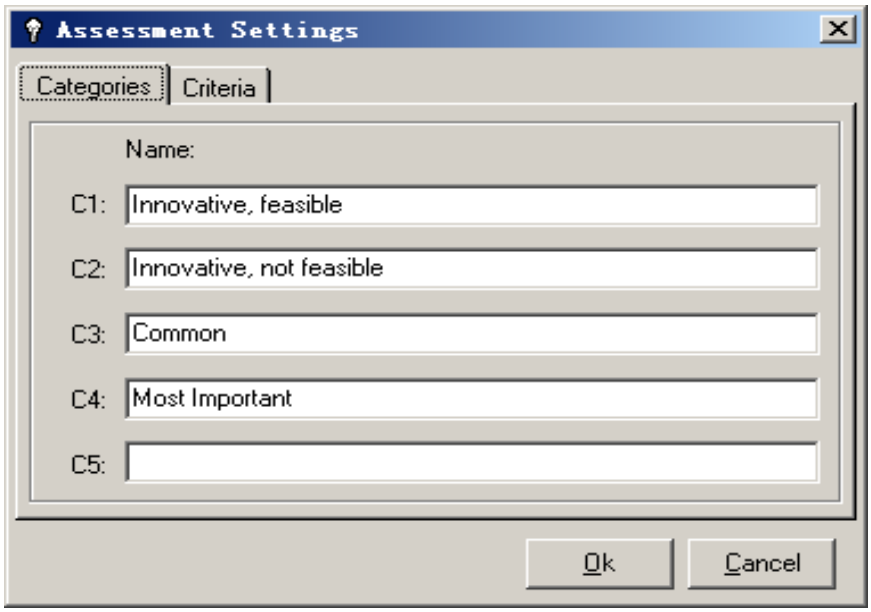

Fig.8.Further Description

As shown in figure 9, then add a detailed description of the problem or the constraints of the problem, and the weight of every part of the whole problem, so that we can better understand the problem and clearly know the answer in a desired direction. It is also an expression of more humane and personalized.

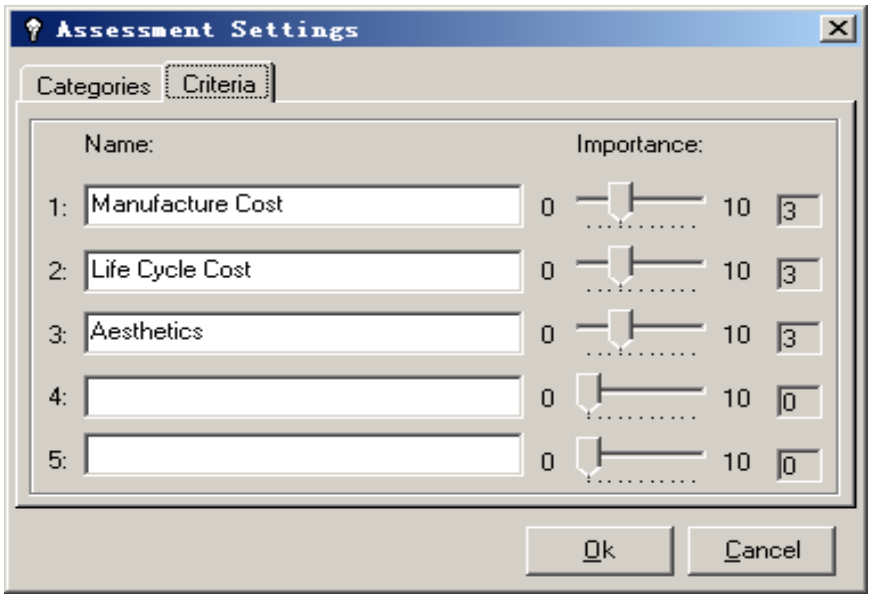

Fig.9.The weight of every part of the whole problem

When user completes description of the problem, clicks the button "Enter". The software will firstly collect, classify and extract the information from users and send to a central server. Then feedback answers to the user that comes from the central server. So as to realize a problem's solving process. The user can assess the solution of the problem. If not satisfied, redefine the problem in "Assessment Settings", or define additional conditions of the proportion, to further standardize the problem, and get the ideal answer.

4. Examples of application

Applications in innovative software in embedded system are also wide, here are a few examples:

1）Innovation software database can be integrated with some financial experts' experience and financial investment. The specific application of the following, can install the innovative software embedded system machine in bank hall, when the bank's depositors to his own money to finance or investment management at the time, can be directly on the machine to complete the objectives. For example, the depositors in equipment inputs occupation, expected investment direction, amount, retiring age or risk types. The equipment will sort out user's problems, and then send to a central server through the retrieval of the existing database. And by using the theory and tool of TRIZ to obtain the ideal solution, and send back to the portable equipment, thus comes to a" tailor-made" financial management program for the user. At the same time store the solutions into a database for later similar query. This not only makes the

bank save employ financial experts expenditure, time and energy, but also is convenient for users.

2） Innovative software application in military affairs is also indispensable. Such as , puts many of the tactics and military experts' military theory into a database, integrates innovation in software and installs in a convenient portable embedded system and can be associated with a central server remote. Exercising or in actual combat, when encountered with some tricky incident, soldiers can send the problems encountered by the hands of the portable instrument to a central server which can quickly get the ideal solution, also can obtain and receive data from the new operational command in the first, greatly improve the accuracy and efficiency of operations.

3） This technology in the automobile repairing can also play a vital role. Now auto repair sometimes encounters with this problem. When a car is seriously damaged, repair workers will face the problem of where to begin with, then so often find the blindness bad parts to repair, which will cause such a problem. Often in the repair of a member at the time, new repaired components on being repaired components forms a barrier, hinders the next parts' repair. It needs to remove the repaired parts. This is an increase of new unnecessary problems, so that the repair efficiency is greatly reduced, at the same time also increases the workload of workers. So if the repairman is equipped with such a device, when with the problems, problems can be through the device sent to the central processor, to search through the integration of a large number of car repair experience, automotive knowledge database and applications of TRIZ theory and tools, then an ideal solution will be feedback to the repair work. It not only can avoid some unnecessary problems, but also can get other people to upload to server some similar problems' solutions. The database can also be different brands, different models of classification, so that workers in the retrieval problems can be more targeted, also can be obtained car manufacturers' recommendations in real time.

5. Conclusion

The main innovation points include the following 3 points:

(1) We propose a CAI system based on the WAN and MT.

(2) We propose a win-win concept between user and software.

(3) We finish the initial development of the system based on the ARM innovation aided software terminal.

The trend of the product development is miniaturization, intelligence, multi-functional, low cost and easy to manufacture, update "The work (Niu Z.W., Xu Y.S,2003.)". Therefore， innovation activities need more interdisciplinary knowledge, more technical support and more perfect theory of innovation design methods and more effective CAI software tools support. The CAI software based on the mobile terminal not only have advantages of large storage ,fast

calculation, reliable performance, eliminating contingency and one-sidedness caused by subjective factor during the process of innovation design, but also have superiorities of good portability, low cost, simple. It must become important technical methods of increasing the speed of response in the market and improving product innovation ability.

6. Acknowledgment

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Research on New Kind of Plough with TRIZ and Design of Experiment

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Abstract

The main part of plough is the share, it digs into the soil, separates the surface soil from the bed soil and then moldboard turns it upside down, but the share's life is very short which is because the friction between the share and the soil. The paper will present a case study of successfully using TRIZ methodology and Robust Design to solve a longstanding design deficiency of plough. Using Su-Field analysis method and physical effects, engineers found a way to reduce the friction with magnetic field and came up with a low-cost solution using existing plough. Robust Design was used next to optimize the settings of the solution. The resulting feature was put into production, and it greatly increased customer satisfaction, prolonged share's life and fortunately after the new plough cultivated the crop yield could be increased.

Keywords: TRIZ, Su-Field analysis method, Plough, Share friction, Design of Experiment.

1. Plough and TRIZ

As a research project, TRIZ was introduced to and practiced at plough by learning and experimenting TRIZ on work. The project had multiple goals, one of which was using TRIZ to tackle a real life technical problem. The problem the group decided to take on was the friction problem on the share of plough.

2. The Plough System

Figure1 is the sketch of a mono-plough, the main parts of it is the share. At working, the share first digs into the soil, separates the surface soil from the bed soil and then the moldboard turns the upper soil upside down. During cultivation, the share's life is very short which is because the big friction between the share and the soil. And the cultivated quality was depended on the share greatly.

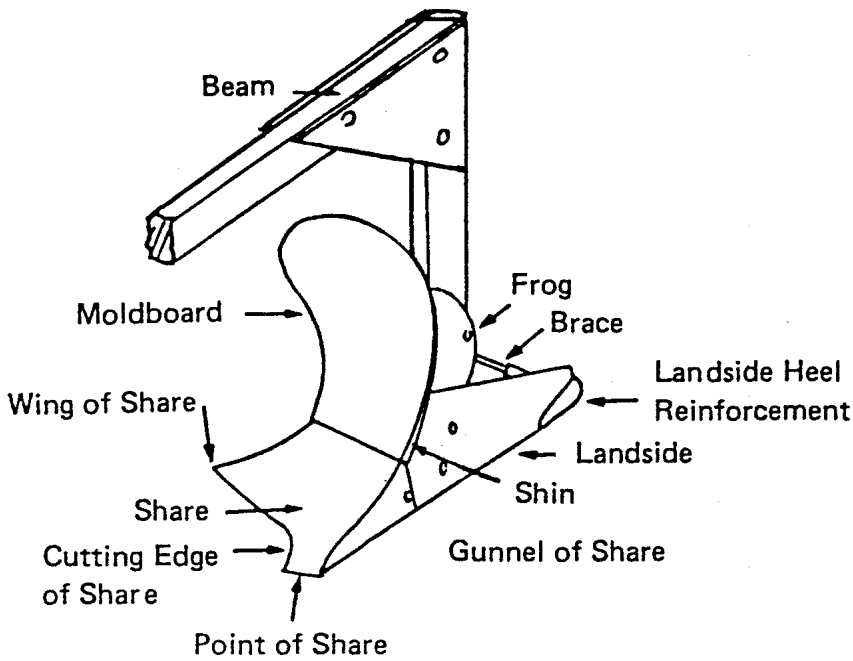

Figure 1. The sketch of a plough

3. Past Attempts to Solve the Problem

In the past, several attempts have been made to remedy the share-friction problem.

Different kinds of alloys have been tried to manufacture the share. Although some kinds of share made of alloys were working well and the share friction is very lower, but the cost was very higher and the customer could not afford on it normally.

Another attempt was to make the plough especially the share to vibrate when cultivating soil. The plough equipped with the vibrating system could reduce the share friction and prolong its life, but the addition of the vibrating system make the cost of the plough increase sharply and some negative effects were derived from the vibrating system.

As a result, the farmer hope the share of plough working longer and cost lower, so it is very important to develop new kind of share on the plough.

4. Practicing S-Field Analysis Method

First, the S-Field of the plough was analyzed as Figure2. S1 is the soil, S2 is the share, and Field is the mechanical force—the draft force of the tractor.

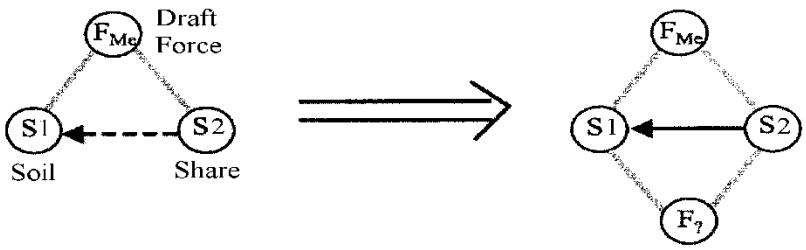

Figure 2. Adding a field to reduce the effect is one standard solution

There are several possibilities for field, which will reduce the effect of friction:

- a pneumatic field using pressure air.
- a magnetic field to magnetize share to improve friction.

Selecting a different solution from the Standard Solutions, insert a substance S3 and another field F2 (Figure 3) to develop a concept to support the solution.

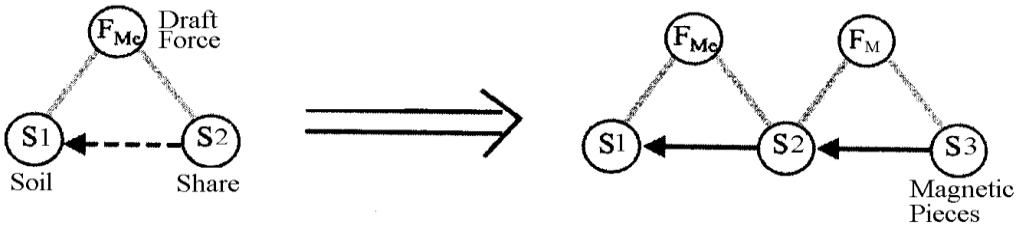

Figure 3. A Solution different from the standard solution

F_M is magnetic field and S3 is magnetic pieces, which attached to the back of the share (Figure 4). The magnetic field (the magnetic field intensity is higher) will affect the soil, causing the share friction down.

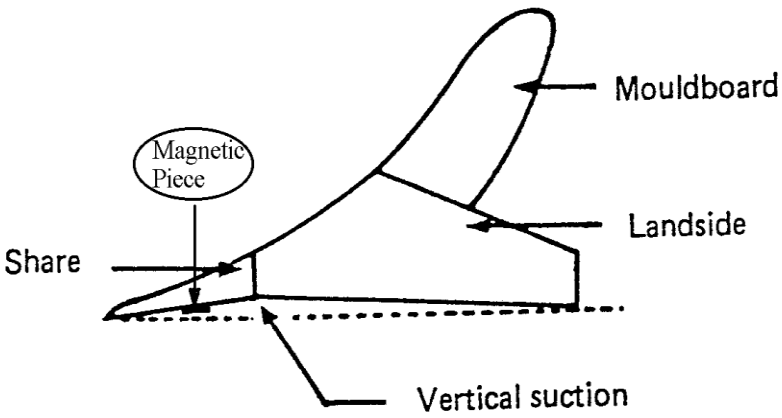

Figure 4. The magnetic pieces were attached to the back of the Share (side view)

5. Robust Design for Optimization

The new kind of magnetic plough was shown as Figure 4. The small magnetic pieces were attached to the back of the share and then the magnetic field was formed around the share, and changes the relations between the soil and the share, therefore reduce the share friction.

For field implementation, the magnetic intensity of the share and the working speed of the plough must be optimized to make plough work well and cost lower. But the share friction is very difficult to be measured, so the two parameters, the plough draft and the engine fuel consumption, were chosen to measure instead of the share friction. A simple two-factor (the speed and the magnetic intensity), three-level DOE (Design of Experiment) was used, and three repetitions were run for each of the nine settings (Table 1).

Table 1. Design of contrast experiment on magnetic plough

Experiment No. #	A	B	A Working speed	B Magnetic field	Experiment result (draft force)		
					Output 1	Output 2	Output 3
1	1	1	A1	B1	30.5	31	32.6
2	1	0	A1	B2	38.5	39.4	37.9
3	1	-1	A1	B3	45.8	46.8	40.2
4	0	1	A2	B1	50.2	51.9	46.7
5	0	0	A2	B2	34.6	37.8	32.1
6	0	-1	A2	B3	56.3	58.1	53.4
7	-1	1	A3	B1	63.2	64.5	69.6
8	-1	0	A3	B2	70.3	69.5	71.6
9	-1	-1	A3	B3	60.1	58.4	57.3

The output of the experiment was a numerical representation of how the plow draft or fuel consumption was, the lower the plow draft or fuel consumption, the lower the share friction was. An average output of 70.46 (No.8) represents a better condition, where an average output of 31.36 (No.1) represents a worse condition. The optimizing settings were achieved with No. 8 (A3, B2).

The contrast experiments between the magnetic plough with No. 8 (A3, B2) and the normal one were done at the same condition like below: The experiment plough with 4 mono-plough, the soil was burozem and soybean field last summer, soil compaction was 30.28 N/cm3, soil water content was 15.98 %, plow depth was 22.5 cm and the mono-plow width was 20 cm.

The experiment results showed that the magnetic plough saved the plow draft 10.55 % and reduced 11.3 % fuel consumption than the normal plough did. The result proven fully that the magnetic

plough could surely get the achievement of saving plough draft, reducing fuel consumption of the engine and finally reduce the share friction, increase the share's life.

Another result was out of expected, compared with the normal field, the crop was grown better on the magnetic plough cultivated field and the crop yield was increased than the normal plough field did.

6. Conclusions

Using S-Field analysis method, a methodology derived from TRIZ, in combination with DOE, magnetic share of plough solved a long-standing share friction deficiency in the cultivated machines. The addition of some small magnetic pieces on the share will increase the total cost of the share, but the saving of plough draft and reducing fuel consumption of the engine can compensate the cost, the farmer also could afford it.

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Process Innovation Knowledge Accumulation Method Based on Bilayer Social Wiki Network

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Abstract

Reasonable and efficient knowledge accumulation is the prerequisite and basis for effective knowledge application in process innovation. By considering the similarity of process innovation knowledge network with biological neural network and demands of knowledge accumulation, the process of knowledge accumulation is divided to two stages: process innovation knowledge unit construction and process innovation knowledge neural network organization. Hence, combining the technical characteristics of social network with wiki, a novel process innovation knowledge accumulation method based on bilayer social wiki network is proposed. And the process of collaborative accumulation is illustrated. In bilayer social wiki network environment, refined process innovation knowledge could be accumulated through participants' social interactions and knowledge activities. The outcomes of this study lay the foundation for knowledge application in future process problem-solving. Finally, a prototype system implemented in a medium manufacturing company is used to evaluate the proposed method.

Keywords: Computer aided process innovation (CAPI), Knowledge accumulation, Process innovation, Process innovation knowledge, Social wiki network

1. Introduction

Innovation has been regarded as an important existential factor for manufacturing enterprises who want to succeed even survive under the intensive competition circumstance of global market. Over the last decades, significant developments in computer aided innovation (CAI) has taken place (Cardillo *et al.* 2011, Cavallucci and Leon 2011, Sheu and Lee 2011) and CAI technology has evolved into CAI 2.0 and Enterprise 3.0 (Hüsig and Kohn 2011, Carbone *et al.* 2012). At the same time, new manufacturing modes and manufacturing processes are expected to appear, due to the need of large number of innovative and complex products. The concept of process innovation is proposed by J. Schumpeter (Schumpeter and Backhaus 2003); and process innovation is a creative practice which creates new technical principles and production modes and improves manufacturing capacity

and efficiency with modern scientific knowledge. As a branch of CAI, computer aided process innovation (CAPI) has received more attention in recent years (Cakir and Cilsal 2008, Geng and Tian 2010, Wang *et al.* 2013).

Process innovation can create new manufacturing technology or improve existing manufacturing technology, while process innovation knowledge (PIK) is used to support process innovation activities correctly implemented and to produce new process knowledge. From the lifecycle of knowledge perspective, PIK mainly has two core activities in process innovation: knowledge accumulation and knowledge application. Therefore, reasonable and efficient knowledge accumulation is the prerequisite and basis for effective knowledge application in process innovation. However, process innovation is different from product innovation (Simonetti *et al.* 1995). Product innovation mainly gives attention to virtual product, but process innovation must pay attention to final product, in-process product and manufacturing process. At the same time, process innovation activity must soak into laborers, producer material, manufacturing objects and their combining mode, and is restricted by enterprise manufacturing capability and other real factors. In general, process innovation has more broad technology domain, more complex and long procedure and needs more mass, fuzzy and discrete innovation knowledge than product innovation.

In the knowledge-based economy, knowledge has been seen as one of the sustainable assets for manufacturing enterprises. PIK is composed of process contradiction matrix, innovative solution instance, science effect and manufacturing capability description etc from the role of knowledge in manufacturing problem-solving, and it has the characteristics of wide range dispersion, fuzziness, high correlation, and multidisciplinary fusion (Wang *et al.* 2013). Besides, process innovation activities involve large number of participants, but their knowledge levels are uneven, and their knowledge domains are different. Thus, our main objective in this study is to explore an open PIK accumulation model which should allow full participation, combine collective intelligence (Chesbrough 2003, Hüsig and Kohn 2011) and obtain refined knowledge so as to support the implement of process innovation.

2. PIK accumulation model based on bilayer social wiki network

Manufacturing experts and technicians have strong ability to solve manufacturing problems, but the discrete and unstructured knowledge can’t be directly used in process innovation. Hence, the process of PIK accumulation should realize that knowledge can be turned from tacit to explicit, from discrete to associative and from rough to refined. Considering knowledge form, the organizing process of PIK could be divided into three phases: discrete knowledge, process innovation knowledge unit (PIKU) and process innovation knowledge network.

Process innovation knowledge network is highly similar to biological neural network. Neural network consists of large numbers of neuron, accepts external stimulus and outputs control action through the interaction between the neurons(Lippmann 1987, Hagan *et al.* 1996). Process innovation knowledge network contains a large number of PIKUs, accepts the stimulus of process problem and

outputs innovative solution through the interaction between PIKUs. Due to the similarity, we proposed a construction method of process innovation knowledge network by the imitating of neural network. So, we consider PIKU (which should have specific interfaces and parameters accurately) as process innovation knowledge neuron (PIKN) in knowledge network, and adequate number of PIKNs constitute process innovation knowledge neural network (PIKNN) in the environment of process problem-solving.

PIKN has knowledge parameter input interface and knowledge result output interface respectively corresponding to dendrite and axon of neuron. The encapsulation space of PIKN is mapped to cell membrane of neuron. The knowledge attribute is mapped to cytoplasm of neuron. The core handling process is mapped to nucleus of neuron. The structure of PIKN is described as displayed in Figure 1.

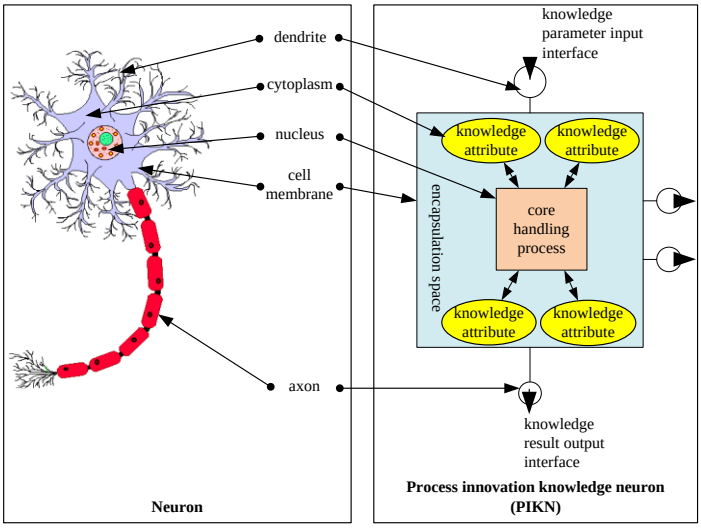


Figure 1. Structure of PIKN

Social network technologies based on relationship network and interested topic could provide a exchanging, sharing and manifesting knowledge platform beyond background and specialty (Jung 2010, Zheng *et al.* 2012). Wiki technologies can provide a knowledge refining and associating platform through page locking and collaborative editing (Baumeister *et al.* 2011, Jung 2012). Thereby, oriented towards knowledge building stages of PIKU and PIKNN, combining the characteristics of social network with wiki, PIK accumulation model based on bilayer social wiki network is proposed as shown in Figure 2.

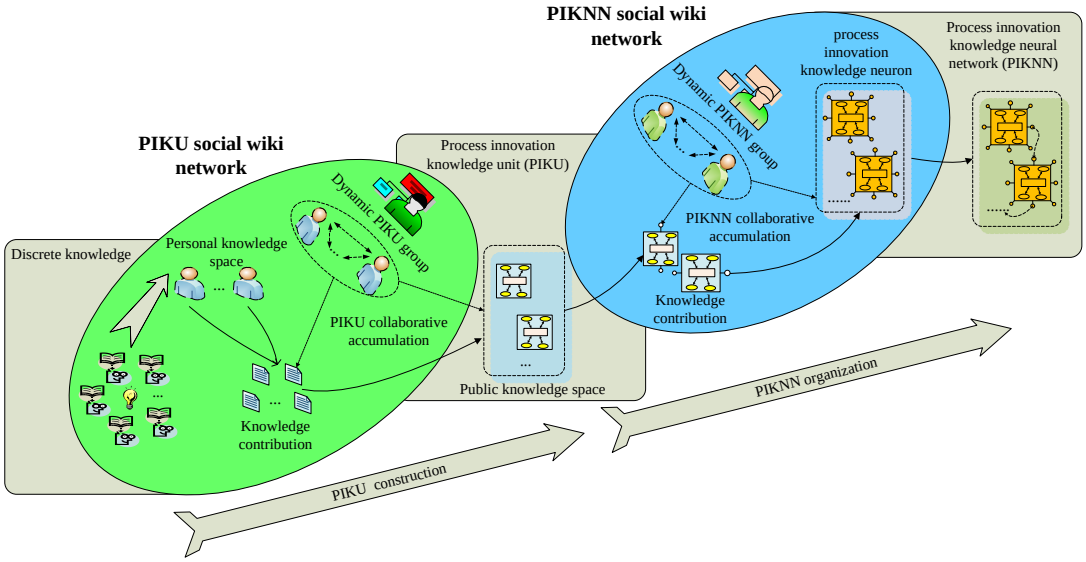


Figure 2. PIK accumulation model based on bilayer social wiki network

From the perspective of knowledge contributors, social wiki can quickly establish innovative community and seek appropriate participants for knowledge accumulation. From the perspective of PIK, social wiki can make knowledge contributors participate in collaborative editing of various innovation knowledge, and guarantee the refined knowledge is obtained. Meanwhile, PIKU social wiki network can make personal discrete knowledge gathered, refined and stored in public knowledge space while PIKNN social wiki network can make technicians collaboratively add knowledge association for PIKNs (e.g., knowledge interfaces) in order to form dynamic self-organizing PIKNN.

3. PIKU social wiki network

The PIKU social wiki network is shown in Figure 3. Discrete technicians publish PIKU themes. The interested technicians for some topics are gathered into an interested group through social relationship. Then they discuss this topic and contribute their knowledge using knowledge template from the point of view of individual specialty and experience. Some of most rational individual knowledge will be merged into a preliminary PIKU. Then, this preliminary PIKU will be locked and be refined editing through wiki technology by knowledge refined group. Finally, the high quality PIKUs will be accumulated.

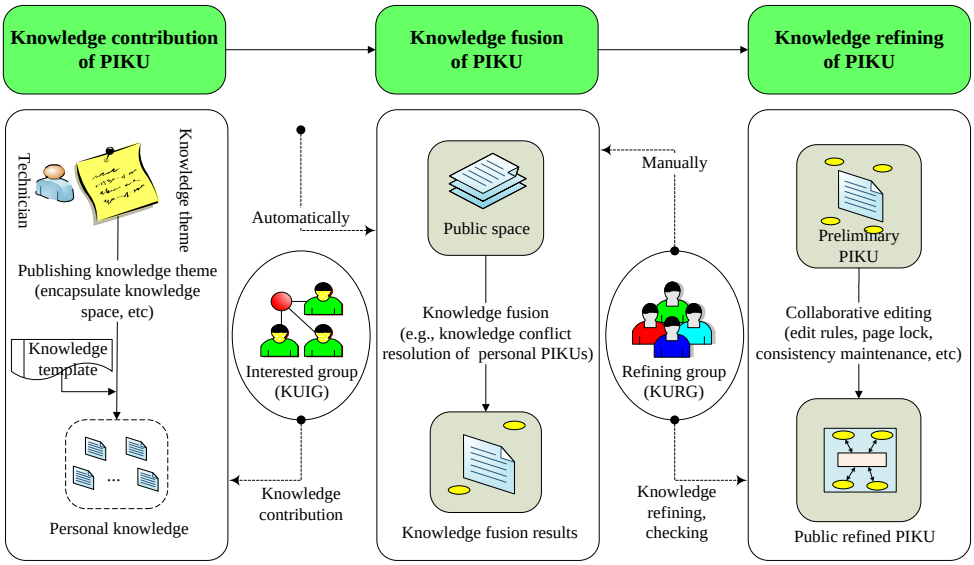


Figure 3. Collaborative accumulation process of PIKU

3.1 Publishing knowledge themes

Knowledge themes which describe the demand of process innovation knowledge could be published by technicians in order to allow a group of social wiki users to contribute their knowledge from geographically dispersed sites. And knowledge template and encapsulate knowledge space should be defined. Moreover, participants should set their personal information of professional fields and interested areas so as to quickly obtain knowledge themes.

3.2 Building PIKU groups

Social wiki users and their social interactions in knowledge collaborative accumulation constitute a complex network. According to individual knowledge contribution, a specific tag containing knowledge credits is given to the participant. So, key nodes can be found within the field of process innovation through the network structure analysis, and we call them as authorities.

The process PIKU construction calls for the following two knowledge groups:

(1) Interested group *KUIG* *KUIG* is used to organize participants in PIKU social wiki network. Users who have a certain knowledge credits own the permission to establish *KUIG* and invite some users to join the group. In addition, other users can also apply to join *KUIG* .

(2) Refining group *KURG* *KURG* could be established by domain experts and technical authorities. Members of *KURG* could participate in the process of knowledge fusion, knowledge refining and knowledge checking.

3.3 Knowledge fusion of PIKU

In the established group $KUIG$, social wiki user can discuss the topics or exchange information with each other and contribute their personal knowledge according to the knowledge template. Furthermore, knowledge properties should be added to personal PIKU. Hence, the PIKUs is simply represented as follows:

$$KU =< K, E, U, P > \tag{1}$$

where K is core handing knowledge, E is a knowledge encapsulation, U are a set of social wiki users, while P are knowledge properties.

Given a user $U_i \in U$, his personal PIKU can be expressed as

$$KU_i =< K_i, E, U_i, P_i > \tag{2}$$

Thus, through merging all of the users' personal PIKU manually (e.g., by $KURG$) or automatically (e.g., by fusion algorithm), the preliminary PIKU of public space $KU_{\Omega_{pre}}$ is obtained.

$$KU_{\Omega_{pre}} = \sum KU_i =< K_{pre}, E, U_{pre}, P_{pre} > \tag{3}$$

However, since collaborative accumulation of PIKU allows social wiki users to use their own semantics and backgrounds for describing knowledge, there are conflicts among users who describe the same PIKU but hold different opinions. So, we should rationally select the better or best knowledge as the result of PIKU fusion. By calculating majority voting of the social wiki users, the conflicted knowledge can be resolved to a certain extent. Given the number of wiki pages n_w (which represents the number of corresponding social wiki users) for an identical PIKU can be measured. When the number of wiki pages for the PIKU is the largest (as shown in Eqs. 4), we can choose $< k, p, k''' >$ as the choice from the conflicted knowledge (e.g., $< k, p, k' >$ $< k, p, k'' >$ and $< k, p, k''' >$).

$$n_w(W_{<k,p,k'>}) < n_w(W_{<k,p,k''>}) < n_w(W_{<k,p,k'''>}) \tag{4}$$

3.4 Knowledge refining of PIKU

The PIKU social wiki network allows participants of refining group $KURG$ to view and edit the preliminary PIKU. The preliminary PIKU can be locked by wiki locking technologies, and then can be improved, revised and checked by the member of $KURG$ so as to form refined PIKU. A value v of a certain property p_k of preliminary knowledge unit $ku_{\Omega_{pre}}$ can be revised to new value v'.

$$< ku_{\Omega_{pre}}, p_k, v > \rightarrow < ku_{\Omega}, p_k, v' > \tag{5}$$

A preliminary PIKU can evolve into a refined PIKU through social wiki activities of experts and authorities.

$$KU_{\Omega_{pre}} =< K_{pre}, E, U_{pre}, P_{pre} >\rightarrow KU_{\Omega} =< K, E, U, P > \quad (6)$$

However, consistency maintenance in the face of concurrent accesses to the identical knowledge is one of the core issues. In order to ensure collaborators can't break the consistency criteria of collaborative editing of public PIKU, a lock based solution is needed to maintain the consistency. Meanwhile, social activities of $KURG$ should avoid the following situation:

(1) The identical PIKU is edited simultaneously by multiple users.

(2) Edit cycles occur in collaborative editing.

4. PIKNN social wiki network

The second layer social WIKI network is used to accumulate PIKNN. The accumulated PIKUs lack specific application domain and application scenario, and they only have basic relationship to solve generalization problem. In this case, we should add specific interfaces and parameters to PIKUs in order to form self-organizing knowledge network and improve process problem solving ability. Their accumulation process is similar to PIKUs accumulation, as shown in Figure 4. Firstly, discrete technicians publish application scenarios. Then some interested technicians for some scenario discuss through social relationship, each of them can add specific interfaces and parameters individually for PIKNs. Then, the different interfaces and parameters of the same PIKN will be merged. Finally the PIKNs will be locked, cooperatively edited and refined. The PIKNs with specific interface and parameters can accept specific problem input, self-organize and self-associate to form the PIKNN and solve the process problem.

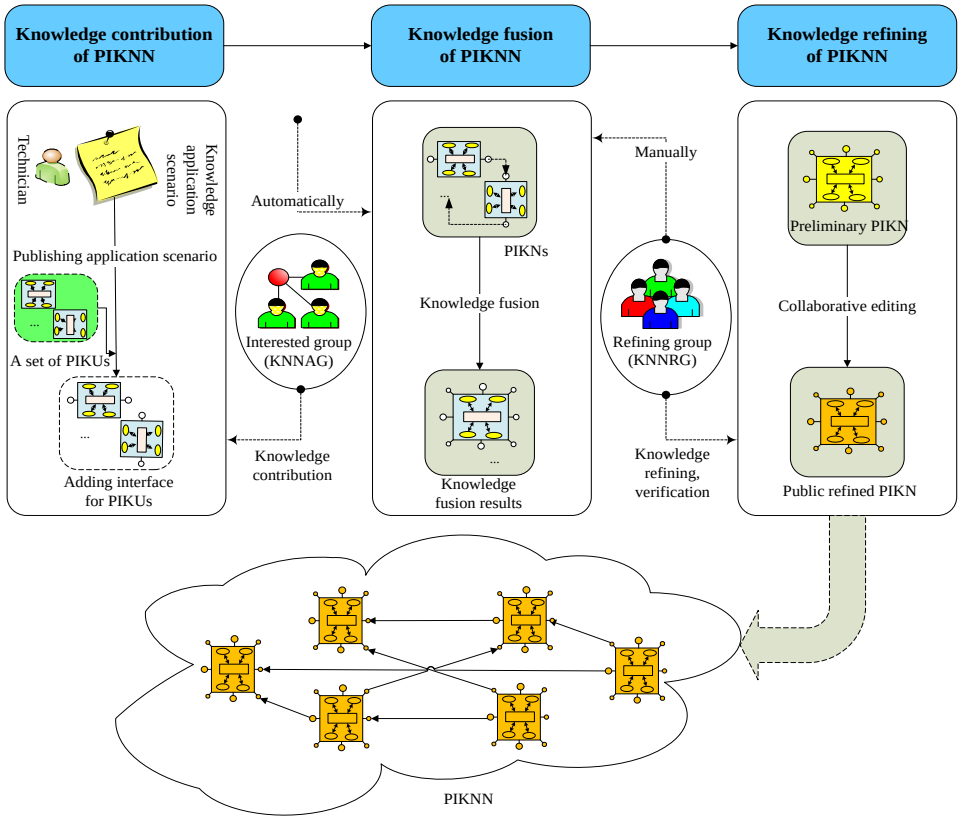


Figure 4. Collaborative accumulation process of PIKNN

4.1 Publishing application scenarios & building PIKNN groups

The discrete PIKUs need contextual knowledge explanation (e.g., knowledge interfaces) to improve their usefulness in different environments. Publishing application scenario is similar to the knowledge theme, and the difference is that the object of knowledge application scenario is mainly for technicians in process innovation practice.

Likewise, we can establish social application group $KNNAG$ and knowledge network refining group $KNNRG$ with similar to building PIKU groups.

4.2 Knowledge fusion of PIKNN

We introduce several definitions in order to formalize the process of knowledge accumulation, as shown follows:

Definition 1 (set of knowledge unit) C refers to a set of PIKU in specific knowledge application scenario, and it is represented as

$$C = \{KU_{\Omega 1}, ..., KU_{\Omega i}, ..., KU_{\Omega n} \,|\, n \le N\} \tag{7}$$

where N is the total number of PIKUs in public knowledge space.

Definition 2 (process innovation knowledge neuron) KN refers to a PIKN which has knowledge interfaces and the ability of information delivery, and it is simply represented as

$$KN =< K, E, U, P, I_i, I_o > \tag{8}$$

where K is core handing knowledge, E is a knowledge encapsulation, U are a set of social wiki users, P are knowledge properties, while the two I_i, I_o are knowledge parameter input interfaces and knowledge result output interfaces respectively.

Definition 3 (knowledge relationship) T indicates a set of associated relationships for PIKN, and it is defined as

$$T = \{< kn, k, R, k', u > \mid kn \in KN, k, R, k' \in \mathrm{O}_\Omega, u \in U\} \tag{9}$$

where k, R, and k' are ontological entities defined in the social wiki ontology O_Ω. Particularly, R is a relationship between k and k'.

In the established group $KUIG$, social wiki user U_t can exchange information with others and contribute his personal knowledge interfaces and knowledge relationships for a set of PIKU C so as to form personal PIKN KN_t and personal knowledge relationship T_{U_t}.

$$KN_t =< K, E, U, P, I_{it}, I_{ot} > \tag{10}$$

$$T_{U_t} = \{< kn, k, R, k', U_t > \mid kn \in KN, k, R, k' \in \mathrm{O}_\Omega\} \tag{11}$$

And then through merging all of the users' personal PIKN and personal knowledge relationship manually or automatically, the preliminary PIKN of public space could be obtained $KN_{\Omega_{pre'}}$. Meanwhile, the resolution of conflicted knowledge should be taken into consideration, but the situation of PIKN fusion could be more complicated because of knowledge interfaces and knowledge relationship.

$$KN_{\Omega_{pre'}} =< K_{\Omega_{pre'}}, E_{\Omega_{pre'}}, U_{\Omega_{pre'}}, P_{\Omega_{pre'}}, I_{i\Omega_{pre'}}, I_{o\Omega_{pre'}} > \tag{12}$$

4.3 Knowledge refining of PIKNN

Knowledge refining group $KNNRG$ is used to revise and check the preliminary PIKN so as to get refined PIKN KN_Ω. The process of refining is similar to PIKU refining.

$$KN_{\Omega_{pre'}} =< K_{\Omega_{pre'}}, E_{\Omega_{pre'}}, U_{\Omega_{pre'}}, P_{\Omega_{pre'}}, I_{i\Omega_{pre'}}, I_{o\Omega_{pre'}} > \rightarrow KN_{\Omega} =< K_{\Omega}, E_{\Omega}, U_{\Omega}, P_{\Omega}, I_{i\Omega}, I_{o\Omega} > \quad (13)$$

When the number of KN_{Ω} is sufficient, a PIKNN could be self-organized in special process problem environment. Thus, knowledge space oriented process problem solving Ω can be denoted by $\Omega =< KN, U, T >$.

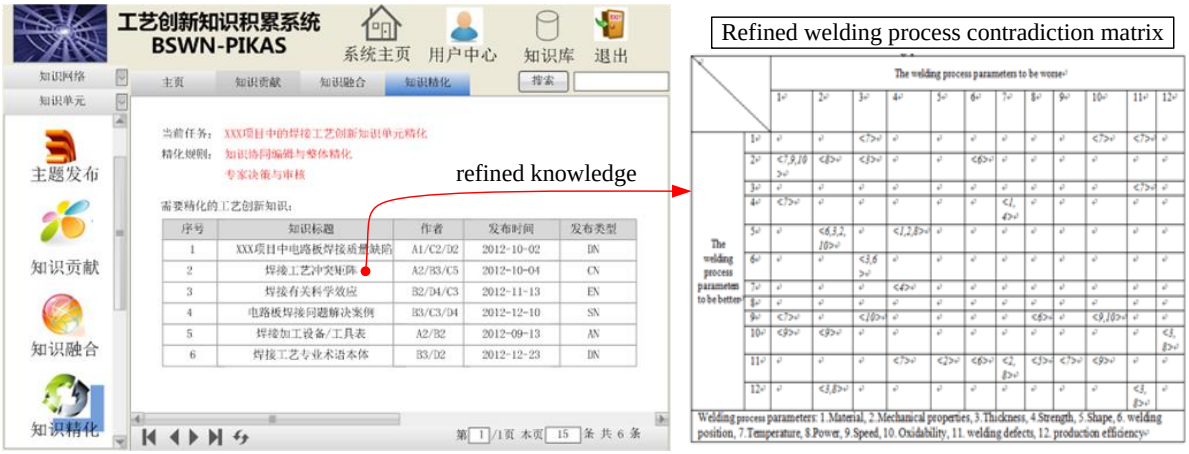
Besides, the case that knowledge interfaces and knowledge relationships of the identical PIKN is edited simultaneously by multiple users should be prevented as well as edit cycles.

5. Application and discussion

We developed a prototype system using the proposed method. In order to evaluate the proposed method and system, we have implemented the PIK accumulation system based bilayer social wiki network (BSWN-PIKAS) by obtaining welding process innovation knowledge in a medium company, who specializes in the design and manufacturing of pressure transmitter.

To conduct the validation, we have invited 60 engineers and 12 domain experts (they have long been engaged in the research and development work) to participate PIK accumulation in the BSWN-PIKAS. Besides, all employees are encouraged to participate in knowledge contribution. All of the activities taken by participators and knowledge contributed by them were collected during 4 months. Figure 5 (a) shows the knowledge refinement interface of BSWN-PIKAS and (b) shows refined welding process contradiction matrix obtained through social wiki activities.

The welding PIKNN containing 162 refined PIKUs has formed by the system's application in this company. And by using the welding PIK in process problem-solving of new pressure transmitter development, the qualified rate of this product has improved from 84% to 97%. System tests and evaluation by social wiki users show that this proposed system is favorable and basically meets the needs of PIK accumulation. Compared to the traditional method (minority and manual), this method facilitates communication between members of established group, and facilitates knowledge application in process innovation due to the relationship between PIKUs. However in the course of test application, we found that there are still some areas for improvement, such as heavy workload in manual knowledge fusion, the rationality and work efficiency of page locking in collaborative editing, and protecting evolutionary direction of continuous PIK accumulation.



(a) (b)

Figure 5. Knowledge refinement of BSWN-PIKAS for a manufacturing company

6. Conclusion and perspective

In this paper, we have proposed a novel knowledge accumulation method based on bilayer social wiki network for process innovation. The proposed method lays the foundation for the successful completion of process innovation, more specifically, for knowledge application in process innovation. Some of the benefits of our approach are listed below.

- By considering the similarity of process innovation knowledge network with biological neural network, and the technical characteristics of social network and wiki, the presented model provides an open knowledge accumulation pattern which allows full participation and combines collective intelligence. It can facilitate knowledge generation in a rapid and reasonable way.
- PIKU social wiki network is used to collect large numbers of PIKUs from a group of users. And PIKNN social wiki network is used to add knowledge interface and relation for PIKUs. Thus, the method could get discrete PIKUs and self-organizing PINNN step by step in bilayer social wiki network.
- Knowledge contribution, knowledge fusion and knowledge refinement are needed for the formation of PIKU and PIKNN. The refined PIK for the implement of process innovation could be obtained by group members' communication and wiki activities.

The contribution of this work is the description of an open knowledge accumulation model based on bilayer social wiki network in order to obtain refined PIK in collaborative manner. This accumulation model opens access to a larger audience of non-professional and untrained users, and through users' social wiki activities refined knowledge of public space could be gotten from preliminary knowledge of personal space. We have made an attempt in the direction of building a PIK accumulation methodology in this work, but the overall problem is far from solved. In our future work, we plan to focus on automatic method of PIK accumulation (e.g., knowledge fusion

method and algorithm, control process of knowledge collaborative editing, protecting evolutionary direction of continuous accumulation, etc.) and process problem solving method using PIK.

Acknowledgements

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Needs Evolution-driven Product User Needs Information Acquisition Supported by CAI System

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Abstract

Need design is the starting point and the primary goal of the product design. Fully and accurately acquire and analyze user need information is the key factor to success for enterprise product innovation design. Needs has the nature of evolution, by analyzing of the nature of need evolution, integrated the laws of need evolution with the theory of technology evolution of TRIZ, to direct the qualitative need evolution direction of product both in macro level and micro level. The principle of user new need information forecasting driven by laws of need evolution is studied and the process of user new needs information acquisition for entirely new product and existing product is set up. Then, overall applying the technique tools of Computer-aided innovation system (CAI) based on TRIZ, a general process model for user needs information acquisition of products is developed. A case study shows the application of the model.

Keywords: TRIZ, CAI, Need evolution, Need information acquisition

1. Introduction

Need design is the starting point and the primary goal of the product design, is the bridge which connects the market, the user and the product development process. The new idea generation and development process of product are largely depending on the cognition of the user needs, those directly impact on the quality of product design and the success rates of new product development. So fully and accurately acquire and analyze user need information, and to develop product which meet the user needs, is the key to success for enterprise product innovation design.

The source of user new need information is mainly based on two ways, that is market pull way[Twiss,1992] and technology push way. Due to the user's needs have the characteristics of fuzziness, complexity and dynamics, the demand information obtained by market pull should be processed accurately to convert to the technical requirements to guide product design. At

present, the main convert methods are fuzzy clustering analysis, entropy processing algorithm, regression analysis, analytic hierarchy process, etc. But these kinds of methods have certain limitation[Veryzer,1998], such as, subjectivity and randomness, the lack of effective acquisition mechanism. In addition, the market pull way and technology push way have little or no consideration of the phenomenon that products technology system has the inherent law of evolution, no consideration of the rich customer demand information that contained in the existing product, leading to the acquired demand information lack of objectivity and continuity. The research trend shows that the acquisition method for user needs is not perfect, further research and development is needed.

The process of human needs keeps constant changes, satisfying these new needs can be implemented through product with new function, and the realization of the new function require development of new system or improve existing system, so needs evolution is the source power for product function and technical evolution[Petrov,2006]. Based on the analysis of the variation law of human needs, TRIZ expert V. Petrov[Petrov,2006] considered that needs is in a state of evolution and is controlled by the objective laws. He summarized five needs evolution laws, which can be used to predict the future user needs, and can be play an important role in macroscopic level to direct the evolution trend of needs. Patterns and lines of technological evolution belong to technological forecasting of TRIZ[Alla, et al. 2006], the lines of technological evolution under each pattern describe specifically the stages of the systems development, can be used to predict the future needs specifically. Therefore, the needs evolution law and patterns and lines of technological evolution can be integrated applied to direct the needs evolution direction from both the macro and micro level qualitatively, and the accuracy of prediction can be effectively increased.

Firstly, the hierarchy and evolution nature of the user needs is introduced. Secondly, integrated of the laws of need evolution and the technology evolution theory of TRIZ, the principle of user future need information forecasting driven by laws of need evolution is studied. And the process of user new needs information acquisition for entirely new product and existing product is summed up. Then, overall applying the technique tools of Computer-aided innovation system (CAI) based on TRIZ, a general process model for user needs information acquisition of products is developed.

2. User Needs Analysis

The research of user needs analysis is that the product developers, manufacturers and operators be engaged in collection, analysis, structuring of the product needs information, and convert the needs information to design specification requirements, and then put forward design task information for product design.

2.1 The hierarchy of user needs

According to the Kano model[Cohen,1995], which is a model of studies of three different types of needs which can be expressed by the consumer with regard to goods and services, user needs of product is divided into three levels: basic demand, standard needs and interests demand. The corresponding product or service quality is divided into: basic quality, standard quality and the quality of interest. A.Maslow[Maslow,1954] arranged the groups of demands in the order of their priority. According to his study the satisfaction of needs moves in the direction from group 1 to group 7, that is physiological needs, security needs, social needs, knowledge needs, respect needs, self-actualization needs and aesthetic needs. If the needs of the lower level are not satisfied, the human will not think about the needs of the next level. Needs levels will be affected by the influence of the individual differences, and change with time elapse.

Accurately understand the level of user needs in product innovation design process, is helpful to clearly understand the user's true need and to carry out the innovative design pointedly. But the division of user needs levels doesn't take into account that the user needs has the nature of evolution, human needs keep constant changes in the process of evolution, causes the appearance of another higher level of needs.

2.2 The evolution nature of user needs

Human needs keep constant changes with the development of the politics, technologies, economy and industry. Satisfying these new needs, the product with new function should be developed, in order to meet the user's existing needs in a great extent and create new needs. Needs evolution has the characteristics of reproduction. One type of needs causes the appearance of another type, which in its turn, causes the appearance of a new one. There exists hierarchical relationship between these needs, to form a tree structure of the needs evolution, as shown in Figure 1.

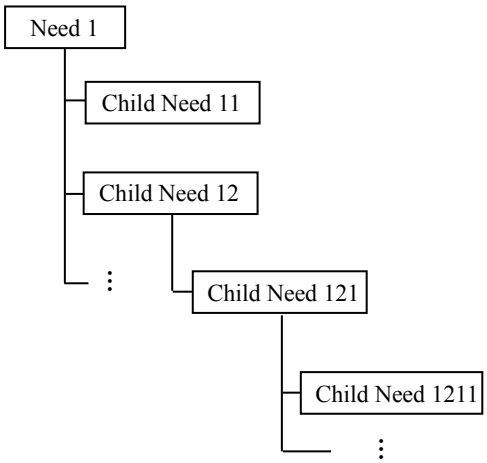

Figure 1. Needs evolution tree structure

3. Laws of Needs Evolution

3.1 Macro laws of needs evolution

Based on the analysis of the variation law of human needs, V. Petrov[Petrov,2006] considered that needs is in a state of evolution and is controlled by the objective laws. The general trend of needs evolution is to satisfy basic needs firstly, and then, to meet intelligent and creative needs. He summarized five needs evolution laws, which are Idealization of needs, Dynamization of needs, Coordination of needs, Integration of needs, Specialization of needs. Law of needs evolution is the latest research results of TRIZ theory system, representing the highest level of study of social demand evolution in the field of TRIZ. Need evolution has the characteristics of diversity, can be used to predict the future needs and the emergence of new needs. Thus, new function and new system should be defined to meet the future needs or new needs.

According to five laws of needs evolution, idealization of needs is performed through dynamization, integration or specialization and the subsequent coordination of needs, as shown in Figure 2. Each law, points out a direction of needs evolution, according to the direction, the researchers can predict possible future needs of product development, and guide enterprises to develop the future products.

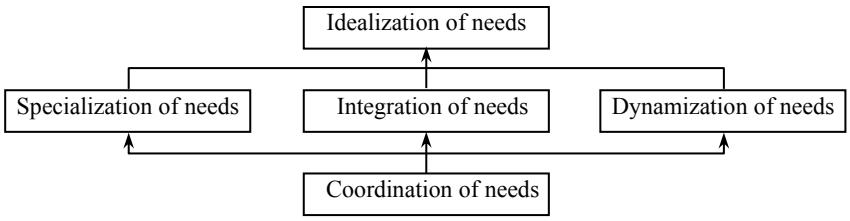

Figure 2. Laws of needs evolution system [Petrov,2006]

Law of needs evolution can be play an important role in macroscopic level to direct the evolution trend of needs. But it just describe the general macro trend of future needs, does not touch on the details of the needs evolution. Lead to its weak operability when it is applied to predict the future needs or new needs of specific product.

3.2 Micro laws of needs evolution forecasting

Patterns and lines of technological evolution belong to technological forecasting of TRIZ [Alla,2001], which can report the probabilities of certain design parameters falling within particular confidence intervals at some future time.

CAI software InventionTool[Tan,2006] provides ten patterns of technology evolution and many lines under each pattern, ten patterns are as following:

Pattern 1: Evolution Toward Increased Complexity and then Simplification
Pattern 2: Evolution from Macro- to Micro-Level
Pattern 3: Evolution Toward Increased Dynamism
Pattern 4: Evolution Toward Increased Curved Surface
Pattern 5: Evolution Toward Increased Dimensionality
Pattern 6: Evolution Toward Increased Concordance
Pattern 7: Evolution Toward to a Higher-Level System
Pattern 8: Evolution Toward Increased Controllability
Pattern 9: Evolution Toward Decreased Human Involvement
Pattern 10: Evolution Toward Increased Ideality

A pattern of evolution delineates a general direction for further system transformation but says nothing about the details of this transformation. The lines of technological evolution under each pattern describe specifically the stages of the systems development. Technology opportunities for the existing product under study can be found by searching different patterns of evolution. User needs for future products and processes can be forecasted by applying the patterns and lines.

Therefore, the needs evolution law and patterns and lines of technological evolution can be integrated to direct the needs evolution direction from the macro and micro level qualitatively, and the accuracy of prediction can be effectively increased.

4. Needs evolution-driven user new needs information acquisition

Needs itself have the action of natural selection on the products, therefore, the successful products contain abundant user needs information. There are two kinds of product innovation, which are creating future products and improving existing product. A large number of product innovations are mainly focus on improving of the existing product. The action of innovation with the aid of the concept of existing product, and no violation of the rules of patent, is a usually product innovation activity in enterprise.

4.1 The principle of needs forecasting driven by the laws of needs evolution

The laws of needs evolution can be used to forecast the future needs and to acquire the user needs information. The basic principle of forecasting the future needs is that the infinite state of idealization is the ideal state of needs, which is the final state of all needs evolution. According to the directions of needs evolution guided by five laws of needs evolution, the needs

that approached the ideal needs step by step are the future latent needs. The new needs are that have not been appeared previously among the future needs.

Figure 3[Tan,2008] shows the principle of needs forecasting driven by the laws of needs evolution. In the Figure 3, the transverse axis is divided into five areas, shows the direction of the five laws of needs evolution, the longitudinal axis shows the direction of needs evolution, which evolves from satisfied needs to predictable needs, and to unpredictable needs. By application of existing knowledge and the laws of needs evolution, the predictable needs are the latent needs that will be appeared in the near future, and most needs in the latent needs are new needs. With the development of technology, the predictable needs will be converted to the satisfied needs. The unpredictable needs are the needs that will be predicted in the remote future because of the human's limited knowledge. The ideal need is the final state of needs. All needs evolve in the direction of the ideal needs.

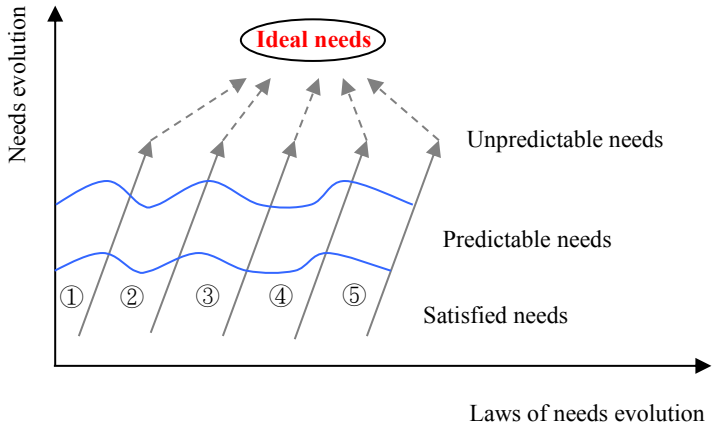

Figure 3. The schematic diagram of future needs forecasting[Tan,2008]

4.2 Needs forecasting by integrated application of the laws of need evolution with the theory of technology evolution

The product is the materialization of user needs information, and the laws of product technology evolution must reflect the change trends of user needs. Patterns and lines of technological evolution of TRIZ, are technology rules summarized from other successful products. The lines of technological evolution describe specifically the stages of the systems development, and can in turn used to guide the product technology development direction of the system, accordingly, can be used to predict future needs specifically. So, the laws of needs evolution and patterns and lines of technological evolution can be used integrated, to direct the qualitative need evolution direction of product both in macro level and micro level, to forecast the future needs direction of product technology more effectively and more reliable.

Corresponding integrated the characteristics correlation of patterns of technologies with the laws of evolution, as shown in Figure 4. The patterns and lines of technology evolution

relevant to one or several laws of need evolution, and the forecasting process is consist of macro forecasting stage and micro forecasting stage. The macro forecasting can be realized by using of the laws of need evolution and the corresponding patterns of technology evolution, and the micro forecasting can be realized by using of the lines of technology evolution.

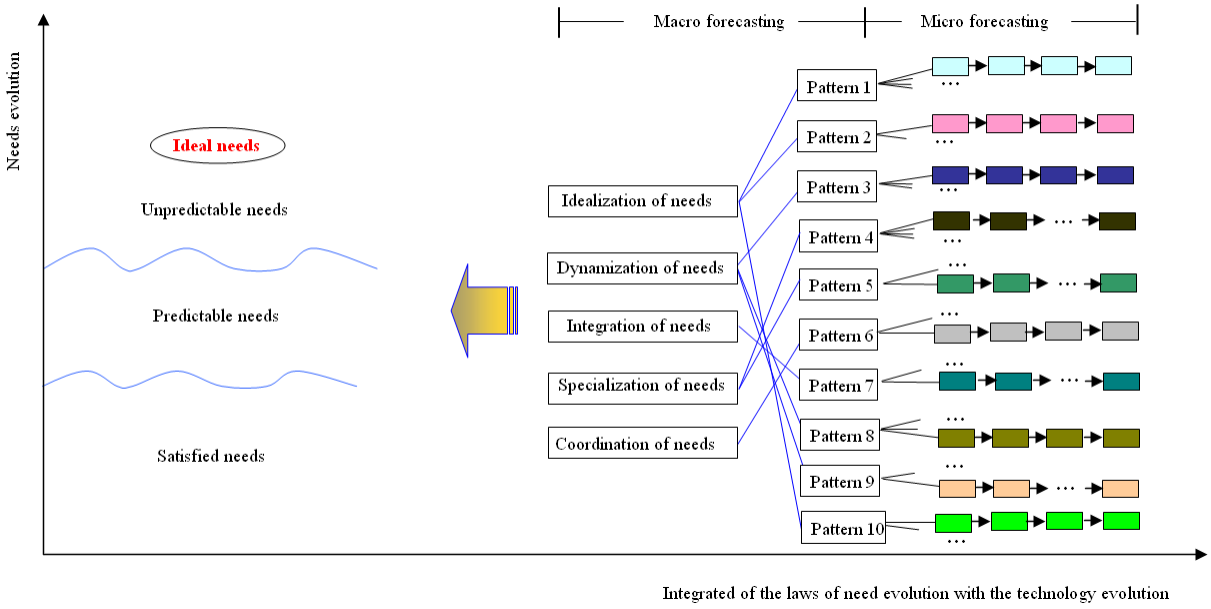

Figure 4. The user needs forecasting based on integrated application of laws of needs evolution and technology evolution

The application procedure of needs forecasting based on integrated application of laws of needs evolution and technology evolution as follows:

(1) First, using laws of needs evolution item by item to analyze the prototype products, the corresponding macro user needs information may be generated, then the needs have satisfied, latent needs can be predicted and unpredicted future needs can be identified.

(2) Select the relevant patterns and lines of technology evolution to analyze the technology features of the predictable latent needs, and integrated the technique of technology evolution potential prediction, to forecast the possible of realization of latent needs. By compared with the existing needs, the new needs may be acquired.

(3) By integrated application of laws of needs evolution and technology evolution, to analyze the technology evolution feature of product, which evolution direction deviate from the direction of needs evolution and technology evolution may be identified. Eliminate the latent defect and future problem in these products can satisfy the existing needs better and generate the new needs.

4.3 Process of user new needs forecasting

There are two kinds of product innovation, which are development of future product and improving of existing product. The needs forecasting of future product should determine a research field first, which can be confirmed by means of the user questionnaire, field investigation, and product analysis, etc. Then, the laws of needs evolution can be used to forecast and discover the new needs. These new needs are original needs. A large number of product innovation activities is the existing product improvement, and usually, is also the product innovation activities in an enterprise. By the similar means to the future product, the improvement information of existing products can be obtained, and the latent needs in the existing products may be the new needs.

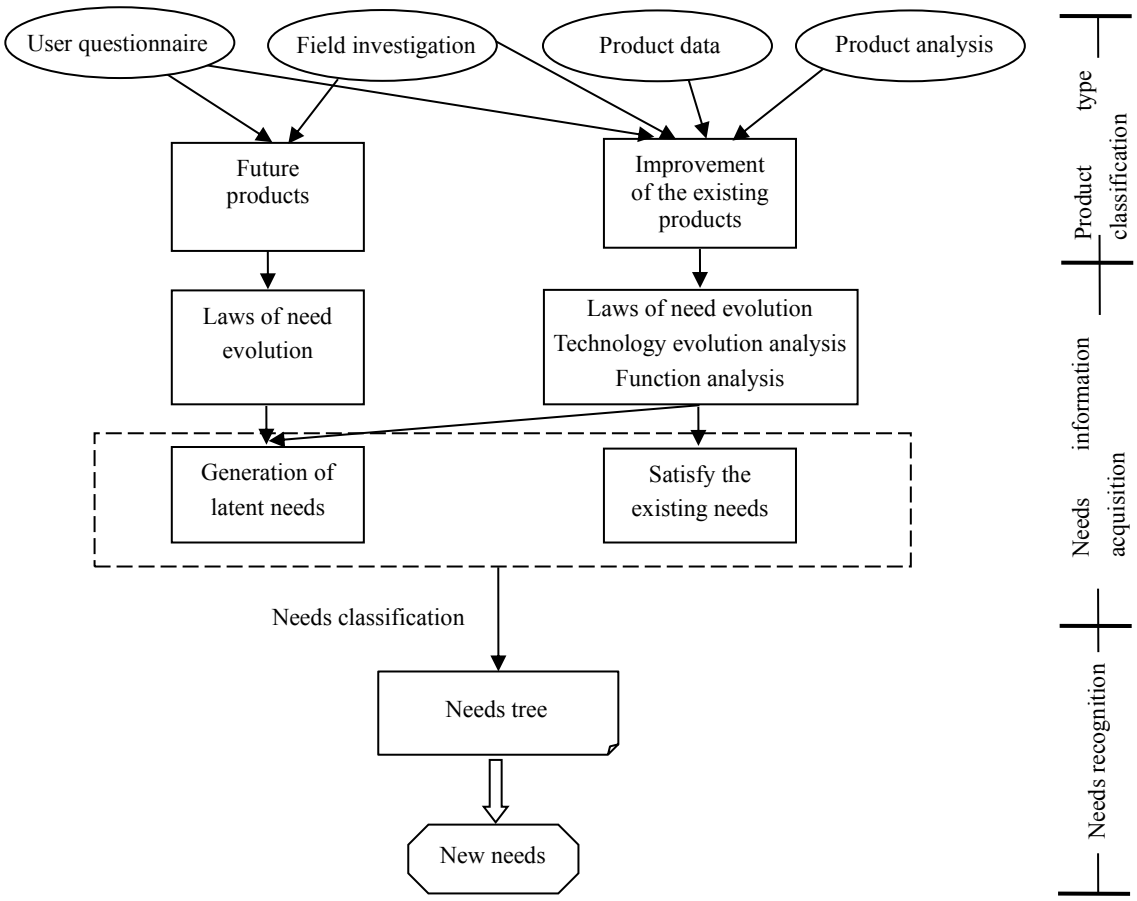

Figure 5. The process of user new needs forecasting

The process of user new needs forecasting as shown in Figure 5, there are three stages in this process.

(1) Product type classification

First, through the market research and product analysis to select the prototype product, the existing product of enterprise or an expected product in a new field both can be the prototype product.

(2) Needs information acquisition

Using of laws of needs evolution, TRIZ tools of technology evolution and function analysis, etc, to forecast user future latent needs and unconfirmed defect or latent problem of the existing product, to confirm the possible improvement direction of product, in order to satisfy the existing needs and to create latent needs.

(3) Needs recognition

By communicating with the users to identify the needs, the satisfied needs and the unsatisfied needs can be distinguished. The potential user needs can be abstract form these needs, and most of the potential user needs are interesting needs. Then, the needs tree can be set up. In consideration of the design level and manufacturing level of enterprise, to determine the realization possibility of needs, and then the new user needs can be determined.

5. A general process model for user needs information acquisition of product supported by CAI system

5.1 CAI technology systems

Today, the development Computer-aided innovation (CAI) systems based on TRIZ has made TRIZ more applicable and practical. A few CAI systems, such as Goldfire Innovator of Invention Machine (USA), IWB of Ideation International (USA), InventionTool (China) have been developed and applied by industries. They include data-base for technological evolution, inventive principles, Su-field and effects, etc. Such as, the function analysis method based on Su-filed of TRIZ can be used to discover the latent problems exist in product, and the Standard solution tools of TRIZ can be used to find the solution. It is feasible that the application of CAI systems makes the designers to find problem solutions more easily in a short time. Accordingly, the problem solutions indicate the new development direction of products, and can satisfy the existing needs or forecast the latent needs. So the user need information can be available by using CAI.

5.2 A general process model for user needs information acquisition of product using CAIs

A general process model for user needs information acquisition of product using CAIs is shown in Figure 6, the process includes the needs information acquisition of future product and the existing products. According to Figure 5, the process is mainly divided into three stages, which are as follows:

Stage1：Selecting prototype product

The existing product of enterprise or the market products can be the prototype product. If enterprise intends to develop a new fields or an expected product, the products of new field or the expected product can be the prototype product.

Stage2：User needs information acquisition

According to the different type of product development, the corresponding routes are taken to acquire the user needs information.

For the future expected product, taking the following steps:

(1) First, using the laws of need evolution to analyze the prototype product, the latent needs can be predicted by integrated using the laws of need evolution and technology evolution.

(2) Then, to seek whether or not there are the new scientific principles or technology breakthrough, which can enable the realization of the latent needs

(3) Developing the new product to create new user needs.

For the improvement of existing product, taking the following steps:

(1) Identify the latent defects or problems of the existing product

Enterprise can do this step itself, the method of functional analysis based on the Su-field of CAI tools can be taken to determine the potential problems or defects of the existing products.

(2) Forecast the future defects or problems of the existing product

By integrated application of laws of needs evolution and technology evolution, to analyze the prototype product, which evolution direction deviate from the direction of needs evolution or technology evolution can be identified. Then, the latent defect or problem in these products can be determined.

(3) Determine the improvement direction of prototype product

Classify and systematize the problems and defects of product, using the technology maturity prediction, technology evolution analysis, to quickly identify the likely development direction, the structure and working principle of next generation product.

(4) Identify the needs information

Analyze the future development direction of products, by communicating with the users to identify the needs. The satisfied needs and the unsatisfied needs can be distinguished. The potential user needs can be abstract form the unsatisfied needs, and most of the potential user needs are interesting needs. Then, the needs tree can be set up to express the satisfied needs and the latent future needs.

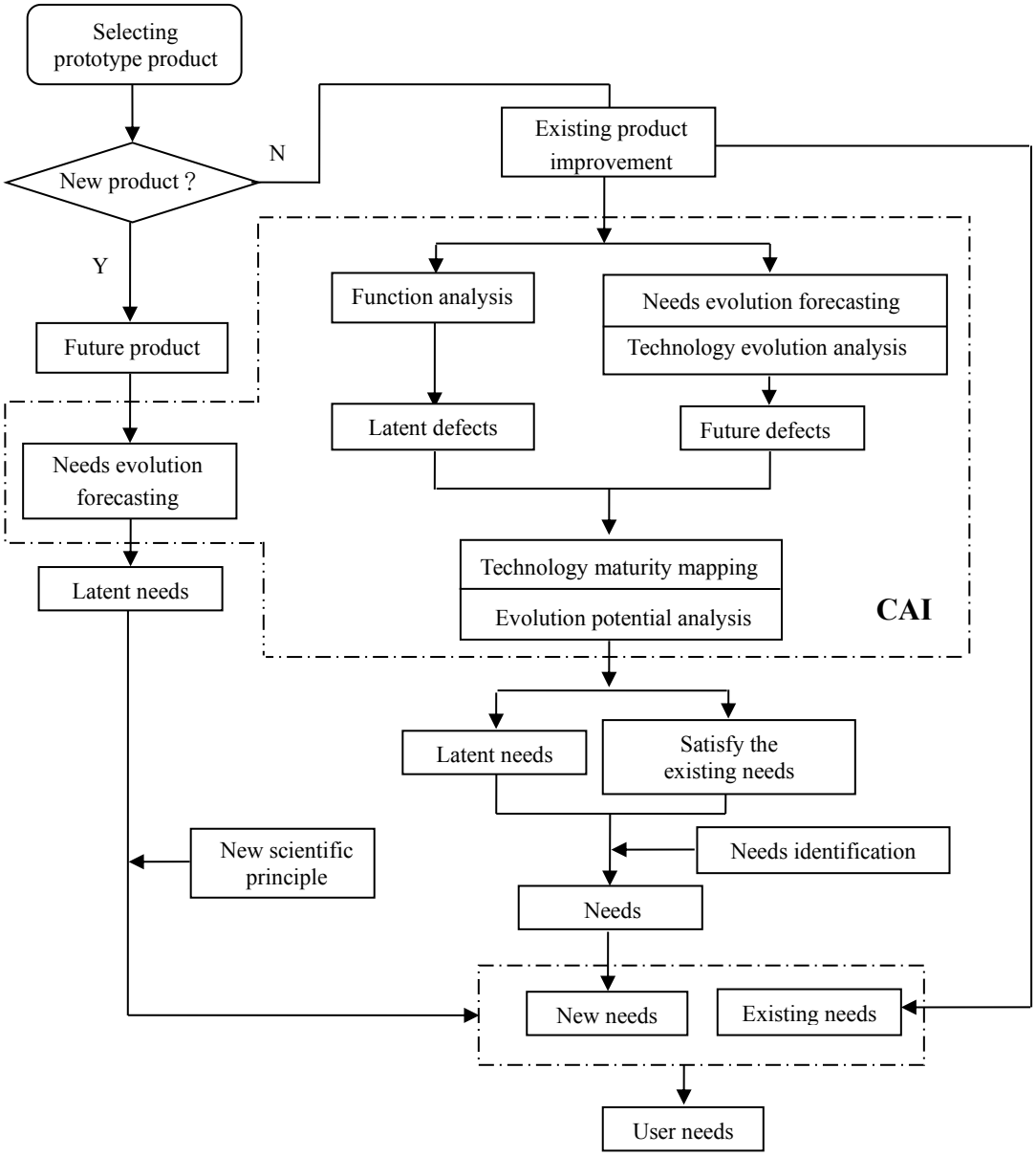

Figure 6. The general process model for user needs information acquisition of product using CAIs

Stage3：Confirm the new user needs information

In consideration of the design level and manufacturing level of enterprise, to determine the realization possibility of new needs of future product and the latent needs of the existing product, and then the new user needs can be determined.

The application of CAI tools in the process of needs information acquisition is summarized as shown in Table 1.

Table 1. The application of CAI tools in the process of needs information acquisition

Products	CAI tools	Functions
Future products	Needs evolution forecasting	Analyze the future expecting products and forecast the future needs
The existing products	Function analysis	Identify the latent defects or problems of the existing product
	Needs evolution forecasting	Identify the future defects or problems of the existing product
	Technology evolution analysis	
	Technology maturity mapping	Determine the improvement direction of the existing product
	Evolution potential analysis	

6. Case Study

Washing machine is a daily appliance, which has function of removed and washed away dirt from clothes. More than one hundred years, the basic work principle of it has been unchanged. That is, the motion of water stream and decontamination of wash act together to accomplish the washing function. The output of washing machine has been increased smoothly in these years. The stability shows that the demand marketing will not increase largely, unless the momentous technological breakthrough will be available. And the technological breakthrough depends on the change of basic washing principle.

Stage1：Selecting prototype product

Now, the roller washing machines have the largest market share in China. So the roller washing machine was selected as the prototype product.

Stage2：User needs information acquisition

The roller washing machine belongs to the existing product, so the following steps are taken to acquire the user needs information.

(1) Identify the latent defects or problems of the existing product

The functional analysis based on the Su-field was taken to analyze the washing machine [Ding,2006].

Figure 7. The roller washing machine

The potential problems of the roller washing machine are summarized as shown in Table 2.

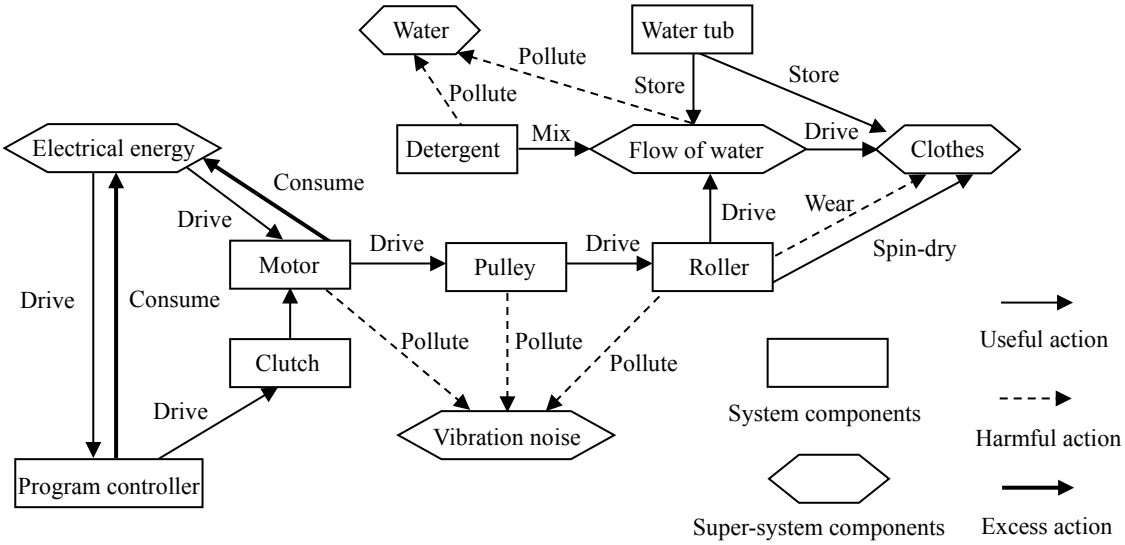

Figure 8. The functional analysis of the roller washing machine[Ding,2006]

Table 2. The potential problems of the roller washing machine

No.	Level	Action	Description of potential problem
1	Excess	Consume	More electrical energy were consumed by the motor and the program controller
2	Harm	Wear	The clothes were worn by the roller to some extent
3		Pollute	Vibration noise was generated when the roller high-speed spins
4			The water was polluted by the detergent

(2) Forecast the future defects or problems of the existing product

By integrated application of laws of needs evolution and technology evolution to analyze the roller washing machine, the future problems of the roller washing machine can be forecasted, as shown in Table 3.

(3) Determine the improvement direction of prototype product

Classify and systematize the problems and defects of the washing machine, then, selecting lines of technology evolution which relevant to the patterns of technology evolution in table 3 to analyze the washing machine. This work can be done by the CAI software InventionTool which has the function module of technology evolutionary potential forecasting. There are nine lines of technology evolution matching to the technology evolution of the roller washing machine. Figure 9 shows the interface in Chinese of the evolution analysis result of roller washing machine by using the InventionTool software.

Table 3. The future problems of the roller washing machine

No.	Laws of needs evolution	Patterns of technology evolution	Future problems forecasting
1	Idealization of needs	Evolution Toward Increased Ideality	The harmful action and the excess action should be eliminated or reduced, such as power saving, water saving and detergent saving.
2	Dynamization of needs	Evolution Toward Increased Dynamism	The dynamism of system needs enhancement, in order to increase the operability.
3		Evolution Toward Decreased Human Involvement	The washing machine can identify the type of detergent, clothing material, water quality, degree of smudges, degree of dry and wet.
4	Integration of needs	Evolution Toward to a Higher-Level System	The integration function of washing, dehydration, degerming, drying, ironing.
5	Coordination of needs	Evolution Toward Increased Concordance	The compatibility of each part needs enhancement, in order to reduce the vibration noise.

The conclusion indicates that washing machine technology may be seen to be mature in terms of lines of 'Surface Segmentation', 'Controllability' and 'Geometric Structure Evolution'. Beyond that, however, there is still considerable potential in the line of 'Frequency Regularity', 'Object Segmentation', 'Dynamics' and 'Decreasing Human Involvement'. Therefore, there are consequently significant improvements that can be developed.

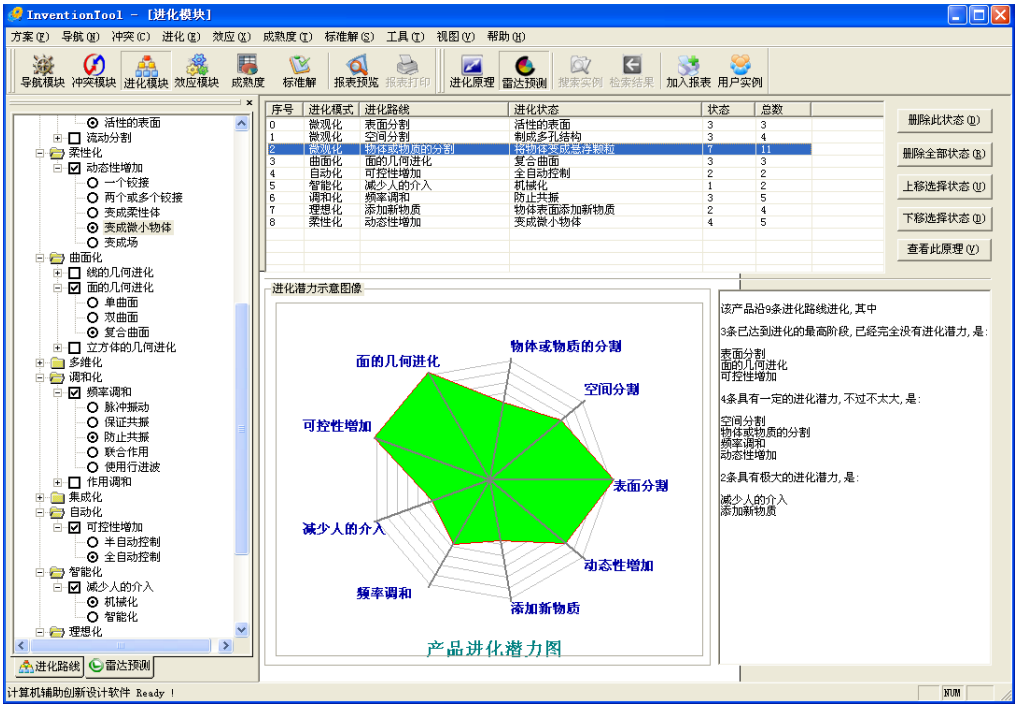

Figure 9. The technology evolution potential forecasting of roller washing machine by using InventionTool software

(4) Identify the needs information

Both the end evolution state of line of 'Object Segmentation' and 'Dynamics' are "application of field". By using of "field", the working principle of washing machine can be the using of electricity field or magnetic field to directly control water flow. So as to save electrical energy, eliminate or reduce the vibration noise and the clothes abrasion at the same time.

By analysis of the line of 'Frequency Regularity' and 'Controllability', the frequency conversion technology can be used to achieve the function of intelligent drying; The feedback system can be added to detect the temperature and the humidity of the air, so as to perceive the degree of dry and wet of clothes.

The ideal solution is that the clothes can be cleaned automatically and no need washing. So the washing machine itself is not the user's real latent need, and the material for clothing that no need washing should be developed.

Stage3：Confirm the new user needs information

Based on above analysis, the user needs information of roller washing machine is list in table 4. The clothes no need washing may not be realized at present because of the limitation of the currently science and technology. The predictable needs may be realized by using of the electricity field or magnetic field and feedback system.

Table 4. The user needs information of washing machine

Satisfied needs	Low noise, less water resource pollution, power saving,
Predictable needs	Water saving, detergent saving or no need detergent, drying and ironing
Unpredictable needs	Clothes can be cleaned automatically or no need washing

7. Conclusions

By analyzing of the hierarchy and evolution nature of user need, integrated the laws of need evolution with the theory of technology evolution of TRIZ, to control the qualitative evolution direction of user needs both in macro level and micro level. A general process model for user needs information acquisition of entirely new product and existing product supported by CAI system is set up by overall applying the technique tools of CAI.

A case study, a part of a real project, is carried out and shows the application of the general process model step by step. The designers of firms can follow the steps to generate new needs information for their own products.

▪Acknowledgment

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A Hybrid Method to Improve Forecasting Accuracy -An Application to Production Data of Various Noodles

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Abstract

In industries, how to improve forecasting accuracy such as production or sales is an important issue. In this paper, a hybrid method is introduced and plural methods are compared. Focusing that the equation of exponential smoothing method(ESM) is equivalent to (1,1) order ARMA model equation, a new method of estimation of smoothing constant in exponential smoothing method was proposed before by us which satisfied minimum variance of forecasting error. Generally, smoothing constant is selected arbitrarily. In this paper, we utilize the above stated theoretical solution. One of the TRIZ methods is extended and applied. Firstly, we make an estimation of ARMA model parameter and then estimate smoothing constants. Thus the theoretical solution is derived in a simple way and it may be utilized in various fields. Furthermore, combining the trend removing method with this method, we aim to improve forecasting accuracy. An approach to this method is executed in the following method. Trend removing by the combination of linear and 2nd order non-linear function and 3rd order non-linear function is executed to the production data of various noodles. The weights for these functions are varied by 0.01 increment and optimal weights are searched. For the comparison, monthly trend is removed after that. Theoretical solution of smoothing constant of ESM is calculated for both of the monthly trend removing data and the non-monthly trend removing data. In all cases, that monthly ratio was used had a better forecasting accuracy. The new method shows that it is useful for the time series that has monthly trend characteristics and we have obtained some interesting results.

Keywords: exponential smoothing method, forecasting, trend

1. INTRODUCTION

In industries, correct forecasting is an important issue. If it is not executed well, it causes a huge stock and/or causes lack of goods. Therefore how to make a correct forecasting is a great concern. Many methods for time series analysis have been presented such as Autoregressive model (AR Model), Autoregressive Moving Average Model (ARMA Model) and Exponential Smoothing Method (ESM) (Box Jenkins [1]), (R.G.Brown[11]), (Tokumaru et al.[3]), (Ko-bayashi[7]). Among these, ESM is said to be a practical simple method.

For this method, various improving method such as adding compensating item for time lag, coping with the time series with trend (Peter [10]), utilizing Kalman Filter (Maeda [4]), Bayes Forecasting (M.West et al. [8]), adaptive ESM (Steinar [13]), exponentially weighted Moving Averages with irregular updating periods (F.R.Johnston [2]), making averages of forecasts using plural method (Spyros [12]) are presented. For example, Maeda[4] calculated smoothing constant in relationship with S/N ratio under the assumption that the observation noise was added to the system. But he had to calculate under supposed noise because he couldn't grasp observation noise. It can be said that it doesn't pursue the optimum solution from the very data themselves which should be derived by those estimation. Ishii[9] pointed out that the optimal smoothing constant was the solution of infinite order equation, but he did not show the analytical solution. Based on these facts, we proposed a new method of estimation of smoothing constant in ESM before (Takeyasu et al. [6]). Focusing that the equation of ESM is equivalent to (1,1) order ARMA model equation, a new method of estimation of smoothing constant in ESM was derived. Furthermore, combining the trend removal method, forecasting accuracy was improved, where shipping data, stock market price data etc. are examined [14] －[20].

In this paper, utilizing the above stated method, a revised forecasting method is proposed. One of the TRIZ methods is extended and applied. In making forecast such as production data of various noodles, a trend removing method is devised. Trend removing by the combination of linear and 2nd order non-linear function and 3rd order non-linear function is executed to the original production data of various noodles. The weights for these functions are varied by 0.01 increment and optimal weights are searched. For the comparison, monthly trend is removed after that. Theoretical solution of smoothing constant of ESM is calculated for both of the monthly trend removing data and the non-monthly trend removing data. Then forecasting is executed on these data. This is a revised forecasting method. Variance of forecasting error of this newly proposed method is assumed to be less than those of previously proposed method. In all cases, that monthly ratio was used had a better forecasting accuracy. The rest of the paper is organized as

follows. Extended analysis method is stated in section 2. In section 3, ESM is stated by ARMA model and estimation method of smoothing constant is derived using ARMA model identification. The combination of linear and non-linear function is introduced for trend removing in section 4. The Monthly Ratio is referred in section 5. Forecasting is executed in section 6, and estimation accuracy is examined.

2. Extended Analysis Method

Boris Zlotin & Alla Zusman proposed the concept of "Trends" in TRIZ CON 2006 (Boris Zlotin et al., 2006). We can further develop this concept as shown in Figure 1.

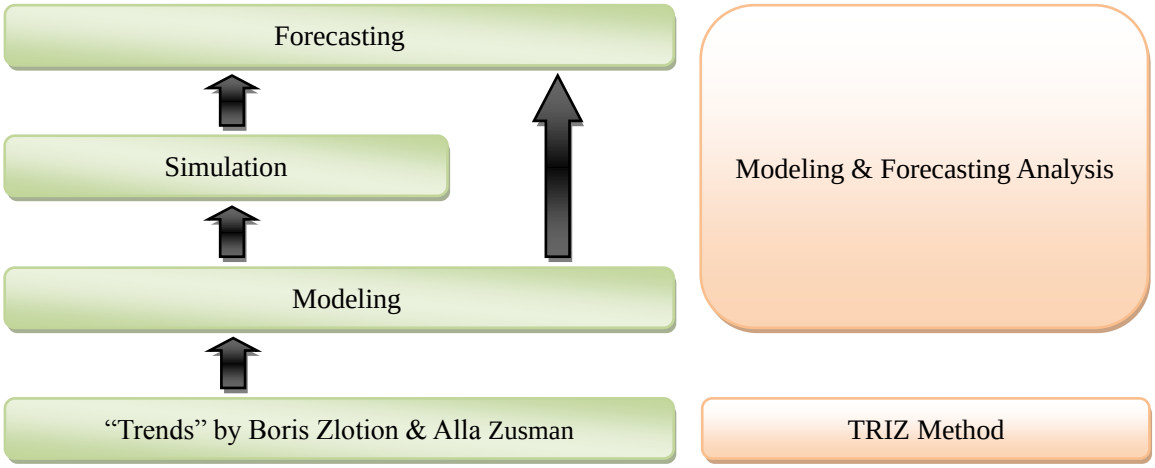

Figure 1. Extended Analysis Method

Based on the TRIZ method, modeling and forecasting analysis method is developed. Extending "Trends", modeling is constructed first. Then we can make simulation by utilizing them. We can make forecasting utilizing the simulation function or directly from the utilization of the model built. These are the process of "Modeling & Forecasting Analysis" based upon TRIZ "Trends" analysis method. Detailed inspection is executed in Section 6.

3. Description of ESM Using ARMA Model (Takeyasu et al. [6])

In ESM, forecasting at time $t+1$ is stated in the following equation.

$$\begin{aligned}\hat{x}_{t+1} &= \hat{x}_t + \alpha(x_t - \hat{x}_t) \\ &= \alpha x_t + (1-\alpha)\hat{x}_t\end{aligned} \tag{1}$$

Here,

$\hat{x}_{t+1}$: forecasting at $t+1$

x_t : realized value at t

α : smoothing constant $(0 < \alpha < 1)$

(1) is re-stated as:

$$\hat{x}_{t+1} = \sum_{l=0}^{\infty} \alpha(1-\alpha)^l x_{t-l} \tag{2}$$

By the way, we consider the following (1,1) order ARMA model.

$$x_t - x_{t-1} = e_t - \beta e_{t-1} \tag{3}$$

Generally, (p,q) order ARMA model is stated as:

$$x_t + \sum_{i=1}^{p} a_i x_{t-i} = e_t + \sum_{j=1}^{q} b_j e_{t-j} \tag{4}$$

Here,

$\{x_t\}$: Sample process of Stationary Ergodic Gaussian Process $x(t)$ $t = 1,2,\cdots,N,\cdots$

$\{e_t\}$: Gaussian White Noise with 0 mean σ_e^2 variance

MA process in (4) is supposed to satisfy convertibility condition.
Utilizing the relation that:

$$E[e_t | e_{t-1}, e_{t-2}, \cdots] = 0$$

We get the following equation from (3).

$$\hat{x}_t = x_{t-1} - \beta e_{t-1} \tag{5}$$

Operating this scheme on t+1, we finally get:

$$\begin{aligned}\hat{x}_{t+1} &= \hat{x}_t + (1-\beta)e_t \\ &= \hat{x}_t + (1-\beta)(x_t - \hat{x}_t)\end{aligned} \tag{6}$$

If we set $1-\beta=\alpha$, the above equation is the same with (1), i.e., equation of ESM is equivalent to (1,1) order ARMA model, or is said to be (0,1,1) order ARIMA model because 1st order AR parameter is -1 (Box Jenkins [1]), (Tokumaru et al.[3]).

Comparing with (3) and (4), we obtain:

$$\begin{cases} a_1 = -1 \\ b_1 = -\beta \end{cases}$$

From (1), (6),

$$\alpha = 1-\beta$$

Therefore, we get:

$$\begin{cases} a_1 = -1 \\ b_1 = -\beta = \alpha - 1 \end{cases} \tag{7}$$

From above, we can get estimation of smoothing constant after we identify the parameter of MA part of ARMA model. But, generally MA part of ARMA model becomes non-linear equations which are described below.

Let (4) be:

$$\begin{cases} \tilde{x}_t = x_t + \sum_{i=1}^{p} a_i x_{t-i} & (8) \\ \tilde{x}_t = e_t + \sum_{j=1}^{q} b_j e_{t-j} & (9) \end{cases}$$

We express the autocorrelation function of $\tilde{x}_t$ as $\tilde{r}_k$ and from (8), (9), we get the following non-linear equations which are well known[3].

$$\left.\begin{aligned} \tilde{r}_k &= \sigma_e^2 \sum_{j=0}^{q-k} b_j b_{k+j} \qquad (k \le q) \\ & \quad 0 \qquad (k \ge q+1) \\ \tilde{r}_0 &= \sigma_e^2 \sum_{j=0}^{q} b_j^2 \end{aligned}\right\} \tag{10}$$

For these equations, recursive algorithm has been developed. In this paper, parameter to be estimated is only b_1, so it can be solved in the following way.

From (3) (4) (7) (10), we get:

$$\left.\begin{aligned} & q = 1 \\ & a_1 = -1 \\ & b_1 = -\beta = \alpha - 1 \\ & \tilde{r}_0 = \left(1 + b_1^2\right)\sigma_e^2 \\ & \tilde{r}_1 = b_1 \sigma_e^2 \end{aligned}\right\} \tag{11}$$

If we set:

$$\rho_k = \frac{\tilde{r}_k}{\tilde{r}_0} \tag{12}$$

The following equation is derived.

$$\rho_1 = \frac{b_1}{1+b_1^2} \tag{13}$$

We can get b_1 as follows.

$$b_1 = \frac{1 \pm \sqrt{1-4\rho_1^2}}{2\rho_1} \tag{14}$$

In order to have real roots, ρ_1 must satisfy.

$$|\rho_1| \le \frac{1}{2} \tag{15}$$

From invertibility condition, b_1 must satisfy.

$$|b_1| < 1$$

From (13), using the next relation,

$$(1-b_1)^2 \ge 0$$
$$(1+b_1)^2 \ge 0$$

(15) always holds.

As

$$\alpha = b_1 + 1$$

b_1 is within the range of

$$-1 < b_1 < 0$$

Finally we get

$$\left.\begin{aligned} b_1 &= \frac{1-\sqrt{1-4\rho_1^2}}{2\rho_1} \\ \alpha &= \frac{1+2\rho_1-\sqrt{1-4\rho_1^2}}{2\rho_1} \end{aligned}\right\} \tag{16}$$

which satisfy above condition. Thus we can obtain a theoretical solution by a simple way.

Here ρ_1 must satisfy

$$-\frac{1}{2} < \rho_1 < 0 \tag{17}$$

in order to satisfy $0 < \alpha < 1$.

Focusing on the idea that the equation of ESM is equivalent to (1,1) order ARMA model equation, we can estimate smoothing constant after estimating ARMA model parameter.

It can be estimated only by calculating 0th and 1st order autocorrelation function.

4.Trend Removal Method

As trend removal method, we describe the combination of linear and non-linear function.

[1] Linear function

We set:

$$y = a_1 x + b_1 \tag{18}$$

as a linear function.

[2] Non-linear function

We set:

$$y = a_2 x^2 + b_2 x + c_2 \tag{19}$$

$$y = a_3 x^3 + b_3 x^2 + c_3 x + d_3 \tag{20}$$

as a 2nd and a 3rd order non-linear function.

[3] The combination of linear and non-linear function

We set:

$$\begin{aligned} y = {} & \alpha_1 (a_1 x + b_1) + \alpha_2 (a_2 x^2 + b_2 x + c_2) \\ & + \alpha_3 (a_3 x^3 + b_3 x^2 + c_3 x + d_3) \end{aligned} \tag{21}$$

$$\begin{aligned} & 0 \le \alpha_1 \le 1 \quad , 0 \le \alpha_2 \le 1 \quad , 0 \le \alpha_3 \le 1 \\ & \alpha_1 + \alpha_2 + \alpha_3 = 1 \end{aligned} \tag{22}$$

as the combination of linear and 2nd order non-linear and 3rd order non-linear function. Trend is removed by dividing the data by (21). Numerical examples for about both of the trend removal case and non-removal case are discussed in section 6.

5 . Monthly Ratio

For example, if there is the monthly data of L years as stated bellow:

$\{x_{ij}\}\ (i=1,\cdots,L)\ (j=1,\cdots,12)$

where $x_{ij} \in R$ in which j means month and i

means year and x_{ij} is a shipping data of i-th year, j-thmonth, then, monthly ratio $\tilde{x}_j$ $(j=1,\cdots,12)$ is calculated as follows.

$$\tilde{x}_j = \frac{\frac{1}{L}\sum_{i=1}^{L} x_{ij}}{\frac{1}{L}\cdot\frac{1}{12}\sum_{i=1}^{L}\sum_{j=1}^{12} x_{ij}} \tag{23}$$

Monthly trend is removed by dividing the data by (23). Numerical examples for about both of the monthly trend removal case and the non-removal case are discussed in section 5.

6. Forecasting the Production Data of Various Noodles

6.1 Analysis Procedure

Following six typical noodles are selected.

Raw Soba noodles (“RSN”)

Boiled Soba noodles (“BSN”)

Raw Chinese noodles (“RCN”)

Boiled Chinese noodles (“BCN”)

Raw Udon (“RU”)

Boiled Udon (“BU”)

Production data are analyzed for the period of 2007 April to 2010 March. First of all, graphical charts of these time series data are exhibited in Figure 6-1 to 6-6.

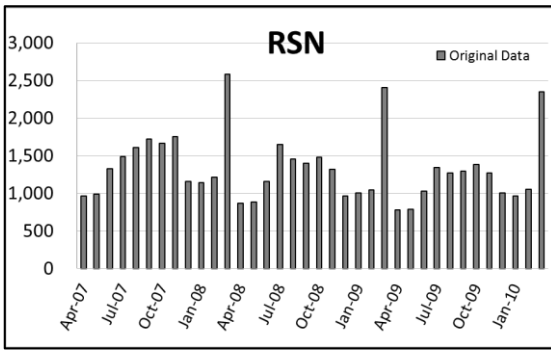

Fig. 6-1. Production data of RSN

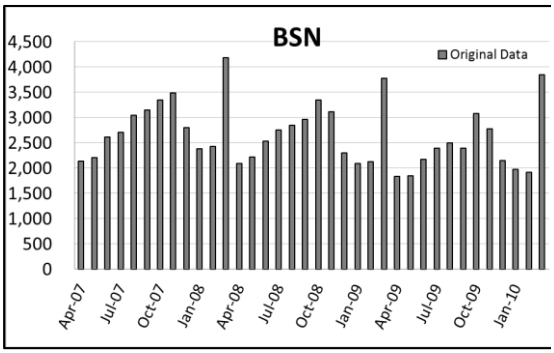

Fig. 6-2. Production data of BSN

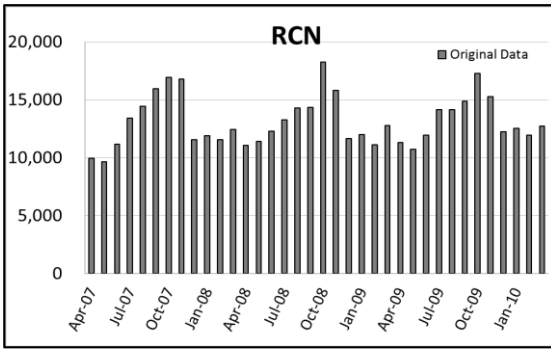

Fig. 6-3. Production data of RCN

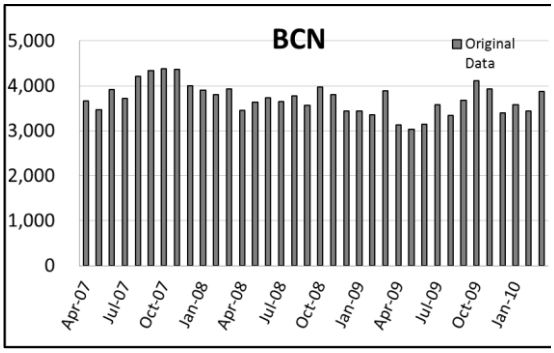

Fig. 6-4. Production data of BCN

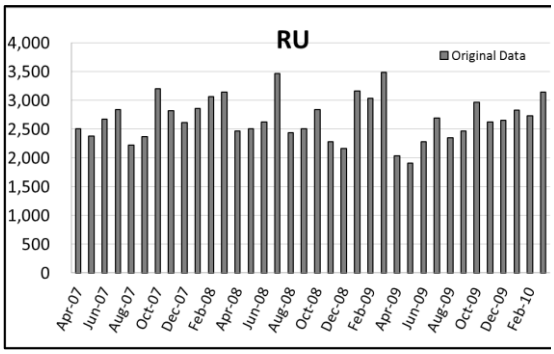

Fig. 6-5. Production data of RU

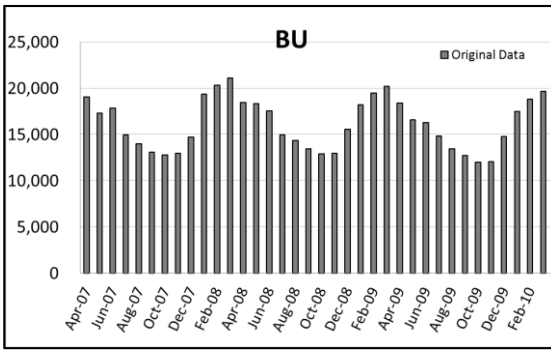

Fig. 6-6. Production data of BU

Analysis procedure is as follows. There are 36 monthly data for each case. We use 24 data(1 to 24) and remove trend by the method stated in section 4. Then we calculate monthly ratio by the method stated in section 5. After removing monthly trend, the method stated in section 3 is applied and Exponential Smoothing Constant with minimum variance of forecasting error is estimated. Then 1 step forecast is executed. Thus, data is shifted to 2nd to 25th and the forecast for 26th data is executed consecutively, which finally reaches forecast of 36th data. To examine the accuracy of forecasting, variance of forecasting error is calculated for the data of 25th to 36th data. Final forecasting data is obtained by multiplying monthly ratio and trend.

Forecasting error is expressed as:

$$\varepsilon_i = \hat{x}_i - x_i \tag{24}$$

$$\bar{\varepsilon} = \frac{1}{N}\sum_{i=1}^{N}\varepsilon_i \tag{25}$$

Variance of forecasting error is calculated by:

$$\sigma_\varepsilon^2 = \frac{1}{N-1}\sum_{i=1}^{N}\left(\varepsilon_i - \bar{\varepsilon}\right)^2 \tag{26}$$

In this paper, we examine the four cases stated in Table 6-1.

Table 6-1. The combination of the case of trend removal and monthly trend removal

	Trend	Monthly trend
Case1	Removal	Removal
Case2	Removal	Non removal
Case3	Non removal	Removal
Case4	Non removal	Non removal

6.2 Trend Removing

Trend is removed by dividing the original data by (21).

Here, the weight of α_1 and α_2 are shifted by 0.01 increment in (21) which satisfy the equation (22). The best solution is selected which minimizes the variance of forecasting error. Estimation results of coefficient of (18), (19) and (20) are exhibited in Table 6-2. Data are fitted to (18), (19) and (20), and using the least square method, parameters of (18), (19) and (20) are estimated. Estimation results of weights of (21) are exhibited in Table 6-3. The weighting parameters are selected so as to minimize the variance of forecasting error.

Table 6-2. Coefficient of (18),(19) and (20)

	1st		2nd			3rd			
	a_1	b_1	a_2	b_2	c_2	a_3	b_3	c_3	d_3
RSN	3.0626	1,345.0507	-0.5256	16.2015	1,288.1156	0.6990	-26.7386	283.7145	674.7299
BSN	4.4900	2,721.0000	-2.2244	60.0998	2,480.0242	0.7592	-30.6950	350.6517	1,813.8123
RCN	40.2704	12,569.2029	-14.1044	392.8807	11,041.2253	1.4259	-67.5745	938.5605	9,790.0257
BCN	-17.3900	4027.3333	-1.8507	28.8781	3826.8384	0.5580	-22.7769	242.4366	3337.1660
RU	14.1478	2558.7355	0.1471	10.4693	2574.6759	0.5586	-20.7989	224.2310	2084.5375
BU	33.3343	15973.0290	10.9222	-239.7211	17156.2693	0.8782	-22.0094	96.3571	16385.6693

Table 6-3. Weights of (21)

		α_1	α_2	α_3
RSN	Case1	0.00	1.00	0.00
	Case2	0.79	0.21	0.00
BSN	Case1	0.00	1.00	0.00
	Case2	0.00	1.00	0.00
RCN	Case1	0.37	0.63	0.00
	Case2	0.75	0.25	0.00
BCN	Case1	1.00	0.00	0.00
	Case2	0.00	1.00	0.00
RU	Case1	1.00	0.00	0.00
	Case2	1.00	0.00	0.00
BU	Case1	0.40	0.60	0.00
	Case2	0.00	1.00	0.00

As a result, we can observe the following three patterns.

① Selected linear model:

BCN: Case1, RU: Case1,2

② Selected 2nd order model:

RSN: Case1, BSN: Case1,2, BCN: Case2, BU: Case2

③ Selected 1st+2nd order model:

RSN: Case2, RCN: Case1,2, BU: Case1

Graphical charts of trend are exhibited in Figure 6-7 to 6-12.

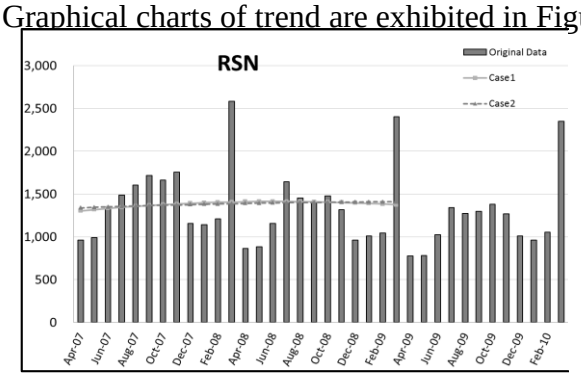

Fig. 6-7. Trend of RSN

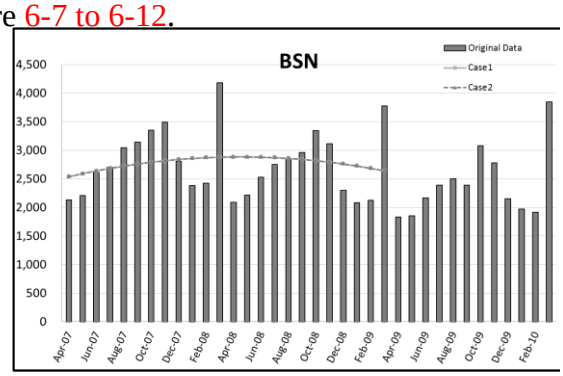

Fig. 6-8. Trend of BSN

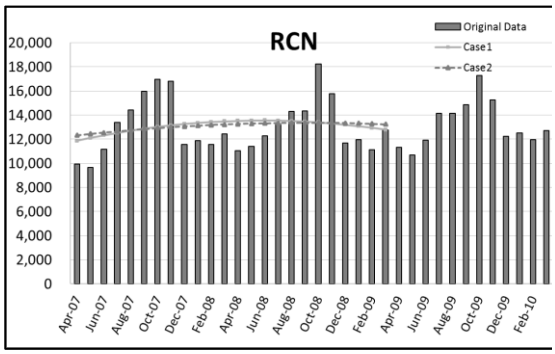

Fig. 6-9. Trend of RCN

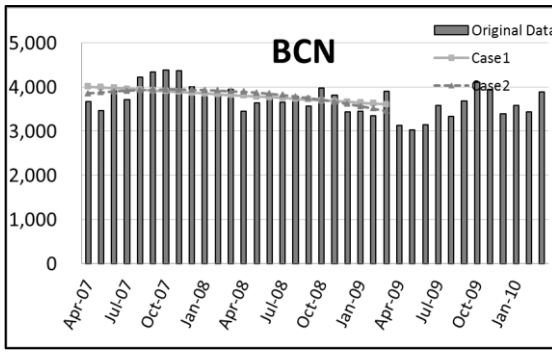

Fig. 6-10. Trend of BCN

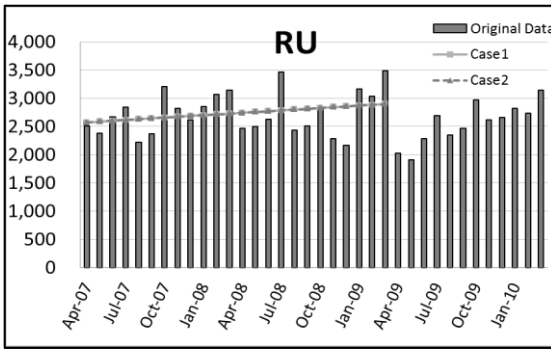

Fig. 5-11. Trend of RU

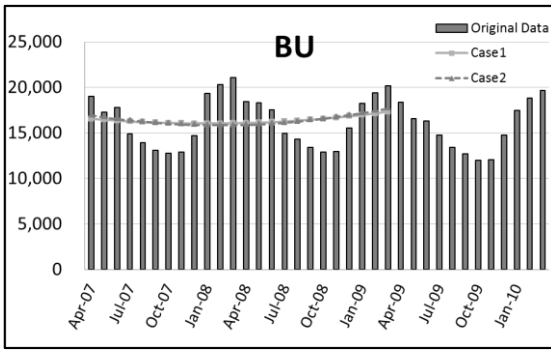

Fig. 5-12. Trend of BU

6.3 Removing Trend of Monthly Ratio

After removing trend, monthly ratio is calculated by the method stated in 5. Calculation result for 1st to 24th data is exhibited in Table 6-4.

Table 6-4. Monthly ratio

		Month											
		4	5	6	7	8	9	10	11	12	1	2	3
RSN	Case1	0.68	0.69	0.91	1.13	1.11	1.12	1.13	1.10	0.76	0.77	0.81	1.79
	Case3	0.66	0.68	0.90	1.13	1.10	1.13	1.13	1.11	0.77	0.78	0.81	1.80
BSN	Case1	0.78	0.81	0.93	0.98	1.06	1.09	1.19	1.18	0.91	0.80	0.82	1.44
	Case3	0.76	0.80	0.93	0.98	1.06	1.10	1.21	1.19	0.92	0.80	0.82	1.43
RCN	Case1	0.83	0.82	0.91	1.03	1.10	1.15	1.33	1.23	0.88	0.90	0.86	0.96
	Case3	0.80	0.80	0.90	1.02	1.10	1.16	1.35	1.25	0.89	0.91	0.87	0.96
BCN	Case1	0.91	0.91	0.99	0.96	1.04	1.03	1.10	1.08	0.99	0.98	0.96	1.06
	Case3	0.93	0.93	1.00	0.97	1.05	1.04	1.10	1.07	0.98	0.96	0.94	1.03
RU	Case1	0.94	0.91	0.99	1.16	0.86	0.89	1.11	0.93	0.86	1.08	1.09	1.18
	Case3	0.91	0.89	0.97	1.15	0.85	0.89	1.11	0.93	0.87	1.10	1.12	1.21
BU	Case1	1.15	1.09	1.09	0.92	0.87	0.81	0.79	0.79	0.92	1.14	1.20	1.24
	Case3	1.14	1.09	1.08	0.91	0.86	0.81	0.78	0.79	0.92	1.15	1.21	1.26

6.4 Estimation of Smoothing Constant with Minimum Variance of Forecasting Error

After removing monthly trend, Smoothing Constant with minimum variance of forecasting error is estimated utilizing (16). There are cases that we cannot obtain a theoretical solution because they do not satisfy the condition of (17). In those cases, Smoothing Constant with

minimum variance of forecasting error is derived by shifting variable from 0.01 to 0.99 with 0.01 interval. Calculation result for 1st to 24th data is exhibited in Table 6-5.

Table 6-5. Estimated Smoothing Constant with Minimum Variance

		ρ_1	α
RSN	Case1	-0.3219	0.6353
	Case2	-0.2823	0.6907
	Case3	-0.3575	0.5792
	Case4	-0.0113	0.9887
BSN	Case1	-0.1913	0.8011
	Case2	-0.2318	0.7542
	Case3	-0.2058	0.7847
	Case4	-0.2464	0.7365
RCN	Case1	-0.7468 (Does not satisfy (17))	0.9900
	Case2	-0.4039	0.4918
	Case3	-0.7356(Does not satisfy (17))	0.1400
	Case4	-0.4053	0.4888
BCN	Case1	-0.3295	0.6238
	Case2	-0.3034	0.6620
	Case3	-0.3149	0.6456
	Case4	-0.2991	0.6679
RU	Case1	-0.2587	0.7211
	Case2	-0.2964	0.6716
	Case3	-0.2681	0.7093
	Case4	-0.2990	0.6681
BU	Case1	-0.4973	0.0982
	Case2	-0.3562	0.5814
	Case3	-0.0704	0.9292
	Case4	-0.3577	0.5788

6.5 Forecasting and Variance of Forecasting Error

Utilizing smoothing constant estimated in the previous section, forecasting is executed for the data of 25th to 36th data. Final forecasting data is obtained by multiplying monthly ratio and trend. Variance of forecasting error is calculated by (26). Forecasting results are exhibited in Figure 6-13 to 6-18 for the cases that monthly ratio is used.

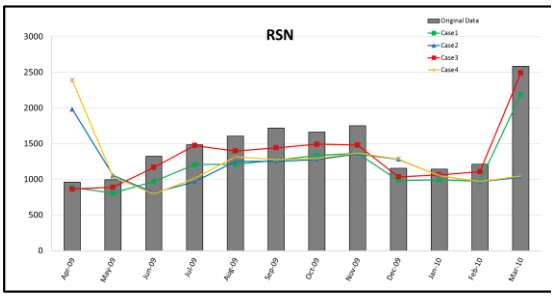

Fig. 5-13. Forecasting Results of RSN

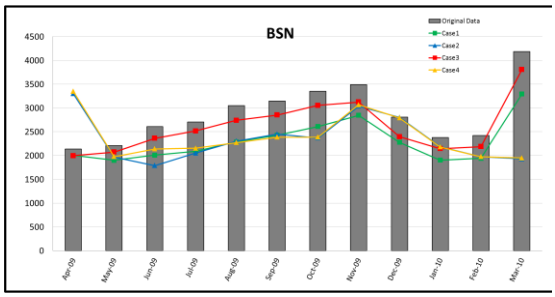

Fig. 5-14. Forecasting Results of BSN

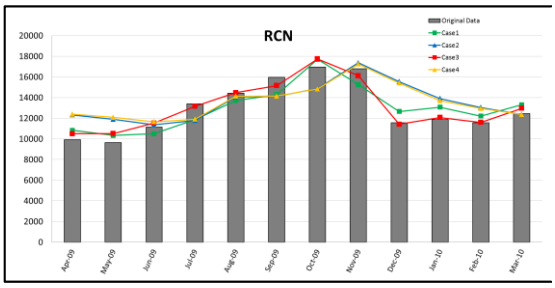

Fig. 6-15. Forecasting Results of RCN

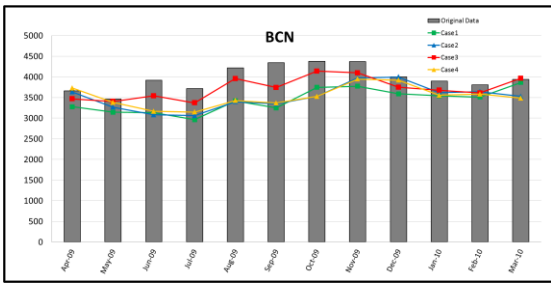

Fig. 6-16. Forecasting Results of BCN

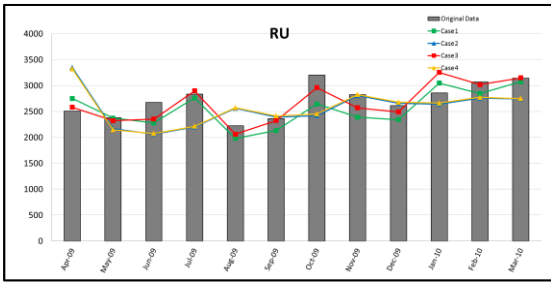

Fig. 6-17. Forecasting Results of RU

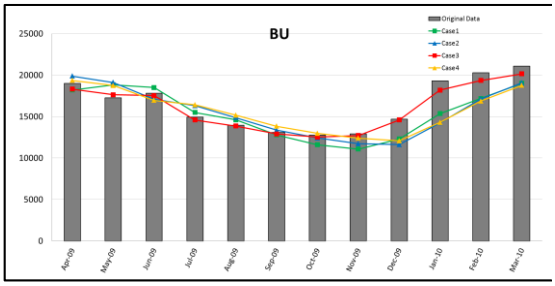

Fig. 6-18. Forecasting Results of BU

Variance of forecasting error is exhibited in Table 6-6.

Table 6-6. Variance of Forecasting Error

		Variance of Forecasting Error	
RSN	Case1	6,682.1562	
	Case2	323,132.4909	
	Case3	2,214.1349	*
	Case4	419,744.7535	
BSN	Case1	55,999.1011	
	Case2	650,337.0845	
	Case3	19,901.9050	*
	Case4	640,556.7935	
RCN	Case1	757,557.3017	
	Case2	2,959,706.8921	
	Case3	68,868.8456	*
	Case4	2,745,076.4557	

BCN	Case1	65,897.2623	
	Case2	142,713.5158	
	Case3	5,990.6602	*
	Case4	142,639.5358	
RU	Case1	118,996.4037	
	Case2	242,590.4188	
	Case3	70,631.4810	*
	Case4	230,243.9441	
BU	Case1	2,405,576.5478	
	Case2	3,454,502.5370	
	Case3	206,731.2528	*
	Case4	3,280,686.2610	

6.6 Remarks

In all cases, that monthly ratio was used had a better forecasting accuracy. In other words, these data include monthly trend greatly. Soba noodles (RSN, BSN) are commonly eaten at the end of the year as a custom (Toshikoshi-Soba i.e. Hoping safely sending the end of the year by eating Soba noodles), which are peculiarly seen in Fig. 6-13, 6-14.

7.Conclusion

Focusing on the idea that the equation of exponential smoothing method(ESM) was equivalent to (1,1) order ARMA model equation, a new method of estimation of smoothing constant in exponential smoothing method was proposed before by us which satisfied minimum variance of forecasting error. Generally, smoothing constant was selected arbitrarily. But in this paper, we utilized the above stated theoretical solution. One of the TRIZ methods was extended and applied. Firstly, we made an estimation of ARMA model parameter and then estimated smoothing constants. Thus the theoretical solution was derived in a simple way and it might be utilized in various fields.

Furthermore, combining the trend removal method with this method, we aimed to improve forecasting accuracy. An approach to this method was executed in the following method. Trend removal by a linear function was applied to the production data of various noodles. The combination of linear and non-linear function was also introduced in trend removing. For the comparison, monthly trend was removed after that. Theoretical solution of smoothing constant of ESM was calculated for both of the monthly trend removing data and the non-monthly trend removing data. Then forecasting was executed on these data. In

all cases, that monthly ratio was used had a better forecasting accuracy.

The new method showed that it was useful for the time series that had monthly trend characteristics and we have obtained some interesting results. Various cases should be examined hereafter.

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A Study on DFSS Design Pattern Innovation

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Abstract

In this paper, the connection of traditional design and design for six sigma(DFSS) is discussed. The existing DFSS process models are listed and analyzed for introduction of the general model of DFSS. The necessity and possibility of combination between DFSS and innovation is discussed by analysis of advantages and disadvantages. The joint points are studied from the angle of goal theory, customer value and conceptual design. A new innovative DFSS system combined with TRIZ is built illustrated by the new design process of DFSS innovation, where some TRIZ tools, innovation and design methods/tools, and quality tools are utilized for solution of design issues. The process involves a set of structured and logical activities that focus on customer, foster effective innovation, ensure robustness, maintain reliability, reduce cost, and ultimately increase value for process and the end customer, which provides a feasible path to design for quality.

Keywords: DFSS, innovation, TRIZ, process model

Introduction

Product design is a problem-solving process built on knowledge and experience. The final result is to form a principle solution which is customer-satisfied and value-added, according to the analysis of current technology and customer needs. An excellent design configures product quality, and determines the intrinsic quality. Along with the change of mode of production, the design theory experiences a development from traditional functionality fulfillment to modern design request for generalization quality, low cost, rapid cycle-time, etc (Wen, 2011). In the late 20th century leading companies are learning that the product development process is as

important as the product itself (Verduyn, 2007). For the past several decades systematic design (SD) has been developed and accepted as the best practice for product design (Stauffer and Pawar, 2007), but failed to fully satisfy the current development of the design requirements. DFSS is an organized and systematic method that could be defined as "a rigorous approach to designing products, services, processes to reduce delivery time, development cost, increase effectiveness, and better satisfy the customers"(Creveling et al., 2003), the use of a roadmap is its core. However, there is not one accept roadmap, but many (Creveling et al., 2003; Antony and Banuelas, 2002; Chowdhur, 2002; Tennant, 2002; Simon, 2003). At the same time, the lack of effective solution innovation and repeatability, the application efficiency of DFSS is low. On DFSS innovation research, Ellen Domb believed coupling TRIZ with six sigma can produce powerful results faster (Domb, 2003); Yang Kai combined DFSS with AD (Yang and EI-Haik, 2003); David Verduyn presented structured "C2C Roadmap" (Verduyn, 2007); Joseph A. De Feo integrated I-TRIZ into DFSS (Joseph and Zion, 2002). It is certain that the combination of DFSS and innovation theory is the future development direction of design theory (Barkan et al, 2010). Although the current research has done some exploration, the overall lack of systematic thinking. Innovative tools didn't match the design process, and no complete innovative DFSS process is proposed.

In view of the above questions, the traditional design process is analyzed. Then integrated the analysis of the traditional design stage and the connotation of DFSS process, the general DFSS process is put forward. Based on goal theory and customer value, the application of TRIZ and other innovative tools as the main line, a complete design process and systematic description on DFSS is formed.

1. Traditional Design Process

Traditional design process includes four relatively independent stages: task clarify, conceptual design, technical design and detail design (Pahl and Beitz, 2000). Fig. 1 shows the traditional design process model.

Traditional product design is based on experience, which including formula, charts, design manuals, and so on accumulated from long-term design practice and theoretical calculation. Function is its main design goal. But this kind of product design is difficult to do thoroughly customer needs analysis and product's whole life cycle design. The lack of support of systematic methods and necessary design tools makes product performance not fully up to expectations, such as quality, robustness, manufacturability, reliability, etc. The quality, cost, cycle-time, defects for product are required higher and higher with the development of science and technology and industry level. Along with day by day intense market competition, the concept of customer prime is highlighted gradually. The defects of traditional design become

obstacle to smooth progress. As a dynamic system, product development system should evolve to adapt unique external environment. DFSS is developed in the external environment.

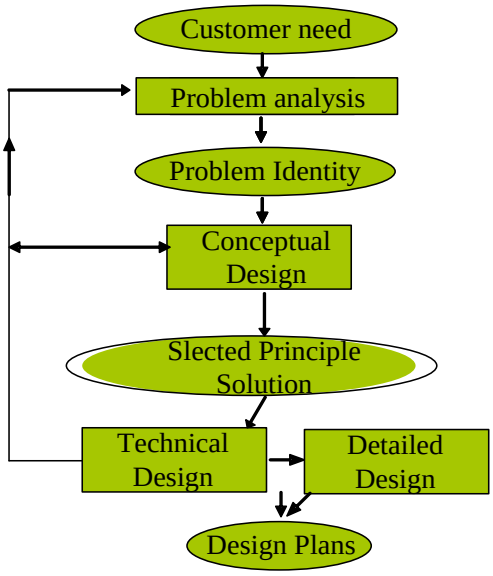

Figure 1. Traditional design process model.

2. Analysis of DFSS standard process

2.1 Process analysis

The design objectives are customer need and design quality. DFSS is based on data, and process as its carrier. DFSS integrate a flexible product development process and a balanced portfolio of tools and best practices to attain the goals of product development (low cost, high quality, and rapid cycle-time). These tools and best practices, including design management, descriptive statistics, design methods, quality control, optimization method, and so on, are integrated, inherited and developed for DFSS system. Its unique advantage is that a logical DFSS process is formed by combining quantified preciseness with a unstructured innovation activities.

DFSS is praised as a real customer oriented design theory which makes the change from adaptability of design or production model to active balance optimization model. The specific process guides the implement of DFSS, but there are no identical or similar in enterprises or organizations' operation. To date, there are numerous versions of DFSS, which a few existing process models are listed in Table 1.

Table 1. Introduction of the existing DFSS process models.

Abbreviation	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
DMADV	Define	Measure	Analyze	Design	Verify
IDEAS	Identify	Design	Evaluate	Assure	Scale-up
IDDOV	Identify	Define	Design	Optimize	Verify
DCCDI	Define	Customer	Concept	Design	Implement
DCOV	Define	Characterize		Optimize	Verify
I2DOV	Invention and Innovation		Develop	Optimize	Verify
DIDOV	Define	Innovation	Design	Optimize	Verify
PIDOV	Plan	Identify	Design	Optimize	Validate
DFACE	Define	Focus	Analyze	Create	Evaluate
DDOVP	Define	Design	Optimize	Validate	Plan
DMEDI	Define	Measure	Explore	Develop	Implement
RCI	Define and Develop Requirement		Develop concept	Define and Develop Improvements	
DIDOV	Define	Innovation	Design	Optimize	Verify
IDOV	Identify	Design		Optimize	Verify
CDOV	Concept development	Design development		Optimize	Verify
DMADOV	Define	Measure	Analyze	Design	Optimize	Verify
DMCDOV	Define	Measure	Characterize	Design	Optimize	Verify
DMADIC	Define	Measure	Analyze	Design	Implement	Control
…	…	…	…	…	…

Even a brief analysis of these process models show that, despite the significant difference in the titles and stated purposes, they often duplicate each other, differing in minute details. Most of those are potent for situation analysis and problem formulation, while others design and implementation based on a selected concept. The middle of the innovation process, idea generation and concept synthesis, is not covered. TRIZ and Six Sigma stand apart form this field, which are recognized by many companies as two of the best innovation technologies.

Analysis shows that although the form of process model vary widely applicable to different types of product design, they all proceed toward the same basic goals using common tools. The difference is the number and the definition of stages. In most cases, the unique process model is suitable for specific situation, the type of product or service, and corporate culture. Meanwhile, innovation is far less structured. The result is innovation that occurs in fits and starts rather than something that can be relied on to deliver consistent growth and profits. For convenience of organizations practicing DFSS methodologies and improving organization's innovation, the general innovative design model for DFSS should be summarized from the height of the methodology by grasping the essence of DFSS and innovation.

▪2.2 The general design model of DFSS

DFSS design pattern is not a substitute for traditional design, but enhancement and optimization. The latter constitutes the basis of the former (Mader, 2003). The generation of general design model should take traditional design process for foundation. Firstly, the task of

DFSS stage should be discussed for a general understanding of DFSS process. So the common form of five-stage process model is picked for explanation.

Stage 1: determine the project goal and customer needs, including external and internal customers.

Stage 2: assess customer needs and specifications.

Stage 3: examine process options to meet the customer requirements.

Stage 4: develop the process to meet the customer requirements.

Stage 5: check the design to ensure meeting customer requirements.

Though chronological order in process stages, also not a serial relationship, it should be in parallel implementation. Each stage should be designed for the following stage. The conceptual design is the most innovative design stage of product development process, also a key link to the following stage. In above five-stage description, the first three stages belong to conceptual design stage. While, adjacent stage overlaps with each other. There is no clear boundary on task decomposition, which makes the beginners confused. So it is necessary to make it refined and stress the importance of conceptual design stage.

Through the analysis of content of each stage in Tab.1, it is found that the content of Stage 1 in DFSS process model is Define or Identify, Stage 2 is Measure or Characterize, Stage 3 is Design or Innovation, Stage 4 is Optimize or Control, Stage 5 is Verify or Scale-up.

There is a common that the product development process is as important as the product itself. This process must involve strategic thinking, customer input, technical discipline, advanced knowledge, creativity, speed, and innovation to ensure a successful output for customers. Organizations must understand the critical elements contained within these methodologies and adapt, customize and integrate what they have learned to fit product development process within corporate culture. Based on task decomposition of each stage, combine with the traditional design process, highlighting the importance of customer needs and Innovation in DFSS process, the DFSS general design model DRIDOV (Define, Requirements, Innovation, Design, Optimize, Verify) is presented. There are two main characteristics, the one hand, it is heritage of the traditional design process making a continuation of thinking and methodology; the other hand, it enhances process innovation, and better meets the quality objectives and customer value added.

2.3 Task decomposition of DRIDOV

The following content illustrates task decomposition for the general DFSS process model DRIDOV, and makes comparison and analysis between traditional design process and DFSS process.

1) *Define Stage:* Preparative phase of design, including project preparation and system analysis. Project preparation includes draft project chapter, assign team memberships and define project management. System analysis includes problem and resource analysis, project goals, process identification, etc.

2) *Requirements Stage:* Requirements acquisition and analysis phase of design. Obtain customer needs and translate VOC into functional and measurable requirements. Identify and establish metrics for customer value and CTSs, and do the risk assessment.

3) *Innovation Stage:* Conceptual design phase of design. Translate CTSs to product/process functional requirements. Establish system function structure by Su-F model abstraction, and apply function evolution and function combination for function innovation, function failure for failure modes identification and elimination. Generate innovative principle solution and evaluate design alternatives, predict process capability, and do risk assessment.

4) *Design Stage:* Technical design phase of design. Draw up technical solution, make the goal of reliability and quality. Identify cost objective and do some necessary analysis. Construct certain product design platform.

5) *Optimize Stage:* Optimization design phase of design. Adjust parameters by a tolerance optimization to targeted performance level. The goal of this phase is to reach balance of quality, cost and delivery time.

6) *Verify Stage:* Validation and process control phase of design. Validate the entity to make sure the end result as designed meets the design requirements. Maintain product design parameters and technical process, and conduct trial production.

According to unique design goals and product features, a phase or some phases can be taken focused design. The implement of DFSS process should be conducted comprehensively, which the implement process could be adjusted or changed according to specific situation. It can be draw form the above analysis that there are some in common on content and process division between traditional design and DFSS. Due to the traditional design's weakness in customer needs analysis, product quality design, robustness control, and so on, the strong complementarily between traditional design and DFSS can be decided. Also, it can be proved again that the integration necessary and feasible because of goal consistency, process interoperability and integration superiority. But introduction DFSS into traditional design perfect is not easy, the uncertainty go through all the time. It is essential for successful design

to elimination or reduction uncertainty in design process. The combination of traditional design's qualitative description and DFSS's quantitative design would help, meanwhile, innovation is indispensable. So design goal can be better achieved by integration innovation with new DFSS system.

3. Integration innovation into DFSS

Innovation is soul of product design. Design will lose vitality and competitiveness that lack of innovation. DFSS is not an exception, which also need promotion of innovation. Larry R. Smith announced that it is only integration with advanced design theory such as AD, QFD, TRIZ, DFSS can be more efficient (Smith, 2001). The importance is obvious that innovation toward DFSS.

3.1 Goal theory and DFSS

DFSS itself represents a remarkable process performance. It can be viewed as a kind of goal-oriented design, which expresses a quality goal of 3.4 DMPO. According to goal theory, the design or improvement of rational system is governed by both knowledge and motivation. In product design, knowledge serves as tool and motivation as indicator. Goal has functions of guiding and motivation, and influence persistence directly or influence indirectly through the use of knowledge and strategy (Wood and Locke, 1990). Goal theory suggests that specific goals (e.g. DFSS goal) result in higher levels of performance than vague non-quantitative goals. It can tell the reason for the success of DFSS, also can be serve as theoretical foundation for DFSS.

3.2 Customer value and DFSS

Customer value is the connection between design and marketing, and a set of interests conveyed by customer to designer. The objective of product design is to meet customer needs and eventually achieve customer satisfaction and customer loyalty which both customer value determined. As a result, the company must make a big buss over product value creation taking customer vale as guide. Customer value innovation is a way for enterprises to be out of competition field, but how to integrate product development and innovation opportunity is still a problem. All it need is DFSS innovation to solve.

3.3 Conceptual design and DFSS

Conceptual design is the most innovative stage in product design, also a weakness part of DFSS (Annamalai et al., 2008). Innovation design method such as AD, TRIZ, Taguchi method can take advantage for conceptual design which also a stage tight connection between

innovation methods and DFSS. Also, the innovation method can do well in solving contradiction of conceptual design and technical design.

3.4 TRIZ and DFSS

DFSS is a bi-system, organized along the lines of process design. TRIZ, on other hand, is focused on principle solution innovation and product development. DFSS is about data collection and analysis, utilizing precise quantitative procedures. TRIZ is about qualitative assessment of the system/situation, utilizing a plethora of analytical tools, aimed at weakening mental inertia of an innovation. TRIZ-DFSS union proved to be very effective for improving the quality of products.

The new design process of DFSS innovation is proposed as shown in Figure 2. Except for detailed process, TRIZ methods and tools suitable for specific stage are also illustrated. Both customer and innovation are taken priority into account. Based on three main goals (quality, cycle-time and cost) and two value requirements (customer value and process value added), the new process involves a set of structured and logical activities that focus on the customer, foster effective innovation, realize process value-added, ensure robustness, maintain reliability, reduce cost, and ultimately increase value for the end customer and shareholders.

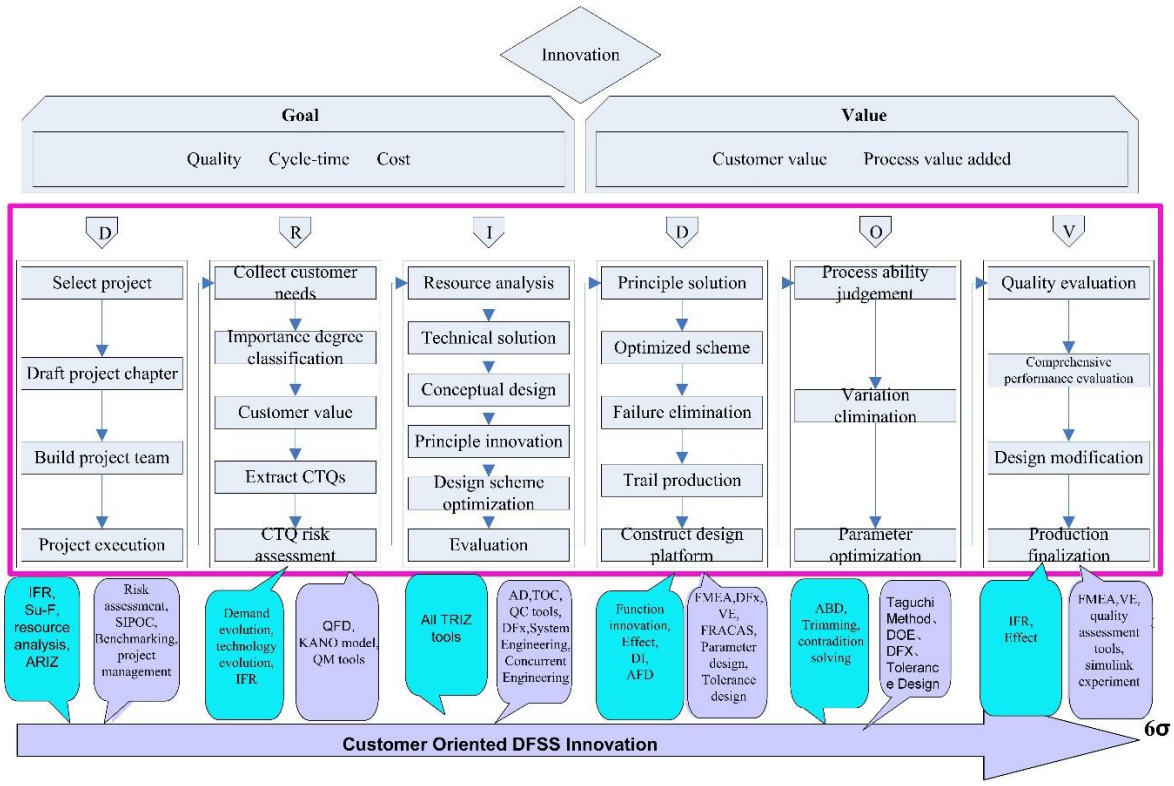

Figure 2. The design process for DFSS innovation.

4. SUMMARY

The traditional design is well structured, and DFSS has many different versions and is still evolving. DFSS provides a systematic methodology. But how to enhance the effective and innovative it will be the research points for DFSS. In this paper, the respective advantages and disadvantages are discussed. According to the essence of product design and the analysis of existing DFSS process models, the general model of DFSS is proposed. The necessity and possibility of combination between DFSS and innovation is discussed. The joint points are studied from the angle of goal theory, customer value and conceptual design. A new innovative DFSS system is built illustrated by the new design process of DFSS innovation. The new DFSS process provides a feasible path to design for quality.

Acknowledgments

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Questionnaire Investigation on Jewelry / Accessory and its Sensitivity Analysis Utilizing Bayesian Network

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ABSTRACT

Recently, the numbers of jewelry/accessories buying via the Internet are increasing, especially for young people. They often have difficulty deciding what kinds of jewelry/accessories to choose, because there are many kinds of jewelry/accessories to choose from. Consulting service to support decisions is required for these matters. In this paper, a questionnaire investigation is executed for the purchasing on-line network, used for jewelry/accessory purchasing in order to get instructions for an on-line network consulting service. Nearly 500 sample data are collected. In this research, we construct the model utilizing Bayesian Network and causal relationship is sequentially chained by the characteristic of customer, the purchase budget and the accessory type. We analyzed them by sensitivity analysis and some useful results were obtained. One of the TRIZ methods is extended and applied. These are utilized for constructing a much more effective and useful on-line network consulting service. To confirm the findings by utilizing the new consecutive purchasing records would be the future works to be investigated.

Keywords : jewelry, questionnaire investigation, Bayesian Network

1. Introduction

Owing to the prevailing Internet, new businesses such as jewelry selling via Internet with on-line consultation, what kind of jewelry/accessory for gift purchasers would be better to choose, is becoming a big trend. Purchasers via Internet have various purchasing patterns and they may have significant relationship with their characteristics and the circumstances they are in. Therefore, if we can make clear the relationship between these, we would be able to make a much more effective marketing plan and execute efficient sales promotion for each of them.

For these purposes, we created a questionnaire investigation of jewelry/accessory purchasing. In recent years, Bayesian Network is highlighted because it has the following good characteristics (Neapolitan, R.E., 2004).

- Structural Equation Modeling requires normal distribution to the data in the analysis. Therefore it has a limitation in making analysis. But Bayesian Network does not require specific distribution type to the data. It can handle any distribution type.
- It can handle the data which include partial data.
- Expert's know-how can be reflected in building Bayesian Network model.

- Sensitivity analysis can be easily executed by setting evidence. We can estimate and predict the prospective purchaser by that analysis.
- It is a probability model having network structure. Related items are connected with directional link. Therefore understanding becomes easy by its visual chart.

In this research, it is suitable to utilize Bayesian Network to analyze jewelry / accessory purchasing because each variable does not necessarily have normal distribution. Reviewing past researches, there are some related researches as follows. Takahashi et al. (2008) made analysis for the future home energy utilizing Bayesian Network. Tsuji et al. (2008) made analysis concerning preference mining on future home energy consumption. There are some papers concerning purchase behavior in the shop (Tatsuoka et al.,2008-a, Tatsuoka et al., 2008-b). But we can hardly see the analysis concerning jewelry / accessory purchasing utilizing Bayesian Network.

In this paper, a questionnaire investigation is executed for on-line network jewelry/accessory purchasing in order to get instructions for an on-line network consulting service. These are analyzed by using Bayesian Network.

The analysis utilizing Bayesian Network enabled us to visualize the causal relationship among items. Furthermore, sensitivity analysis brought us estimating and predicting the prospective purchaser.

Some interesting and instructive results are obtained. These are utilized for constructing a much more effective and useful on-line network consulting service. One of the TRIZ method is extended and applied. These are analyzed by using Bayesian Network.

The rest of the paper is organized as follows. In section 2, Extended Analysis Method is stated. Outline of questionnaire research is stated in section 3. In section 4, Bayesian Network analysis is executed which is followed by the sensitivity analysis in section 5. Remarks is stated in section 6. In section 7, Discussion-Comparison with the experiences of Shop owner and employees is executed. Section 8 is Conclusion.

2. Extended Analysis Method

The function “Moves” is a fundamental function of TRIZ [6],[7].
We can further develop this concept as shown in Figure 1.

Based on the TRIZ method, sensitivity analysis is developed utilizing Bayesian Network. Applying “Moves” function, shift the probability of the variable to ascertain its influence. Set evidence to, for example, “1.0” to the variable, calculate probabilistic inference by Bayesian Network in the “Back Propagation” manner. Then, examine the change of probability.

These are the process of “Sensitivity Analysis” based upon TRIZ “Moves” method. Detailed inspection is executed in section 5.

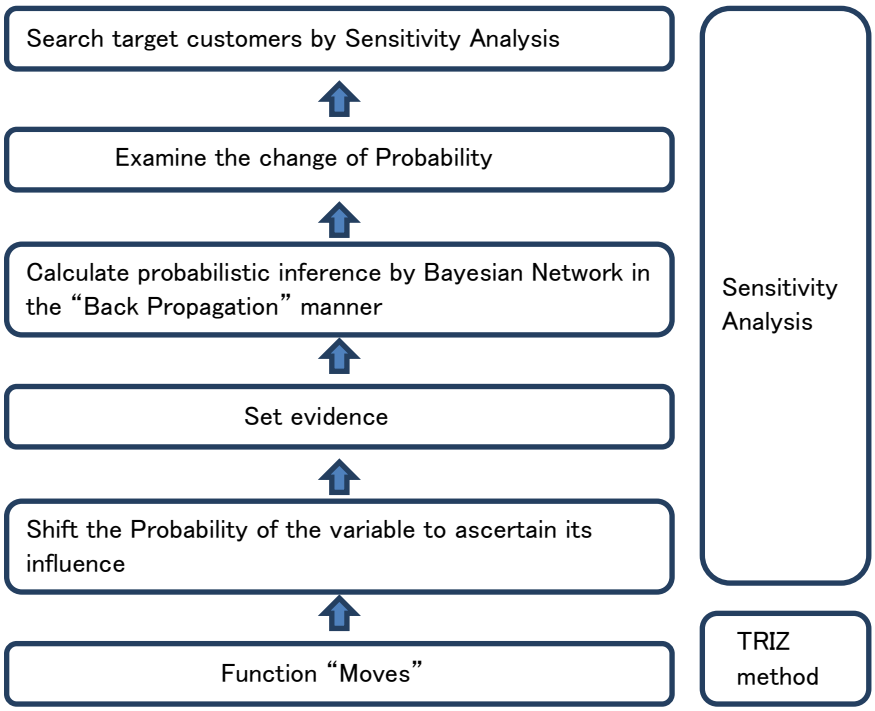

Figure1. Extended Analysis Method

3. Outline of Questionnaire Research and Examinees

3.1. Outline of Questionnaire Research

Outline of questionnaire research is as follows.

Scope of investigation: Young Persons, Japan
Period : May 2008～June 2009
Method : Mail and self writing
Collection : Number of distribution 1,500, Number of collection 421 (Collection rate 28.1%)

Analysis methods are as follows.

Questionnaire results are analyzed by the following three methods. First, analysis by Cross Tabulation is executed in 3 in order to confirm the outline of the data. Second, analysis by Bayesian Network is executed in 4 in order to clarify and visualize the causal relationship among the items. Third, analysis by sensitivity analysis is executed in 5 in order to predict the prospective purchaser as is shown in Table 1.

Table 1. Analysis Procedure

Step	Aim of analysis	Used Method
①	Confirm the outline of the data	Cross Tabulation
②	Build Bayesian Network in order to clarify and visualize the causal relationship among items	Bayesian Network Analysis
③	Predict the prospective purchaser	Sensitivity Analysis

3.2. Outline of Examinees

①Sex (Q45)
- Male : 67%
- Female : 33%

②Age (Q46)
- Under 18 : 1%
- 18～22 : 36%
- 23～27 : 15%
- 28～32 : 12%
- 33～37 : 14%
- 38～42 : 10%
- 43～47 : 4%
- More than 48 : 8%

③Occupation (Q47)
- Student : 39%
- Officer : 2%
- Company Employee : 46%
- Clerk of Organization : 1%
- Independents : 6%
- Miscellaneous : 6%

④ Address (Q48)
- Osaka : 57%
- Hyogo : 7%
- Kagawa : 6%
- Wakayama : 5%
- Fukui : 5%
- Nara : 4%
- Others : 16%

4. Bayesian Network Analysis

In constructing Bayesian Network, it is required to set an outline of the model reflecting the causal relationship among groups of items. Concept chart in this case is exhibited in Figure 1.

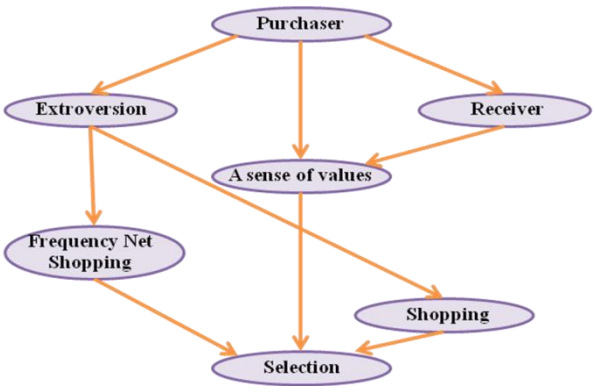

Figure 1. Node and Parameter

Based on this, a model is built as is shown in Figure 2.

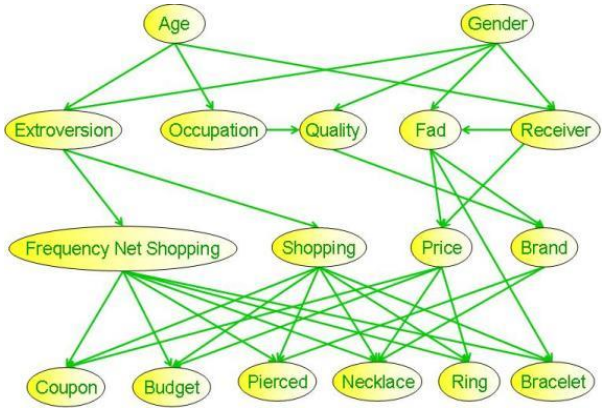

Figure 2. A Built Model

We used BAYONET software (http://www.msi.co.jp/BAYONET/). When plural nodes exist in the same group, it occurs that causal relationship is hard to set a priori. In that case, BAYONET system set the sequence automatically utilizing AIC standard. Node and parameter of Figure 2 are exhibited in Table 12.

Table 12. Node and Parameter

Group Name	Node in Group	Parameter				
		1	2	3	4	5
Purchaser	Age	Under22	23~32	33~42	Over43	
	Gender	Male	Female			
	Occupation	Students	Employee	Independent	Others	
Receiver	Receiver	Lover	Parents	Sweet Heart	Myself	Others
Extrover-sion	Extroversion	Outdoor	Indoor	Not Either		
A sense of values	Fad, Brand, Price, Quality	Important	Ordinary	Not		
Internet Shopping	Frequency of Net Shopping	Often	Sometimes	Rarely	Never	
Shopping	Shopping	Important	Ordinary	Not		
Selection	Budget	~10000	~20000	~30000	Over 30000	
	Ring, Necklace, Pierced, Bracelet	Buy	Not			
	Coupon	Important	Ordinary	Not		

"Very important" and "Slightly important" are condensed into one as "Important" in order to decrease node number.

5. Sensitivity Analysis

Now, posterior probability is calculated by setting evidence as, for example, 1.0. Comparing Prior probability and Posterior probability, we can seek the change and confirm the instruction for purchasing.

We set evidence to all parameters. Therefore the analysis volume becomes too large. In this paper, we pick up half of the total cases and make analysis. Nodes we analyze here are "Age", "Extroversion", "Occupation", "Quality", "Frequency of Net Shopping", "Shopping", "Coupon" and "Budget". We prepare another paper for the latter half.

As stated above, we set evidence for each parameter, and the calculated posterior probability is exhibited in Appendix Table A. The value of "Posterior probability – Prior probability" (we call this "Difference of probability" hereafter) is exhibited in Appendix Table B. The sensitivity analysis is executed by mainly using this table. It is well known that difference of probability becomes small as the node becomes distant (Takahashi et al.).

Here, we pick up major parameters by the distance of node.

・Node separated by 1 class: Select major parameter of which absolute value of difference of probability is more than 0.02

・Node separated by 2 class: Select major parameter of which absolute value of difference of probability is more than 0.005

・Node separated by 3 class: Select major parameter of which absolute value of difference of probability is more than 0.001

In selecting parameters, negative value does not necessarily have distinct meaning, therefore we mainly pick up positive value in the case meaning is not clear.

Now we examine each case.

5.1 Sensitively Analysis for "Age"

(1) Setting evidence to "Less than 22 years old"

①Node separated by 1 class

Occupation	Students	＋
Extroversion	Indoor	＋
Receiver	Lover	＋

②Node separated by 2 class

Quality	Not important	＋
Fad	Important	＋
Price	Important	－

③Node separated by 3 class

Coupon	Important	－
Budget	20,000～	＋
Pierced earrings	Buy	＋
Bracelet	Not buy	＋
Brand	Ordinary level	＋

We can observe that "Those who are less than 22 years old, are students of indoor type, make present to lover, do not esteem Quality but esteem Fad, Price and Coupon, and set Brand in intermediate level for it, do not buy Bracelet but buy Pierced earrings with Budget more than 20,000 yen."

(2) Setting evidence to " 23～32 years old"

①① Node separated by 1 class

Occupation	Employee	＋
Extroversion	Not either	＋
Receiver	Lover	＋

②②Node separated by 2 class

Quality	Ordinary	＋
Price	Important	－

③③Node separated by 3 class

Coupon	Not important	＋
Budget	20,000～	＋
Pierced earrings	Not buy	＋
Bracelet	Not buy	＋
Brand	Important	＋

We can observe that "Those who are 23～32 years old, are Company Employee of "Not either" of outdoor or indoor type, make present to lover, do not esteem price nor coupon but esteem Brand, and set Quality in intermediate level for it, do not buy Pierced earrings nor Bracelet with Budget more than 20,000 yen."

(3) Setting evidence to " 33～42 years old"

①①Node separated by 1 class

Occupation	Employee	＋
Extroversion	Not either	＋
Receiver	Sweet Heart	＋

②②Node separated by 2 class

Quality	Ordinary	＋
Fad	Important	－
Price	Important	－

③③Node separated by 3 class

Coupon	Important	＋
Budget	10,000～20,000	＋
Pierced earrings	Not buy	＋
Bracelet	Buy	＋
Brand	Important	＋

We can observe that "Those who are 33～42 years old, are Company Employee of "Not either" of outdoor or indoor type, make present to Sweet Heart, do not esteem Fad but esteem Price, Coupon and Brand, and set Quality in intermediate level for it, do not buy Pierced earrings, but buy Bracelet with Budget of 10,000～20,000 yen".

(4) Setting evidence to "More than 43 years old"

①① Node separated by 1 class

Occupation	Independents	＋
Extroversion	Outdoor	＋
Receiver	Sweet Heart	＋

②②Node separated by 2 class

Quality	Ordinary	＋
Fad	Not important	＋
Price	Important	＋

③③Node separated by 3 class

Coupon	Important	＋
Budget	～20,000	＋
Bracelet	Buy	＋
Brand	Not important	＋

We can observe that "Those who are more than 43 years old, are Independents of Outdoor type, make present to Sweet Heart, do not esteem Fad nor Brand but esteem Price and Coupon, and set Quality in intermediate level for it, buy Bracelet with Budget less than 20,000 yen".

5.2 Sensitivity Analysis for "Extroversion"

(1) Setting Evidence to "Outdoor"

① ①Node separated by 1 class

Age	43～	＋
Gender	Male	＋
Shopping	Like	＋

②②Node separated by 2 class

Receiver	Sweet Heart	＋
Occupation	Miscellaneous	＋

③③Node separated by 3 class

Price	Important	＋
	Not important	＋
Coupon	Important	＋
Bracelet	Buy	＋
Pierced earrings	Buy	＋
Ring	Not buy	＋
Budget	～20,000	＋
Quality	Important	－

④Miscellaneous (Although Node is located in ① or ②, variance is small (③ class).)

Frequency of Net shopping	Sometimes	＋
Fad	Ordinary	＋

(These words have weak meanings, therefore we state them by italic in the following statement.)

We can observe that "Those who are outdoor type, are male of more than 43 years old, whose Occupation are miscellaneous (Not : student, officer, Company employee, clerk of organization, Independents), like shopping and *sometimes execute net shopping*, make present to Sweet Heart, do not esteem Quality but esteem Price and Coupon, and set *Fad in intermediate level for it*, do not buy Ring but buy Bracelet and Pierced earrings with Budget less than 20,000 yen".

(2) Setting evidence to "Indoor"

① ①Node separated by 1 class

Age	～22	＋
Gender	Female	＋
Shopping	Not important	＋

②②Node separated by 2 class

Receiver	Myself	＋

Occupation	Student	＋
Fad	Important	＋

③③Node separated by 3 class

Price	Ordinary	＋
Coupon	Not important	＋
Bracelet	Not buy	＋
Pierced earrings	Buy	＋
Budget	20,000～	＋
Quality	Important	＋

④Miscellaneous

Frequency of Net shopping	Often	＋
	Never	＋

We can observe that "Those who are Indoor type, are girl students of less than 22 years old, dislike shopping and *often or never execute net shopping*, make present to themselves, do not esteem Coupon but esteem Fad, and set Price in intermediate level for it, do not buy Bracelet but buy Pierced earrings with Budget more than 20,000 yen".

5.3 Sensitivity Analysis for "Frequency of Net shopping"

(1) Setting evidence to "Often"

① ①Node separated by 1 class

Coupon	Not important	＋
Bracelet	Buy	＋
Pierced earrings	Buy	＋
Necklace	Buy	＋
Ring	Buy	＋
Budget	20,000～	＋

②②Node separated by 2 class

No corresponding data

③③Node separated by 3 class

No corresponding data

④④Miscellaneous

Age	～22	＋
Gender	Female	＋
Occupation	Student	＋
Extroversion	Indoor	＋

We can observe that "Those who often execute net shopping, are indoor typed girl students less than 22 years old, do not esteem Coupon, buy Bracelet, Pierced earrings, Necklace and Ring with Budget more than 20,000 yen".

(2) Setting evidence to "Sometimes"

①① Node separated by 1 class

Coupon	Important	＋
Pierced earrings	Not buy	＋
Necklace	Buy	＋

Ring	Buy	＋
Budget	10,000～20,000	＋

②②Node separated by 2 class
No corresponding data
③③Node separated by 3 class
No corresponding data
④④Miscellaneous

Gender	Male	＋
Extroversion	Outdoor	＋
Bracelet	Not buy	＋

We can observe that "Those who execute net shopping sometimes, are *Male of outdoor type*, esteem coupon, do not buy Pierced earrings nor *Bracelet* but buy Necklace and Ring with Budget of 10,000～20,000 yen".

(3) Setting evidence to "Rarely"
① ①Node separated by 1 class

Coupon	Ordinary	＋
Bracelet	Buy	＋
Pierced earrings	Not buy	＋
Necklace	Not buy	＋
Ring	Not buy	＋
Budget	20,000～	＋

②②Node separated by 2 class
No corresponding data
③③Node separated by 3 class
No corresponding data
④④Miscellaneous

Extroversion	Not either	＋

We can observe that "Those who rarely execute net shopping, are "Not either" of outdoor or indoor type, intermediate level in esteeming Coupon, do not buy Pierced earrings, Necklace nor Ring but buy Bracelet with Budget more than 20,000 yen".

(4) Setting evidence to "Never"
①①Node separated by 1 class

Coupon	Not important	＋
Bracelet	Not buy	＋
Necklace	Not buy	＋
Ring	Not buy	＋
Budget	～10,000	＋

②②Node separated by 2 class

Extroversion	Indoor	＋

③Node separated by 3 class

Occupation	Student	＋

④④Miscellaneous

Age	～22	＋
Gender	Female	＋
Pierced earrings	Buy	＋

We can observe that "Those who never execute net shopping, are Indoor typed *girl students of less than 22 years old*, do not esteem coupon, do not buy Bracelet, Necklace nor Ring but buy *Pierced earrings* with Budget less than 10,000 yen".

5.4 Sensitivity Analysis for "Shopping"

(1) Setting evidence to "like"

① ①Node separated by 1 class

Coupon	Important	＋
Ring	Not buy	＋
Budget	～20,000	＋

②②Node separated by 2 class

No corresponding data

③③Node separated by 3 class

Occupation	Student	＋

④④Miscellaneous

Age	～22	＋
Gender	Male	＋
Extroversion	Outdoor	＋
Necklace	Buy	＋
Pierced earrings	Buy	＋
Bracelet	Buy	＋

We can observe that "Those who like shopping, are *outdoor typed male students of less than 22 years old*, esteem coupon, do not buy Ring but buy *Necklace, Pierced earrings and Bracelet* with Budget less than 20,000 yen".

(2) Setting evidence to "Ordinary level"

① ①Node separated by 1 class

Pierced earrings	Not buy	＋

②②Node separated by 2 class

No corresponding data

③③Node separated by 3 class

Occupation	Employee	＋

④④Miscellaneous

Age	23～42	＋
Gender	Female	＋
Extroversion	Not either	＋
Budget	～30,000	＋
Ring	Buy	＋
Necklace	Buy	＋
Bracelet	Not buy	＋

Coupon	Important	＋

We can observe that "Those who put ordinary level concerning liking or disliking in shopping, are *Female Company Employee of 23～42 years old, "Not either" of outdoor or indoor type*, esteem coupon, do not buy Pierced earrings nor bracelet but *buy Ring and Necklace* with *Budget less than 30,000 yen*".

(3) Setting evidence to "Dislike"

① ①Node separated by 1 class

Coupon	Not Important	＋
Pierced earrings	Buy	＋
Budget	30,000～	＋

②②Node separated by 2 class

No corresponding data

③③Node separated by 3 class

Occupation	Student	＋

④Miscellaneous

Age	～22	＋
Gender	Female	＋
Extroversion	Indoor	＋
Ring	Buy	＋
Necklace	Not buy	＋
Bracelet	Buy	＋

We can observe that "Those who dislike shopping, are *Indoor typed girl students of less than 22 years old*, do not esteem coupon, *do not buy Necklace* but buy Pierced earrings, *Ring and Bracelet* with Budget more than 30,000 yen".

5.5 Sensitivity Analysis for "Coupon"

(1) Setting evidence to "Important"

① ①Node separated by 1 class

Frequency of Net shopping	Sometimes	＋
Shopping	Important	＋
Price	Important	＋

②②Node separated by 2 class

Budget	～20,000	＋
Pierced earrings	Not buy	＋
Ring	Not buy	＋

③③Node separated by 3 class

Age	43～	＋
Gender	Female	＋
Fad	Important	＋

④④Miscellaneous

Receiver	Myself	＋
Extroversion	Outdoor	＋
Necklace	Buy	＋

Bracelet	Not buy	＋

We can observe that "Those who esteem coupon, are *outdoor typed* Female of more than 43 years old, execute net shopping sometimes, like shopping, esteem Price and Fad, *make present to themselves*, do not buy Pierced earrings, Ring nor Bracelet *but buy Necklace* with Budget less than 20,000 yen".

(2) Setting evidence to "Ordinary level"

① ①Node separated by 1 class

Frequency of Net shopping	Rarely	＋
	Often	＋
Shopping	Important	＋
	Not important	＋

②②Node separated by 2 class

No corresponding data

③③Node separated by 3 class

Gender	male	＋
Fad	Not important	＋
Receiver	Lover	＋

④Miscellaneous

Price	Not important	＋
Budget	20,000～	＋
Ring	Not buy	＋
Bracelet	Buy	＋

We can observe that "Those who put ordinary level concerning esteeming or not esteeming coupon, are male, execute Net shopping rarely or often, like or dislike shopping, make present to Lover, do not esteem Fad nor *Price, do not buy Ring but buy Bracelet with Budget more than 20,000 yen*".

(3) Setting evidence to "Not important"

①①Node separated by 1 class

Frequency of Net shopping	Often	＋
	Never	＋
Shopping	Not important	＋

②②Node separated by 2 class

Budget	20,000～	＋
Pierced earrings	Buy	＋
Necklace	Not buy	＋
Ring	Buy	＋

③③Node separated by 3 class

Age	～32	＋
Gender	Male	＋
Fad	Not important	＋
Receiver	Others	＋
	Lover	＋
Brand	Not important	＋

④④Miscellaneous

Occupation	Student	＋
Extroversion	Indoor	＋
Price	Not important	＋
Bracelet	Buy	＋

We can observe that "Those who do not esteem Coupon, are *Indoor typed* Male *student of less than 32 years old*, execute Net shopping often or never, dislike shopping, make present to Lover or Miscellaneous (Not: Father/Mother, Children, Sweet heart, Myself), do not esteem Fad, Brand nor *Price*, do not buy Necklace but buy Pierced earrings, Ring and *Bracelet* with Budget more than 20,000 yen".

5.6 Sensitivity Analysis for "Budget"

(1) Setting evidence to "～10,000 yen"

① ①Node separated by 1 class

Shopping	Important	＋
Frequency of Net shopping	Never	＋

②Node separated by 2 class

Price	Important	＋
Receiver	Myself	＋
Coupon	Important	＋
Pierced earrings	Not buy	＋
Necklace	Not buy	＋
Ring	Not buy	＋

③③Node separated by 3 class

Age	43～	＋

④④Miscellaneous

Extroversion	Outdoor	＋
Gender	Female	＋
Fad	Important	＋
Bracelet	Not buy	＋

We can observe that "Those who put Budget to "～10,000 yen", are *outdoor typed Female* of more than 43 years old, like shopping, never execute Net shopping, esteem *Fad*, Price and Coupon, make present to themselves, do not buy Pierced earrings, Necklace, Ring nor *Bracelet*".

(2) Setting evidence to "10,000～20,000 yen"

① ①Node separated by 1 class

Fad	Important	＋
Shopping	Important	＋
Frequency of Net shopping	Sometimes	＋

②②Node separated by 2 class

Price	Important	＋
Pierced earrings	Not buy	＋

③Node separated by 3 class

Age	43～	＋

④④Miscellaneous

Receiver	Myself	＋
	Sweet heart	＋
Extroversion	Outdoor	＋
Ring	Buy	＋
Necklace	Buy	＋
Bracelet	Not buy	＋
Coupon	Important	＋

We can observe that "Those who put Budget to "10,000～20,000 yen", are *outdoor typed* customers of more than 43 years old, like shopping, execute Net shopping sometimes, *make present to themselves or Sweet heart*, esteem Price and *Coupon*, do not buy Pierced earrings nor *Bracelet but buy Ring and Necklace*".

(3) Setting evidence to "20,000～30,000 yen"

① ①Node separated by 1 class

Shopping	Important	＋
Frequency of Net shopping	Rarely	＋
	Often	＋

②②Node separated by 2 class

Coupon	Not important	＋

③③Node separated by 3 class

Age	～22	＋

④④Miscellaneous

Fad	Ordinary	＋
Occupation	Student	＋
Receiver	Myself	＋
	Miscellaneous	＋
Extroversion	Indoor	＋
Price	Ordinary	＋
Necklace	Not buy	＋
Pierced earrings	Buy	＋
Bracelet	Buy	＋

We can observe that "Those who put Budget to "20,000～30,000 yen", are *indoor typed students* of less than 22 years old, dislike shopping, execute Net shopping Rarely or Often, *make present to themselves or miscellaneous (Not: Lover, Father/Mather, Children, Sweet Heart)*, do not esteem Coupon, intermediate level in esteeming *Fad* and *Price, do not buy Necklace but buy Pierced earrings and Bracelet*".

(4) Setting evidence to "30,000～ yen"

① ①Node separated by 1 class

Fad	Not important	＋
Shopping	Not important	＋
Frequency of Net shopping	Often	＋

②②Node separated by 2 class

Price	Not important	＋
Receiver	Lover	＋
Coupon	Important	—
Pierced earrings	Buy	＋
Necklace	Not buy	＋
Ring	Buy	＋
Bracelet	Buy	＋

④　③Node separated by 3 class

Age	～32	＋

④Miscellaneous

Gender	Male	＋
Occupation	Student	＋
Extroversion	Indoor	＋

We can observe that "Those who put Budget to "30,000～ yen", are *indoor typed male students* of less than 32 years old, dislike shopping, often execute Net shopping, make present to Lover, do not esteem Fad, Price nor Coupon, do not buy Necklace but buy Pierced earrings, Ring and Bracelet".

6. Remarks

Setting evidence to all parameters, we can obtain following findings.

(1) If the model is spread toward lower level with branch, observation data tends to be small. Therefore ripple effect becomes small as it passes through node to node.

(2) The change of differences of probability (ie. "Posterior probability - Prior probability") decreases exponentially as a node is separated from the source node where evidence is set. To cope with this, such methods as Reinforcement Learning, transformation by logarithmic scale would be effective. As the depth of a model becomes deep, above phenomenon occurs, therefore model building of shallow depth is required.

(3) In the case selecting items are, for example, "Yes", "Ordinary level"(intermediate one), "No", we can obtain more clear result by setting evidence to "Yes" or "No" rather than to "Ordinary level" (intermediate one) in general. For example, we pick up the case "coupon" and calculate the average of the sum of the differences of probability from Table B. Then it becomes as follows.

Table 13 Case of "Coupon"

Important	0.009
Ordinary level	0.004
Not	0.021

(4) We can state the condition strongly, ordinary or weakly by the value of the differences of probability. Therefore, if we take the following statement method, we can easily catch the characteristics of the contents. "We can say **strongly A**, ordinary B, and *weakly C*." In this paper, only the writing method of "*weakly C*" is adopted.

7. Discussion-Comparison with the experiences of Shop owner and employees

Shop owner and employees discussed about their own experiences based upon daily consumer's purchasing activities.

(1) As ages increase, consumers esteem value of goods rather than fad or trend. Young people may not have enough knowledge about quality.

(2) Female is more sensitive about coupon than male. Male is satisfied if the price is qualified to the value of the goods. They have less tendency than women that they buy goods because it becomes cheap.

(3) Although ages increase, budget does not necessarily increase. If they are married, budget is restricted. Budget of female is lower than those of male in general. Women seek high quality goods with less amount of budget, therefore hurdle is high for purchasing.

(4) We wonder if consumers think brand as a tool to measure quality of the goods concerning the theme whether they esteem brand or not. If so, it is assumed that those who esteem quality esteem brand.

(5) There are many cases that young girl up to 22 years old often buy pierced earrings. It may be because these are cheap compared with other genre products. Those who have low budget can easily buy pierced earrings.

(6) It is easy to gather repeated purchasing customer by the periodical distribution of coupon. Therefore, those who like shopping esteem coupon.

These can be observed strongly or weakly or partially in the above analysis. We are intending to confirm these instructions by analyzing the new consecutive purchasing records, the data of which are already obtained.

8. Conclusion

Jewelry/accessory buying via the Internet is increasing, especially for young people. They often had difficulty deciding what kind of jewelry/accessory, because there were many kinds of jewelry/accessories to choose from. Consulting service to support decision was required for these matters. In this paper, a questionnaire investigation was executed for purchasing on-line network, used for jewelry/accessory purchasing in order to get instruction for an on-line network consulting service. These were analyzed by using Bayesian network. One of the TRIZ methods was extended and applied. Some interesting and instructive results were obtained. These would be utilized for constructing a much more effective and useful on-line network consulting service. Examining such trials should be traced hereafter.

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APPENDIX: Questionnaire Concerning the Purchasing of Jewelry/ Accessories for Gifts

Please answer the following questions.

Please write down ○ to the answering items. Plural selection is allowed for Question 1, 13, 14, 17, 20, 39, 40, 43, 44. Select ①～⑤ of the right column for the Question 2～11, 21～29, 32～36.

1. When you make a gift of jewelry/ accessory to someone, what point do you stress? (Plural Answers Allowed)

Q1 ①Price ②Brand ③Trend/Design ④Raw Materials/Quality ⑤Kind/Items ⑥Response of the shop members ⑦Existence of Certification ⑧Relatively Cheap ⑨Desire of the receiver of the gift ⑩Miscellaneous ( )

2. When you choose, how is the importance of each item?

	Very important	Slightly important	Ordinary level	Not so important	Not important
Q2 Price	①	②	③	④	⑤
Q3 Brand	①	②	③	④	⑤
Q4 Trend/Design	①	②	③	④	⑤
Q5 Raw Materials/Quality	①	②	③	④	⑤
Q6 Kind/Items	①	②	③	④	⑤
Q7 Response of the shop members	①	②	③	④	⑤
Q8 Existence of Certification	①	②	③	④	⑤
Q9 Relatively Cheap	①	②	③	④	⑤
Q10 Desire of the receiver of gift	①	②	③	④	⑤
Q11 Miscellaneous ( )	①	②	③	④	⑤

3. How much do you spend for one gift? [Unit: yen]

Q12 ①～5,000 ②～10,000 ③～15,000 ④～20,000 ⑤～25,000 ⑥～30,000 ⑦more than that

4. What kind of jewelry/accessory have you given? (Plural Answers Allowed)

Q13 ①Ring ②Necklace/ Pendant ③Pierced earrings ④Bracelet/Bungle ⑤Brooch ⑥Necktie Pin ⑦Miscellaneous ( )

5. Why did you select them? (Plural Answers Allowed)

Q14 ①Desire of the receiver ②Trend ③Because it was popular ④Famous entertainers have them ⑤Recommendation of the sales person in the shop ⑥Budget ⑦Special Sales ⑧Miscellaneous ( )

6. Who do you consult with when you choose?

Q15 ①Lover ②Friend ③Sales person of the shop ④Do not consult with anybody ⑤Miscellaneous ( )

7. Where do you buy gifts?

Q16 ①Department Store ②Jewelry/Accessory Shop ③Remote Sales by Catalogue ④Internet Shop ⑤Miscellaneous ( )

8. Why is it? (Plural Answers Allowed)

Q17 ①Desire of the receiver ②Reliability of the shop ③Plenty of items ④There are favorite brands ⑤Specified shop to buy(Always buy from the shop) ⑥Friends often shop there ⑦Rather cheap compared with quality ⑧Able to get additional points when using a credit card ⑨There is DM(Direct Mail) guidance when gift seasons come ⑩Miscellaneous ( )

9. Whom do you make a gift to?

Q18 ①Lover ②Father/Mother ③Children ④Sweet heart ⑤Myself ⑥Miscellaneous ( )

10. How many times do you make gifts in a year?

Q19 ①Once ②Twice ③Three times ④Four times ⑤More than that ⑥None (Reason:)

11. On what occasions do you give presents? (Plural Answers Allowed)

Q20 ①Birthday ②Xmas ③Valentine day ④White day ⑤Grown up anniversary ⑥Wedding Anniversary ⑦Congratulate for birth ⑧Congratulate for getting job ⑨Congratulate for commencement of studying at school ⑩Miscellaneous ( )

12What is your hobby?

	Very important	Slightly important	Ordinary level	Not so important	Not important
Q21 12-1 Sports: ①Baseball ②Football ③Tennis ④Miscellaneous ( )	①	②	③	④	⑤
Q22 12-2 Reading Books: ①Novel ②Business Affair ③Weekly Magazine ④Comic ⑤Miscellaneous ( )	①	②	③	④	⑤
Q23 12-3 Shopping	①	②	③	④	⑤
Q24 12-4 Traveling: ①Sightseeing ②Hot Springs ③Gourmet ④Miscellaneous ( )	①	②	③	④	⑤
Q25 12-5 Music: ①Classic ②Western POPS ③Japanese POP ④Miscellaneous ( )	①	②	③	④	⑤
Q26 12-6 Movie: ①Love ②Action ③Comedy ④Miscellaneous ( )	①	②	③	④	⑤
Q27 12-7 Theater: ①Song ②Dance/Ballet ③Drama ④Miscellaneous ( )	①	②	③	④	⑤
Q28 12-8 Drinking: ①Beer ②Wine ③Japanese wine-sake ④Japanese liquor-shochu ⑤Miscellaneous ( )	①	②	③	④	⑤
Q29 12-9 Miscellaneous: ( )	①	②	③	④	⑤

13. What kind of lifestyle do you like?

Q30 13-1 Pleasure: ①Outdoor ②Indoor ③Not either

Q31 13-2 Work: ①Desk Work ②Outdoor activity such as visiting sales ③Not either

14. Which method of payment do you want to choose?

	Very important	Slightly important	Ordinary level	Not so important	Not important
Q32 14-1 ①Cash/Cash on Delivery	①	②	③	④	⑤
Q33 14-2 Credit Card	①	②	③	④	⑤
Q34 14-3 Discount	①	②	③	④	⑤
Q35 14-4 Point Card/Coupon	①	②	③	④	⑤

Q36 14-5 Miscellaneous (　)	①	②	③	④	⑤

15.How often do you use the Internet?

Q37①Very often ②Sometimes ③Rarely ④Never

16. How do you use Internet?

Q38 16-1 How often do you use Internet Shopping?: ①Very often ②Sometimes ③Rarely ④Never

Q39 16-2 If you have answered "Yes"(16-1①②), tell us the reason why. (Plural Answers Allowed)
①Convenient ②Able to compare goods easily ③Cheap ④Plenty of goods ⑤Able to consult with other people ⑥Miscellaneous (　)

Q40 16-3 If you have answered "No"(16-1③④), tell us the reason why. (Plural Answers Allowed)
①Difficult to buy ②anxious ③Can not observe actual goods ④Can not identify which shop is good ⑤Can not get goods immediately ⑥Miscellaneous (　)

Q41 16-4 If you have answered "Yes", which method do you use? ①PC ②Mobile Phone ③Miscellaneous (　)

Q42 16-5 Do you want to buy jewelry/Accessory via the Internet?　①Yes ②Perhaps ③No ④I do not know

Q43 16-6 If you have answered "Yes"(16-5①②), tell us the reason why. (Plural Answers Allowed)
①Convenient ②Able to compare goods easily ③Cheap ④Plenty of goods ⑤Able to consult with other people ⑥Miscellaneous (　)

Q44 16-7 If you have answered "No"(16-5③④), tell us the reason why. (Plural Answers Allowed)
①Difficult to buy ②anxious ③Can not observe actual goods ④Can not identify which shop is good ⑤Can not get goods immediately ⑥Miscellaneous (　)

17. Ask about yourself.

Q45 17-1 Sex: ①Male ②Female

Q46 17-2 Age: ①Under 18 ②18～22③23～27④28～32 ⑤33～37⑥38～42⑦43～47⑧More than 48

Q47 17-3 Occupation: ①Student ②Officer ③Company Employee ④Clerk of Organization ⑤Independents ⑥Miscellaneous

Q48 17-4 Address: ①Prefecture(　　) ②City(　　)

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Applying Extenics in the Project-based Learning to Improve Students' Innovation Ability

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Abstract
With the rapid development of science and technology, the demand of innovative talents continues to increasing. So in the current it has became an urgent task for universities to training college students with practice and innovation ability. In this paper the extenics was introduced into the project-based learning to improve students' innovation ability. According to the process of contradictory problem solving, the solving steps of non-compatible problem were described in detail combined with the design of a mechanical transmission device. The practice shows that the method is feasible to improve the students' ability of analyzing and solving the question and train students' innovation ability and the research results can provide a certain reference for other teaching fields and links of universities.
Keyword: Extenics; Innovation ability; contradictory problem

1. Introduction
With the rapid development of science and technology, the demand of innovative talents continues to increasing. So in the current it has became an urgent task for universities to training college students with practice and innovation ability. Practice teaching is the key teaching link of training students' practice and innovation ability in which theory and practice are combined. So the teacher should take students as the center, regard training innovative and technical talents as the goal lead the students to train the self consciousness of innovation [1].

2. Introducing Extenics to Projected-based Learning
Project-based learning is such a type of teaching mode. In the mode, students are regarded as the center of learning, they study through group discussion in the lead of teachers [2-5] and the knowledge which would be taught is contained by one or more project instead, students completed the project and then master the knowledge. Compared with the traditional teaching methods, project -based learning with concept of innovative education throughout the whole teaching process, enable students to participate directly, then can arouse students' learning enthusiasm and initiative, train the student to obtain the ability to analyze the question and solve the question and then train the practice and innovation ability.
The completion of a project is usually achieving one or more objectives based on certain conditions. Sometimes the expected goal can directly reach according to existing conditions. But in most cases, the expected goal can not be realized directly according to existing conditions. This needs to seek and take some strategies to solve the contradictory problem between the existing condition and the expected goal. A project generally can be divided into several sub projects which are relatively independent but closely linked; complete such a sub project may also need to solve some contradictory problems, so a project can actually be regarded as a system consisting of several contradictory problems. For example, figure 1 shows the work flow of product design project.

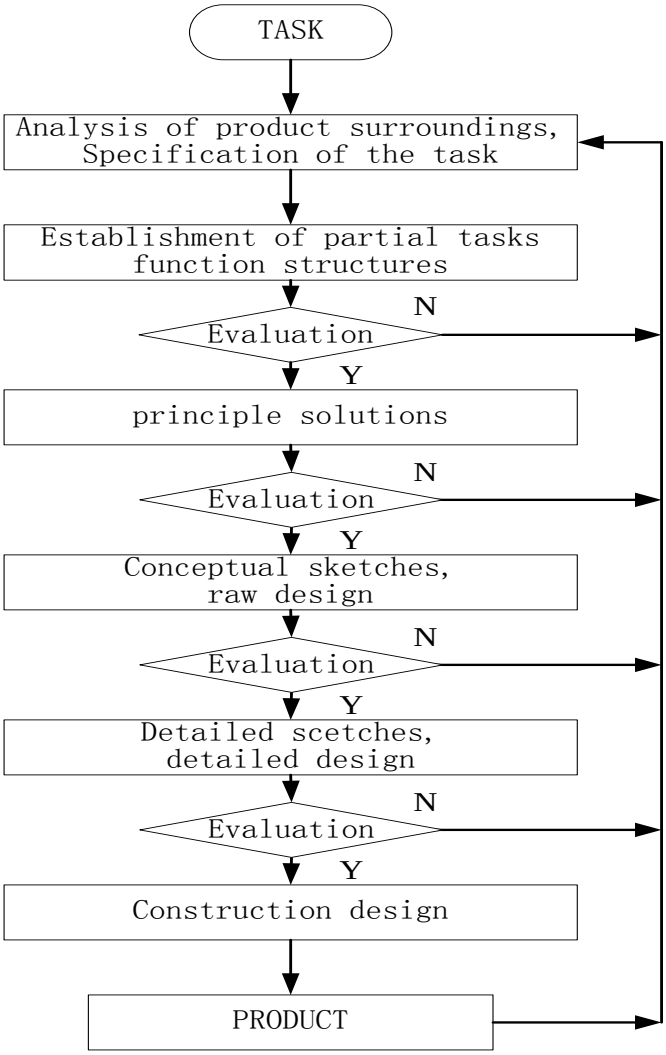

Figure 1. The work flow of the product design project

The solution of the contradictory problem in this system put forward higher requirements for teachers who should not only master the knowledge but also have the ability to analyze and solve problems, and also need the students' initiative, positive input. Well, students are usually lack of experience during the study in the university and often solve the contradictory problem by traditional thinking method, such as method of trial and error, brainstorming. But these traditional methods are often time-consuming and laborious, have great randomness and contingency, and innovation effect is very difficult to guarantee. If students can break the thinking inertia and traditional way of thinking problems, learn to expand thinking, master the innovative method, the solving of the problem will be accelerated and the creativity of the problem solving will be improved , so as to the students' innovation ability can be improved. "Extenics" is a new discipline created by Chinese scholars led by professor Cai Wen [6-11]. It studies the extensive possibility of things and the law, method of innovation by using formal model, and then uses the law and method to treat the contradictory problem. The contradictory problems can be classified into three subclasses: contradictory problem between subjective goals and objective conditions, contradictory problem between subjective goals and contradictory problem between objective goals. Extenics mainly study the first and second kinds of contradictory problems usually referred to as the non-compatible problem and opposite problem respectively. Extension theory thinks that in order to solve contradictory problem we should change our thinking from the traditional equivalent thinking into" expand" thinking, obtain a batch of object and then find a suitable object for solving the problem. The logic cell of Extenics is basic element, which includes matter element, affair element and relationship element. Extenics study presents the extension methods such as divergent tree, split-combination chain, related network, contains lines, conjugated equivalence, extension transformation such as basic

transformation, composite transform and conduction transform and comprehensive methods such as Rhombus thinking and transforming bridge. The process of treating contradictory problem in Extenics consists of four basic steps, which are representation, extension, transformation, evaluation, and then eventually seek the optimal solution. In the following the solving steps of non-compatible problem were described in detail combined with the design of a mechanical transmission device in project-based learning.

3. Example analysis

Work requirements of the conveyor belt *E*: work power is 5*kW*, the speed is 80±5%*r/min*, but the driving device is the motor *F*, whose full speed is 960*r/min*, work power is 11*kw*. Now need to design a mechanical transmission device for the conveyor belt *E*.

3.1. Representation

The extension model of the problem can be written as:

$$P = G * L = \begin{bmatrix} supply, & control\text{-}object, & A \\ & implement\text{-}object, & motorF \\ & accept\text{-}object, & conveyor\ beltE \end{bmatrix} * \left(motorF,\ function, \left(supply,\ control\text{-}object,\ B\right)\right)$$

In which:

$$A = \left(movementA_1,\ \text{speed},\ \langle 76,84\rangle r/min\right)\quad B = \left(movementB_1,\ \text{speed},\ 960r/min\right)$$

The extension model of the core problem of this problem can be written as:

$$\begin{aligned} P_0 &= g_0 * l_0 \\ &= \left(movementA_1,\ The\ required\ input\ speed,\ \langle 76,84\rangle r/min\right) * \left(movementB_1,\ \text{output}\ speed,\ 960r/min\right) \\ &= \left(A_1,\ c_{0s},\ \langle 76,84\rangle r/min\right) * \left(B_1,\ c_{0t},\ 960r/min\right) \end{aligned}$$

Take X=〈 76,84〉 as positive region, optimal x_0=80,simple compatible function can be written as

$$K(l) = k(x) = \begin{cases} \dfrac{x-76}{80-76}, & x \le 80 \\ \dfrac{84-x}{84-80}, & x \ge 80 \end{cases}$$

Then when x=960r/min,

$$K(l_0) = k(960) = \frac{84-960}{84-80} = -219,$$

The result shows that $P = G * L$ is an non-compatible problem。

3.2. Expandation

There are three ways to solve non-compatible problem:solving problem by changing conditions with goal unchanged; solving contradictory problem by changing goal with conditions unchanged; solving contradictory problem by changing conditions and goal at the same time. The condition of this non-compatible problem is an identified motor, so we can only look for available resources from the outside. According to the extension analysis principle, it is possible for matter, affair and relationship to be combined, decomposed and expanded. According to the combination, a thing can be associated with other things together to create something new, and thus provide the possibility of solving contradictory problems. In this problem the motor‘s output speed is much higher than the needed input speed of the working machine , if we can find a matter element having a speed reduction function, combine it with the matter element of condition, enabling the output speed reduced [12], then the problem may be solved.

According to the divergence analysis:

$$\left(motorF,\ function,\left(supply,\ control\ object,\ B\right)\right) \dashv \begin{cases} \left(Involute\ cylindrical\ gearP_1,\ function,\ \left(transfer,\ control\ objec,\ N_1\right)\right) \\ \left(Involute\ straight\ bevel\ gearP_2,\ function,\ \left(transfe,\ control\ objec,\ N_2\right)\right) \\ \left(Ordinary\ cylindrical\ wormP_3,\ function,\ \left(transfe,\ control\ objec,\ N_3\right)\right) \\ \left(Common\ V\ beltP_4,\ function,\ \left(transfe,\ control\ objec,\ N_4\right)\right) \\ \left(Roller\ chainP_5,\ function,\ \left(transfe,\ control\ objec,\ N_5\right)\right) \end{cases},$$

in which: $N_1 = \left(movementO_1,\ \text{speed},\ \langle 135,960\rangle r/min\right)$, $N_2 = \left(movementO_2,\ \text{speed},\ \langle 120,960\rangle r/min\right)$,
$N_3 = \left(movementO_3,\ \text{speed},\ \langle 12,960\rangle r/min\right)$, $N_4 = \left(movementO_4,\ \text{speed},\ \langle 96,960\rangle r/min\right)$,
$N_5 = \left(movementO_5,\ \text{speed},\ \langle 120,960\rangle r/min\right)$

From the above analysis, some combining elements to the basic element of the original condition can be obtained, each combined element can also be expanded further in accordance with the principle of expanding, so more ways to solve the non-compatible problems can be obtained.

3.3. transformation

Based on the above expanding analysis , at least you can choose to do the following 5 transformation of conditions:

(1) $T_1 l_0 = \left(B_1 \oplus O_1,\ c_{0t}\ \langle 135,960\rangle\right) = l_1$

$k(135)$=-12.75,$k(960)$= -219, then $K(l_1) \in \langle -219,-12.75\rangle$ $K(l_1)$<0

The meaning of T_1 is connecting motor F with involute cylindrical gear P_1 whose maximum transmission ratio is 7.1 to drive the execution part.

(2) $T_2 l_0 = \left(B_1 \oplus O_2,\ c_{0t}\ \langle 120,960\rangle\right) = l_2$

$k(120)$=-9,$k(960)$= -219, then $K(l_2) \in \langle -219,-9\rangle$ $K(l_2)$<0

The meaning of T_2 is connecting motor F with involute straight bevel gear P_2 whose maximum transmission ratio is 8 to drive the execution part.

(3) $T_3 l_0 = \left(B_1 \oplus O_3,\ c_{0t}\ \langle 12,960\rangle\right) = l_3$

$k(12)$=-16,$k(960)$= -219, $k(80)$= 1,then $K(l_3) \in \langle -219,1\rangle$

The meaning of T_3 is connecting motor F with ordinary cylindrical worm P_3 whose maximum transmission ratio is 80 to drive the execution part.

(4) $T_4 l_0 = \left(B_1 \oplus O_4,\ c_{0t}\ \langle 96,960\rangle\right) = l_4$

$k(96)$=-3,$k(960)$= -219,then $K(l_4) \in \langle -219,-3\rangle$ $K(l_4)$<0

The meaning of T_4 is connecting motor F with common V belt P_4 whose maximum transmission ratio is 10 to drive the execution part.

(5) $T_5 l_0 = \left(B_1 \oplus O_5,\ c_{0t}\ \langle 120,960\rangle\right) = l_5$

$k(120)$=-9,$k(960)$= -219 ,then $K(l_5) \in \langle -219,-9\rangle$ $K(l_5)$<0

The meaning of T_5 is connecting motor F with roller chain P_5 whose maximum transmission ratio is 8 to drive the execution part.

In the five transformations, only T_3 can make $k(x) \geq 0$, that is T_3 can change this problem from non-compatible into compatible. While the other four transformations can not solve the non-compatible problem. But if we make

$$T_1' = T_1 \wedge T_2, \text{ then}$$

$T_1' l_0 = \left(B_1 \oplus O_1 \oplus O_2,\ c_{0t},\ \langle 17,960\rangle\right) = l_1'$

$k(17)$=-14.75,$k(960)$= -219, $k(80)$= 1,then $K(l_1') \in \langle -219,1\rangle$

The meaning of T_1' is adding involute cylindrical gear and involute straight bevel gear at the same time (i.e., and operation of transformation's) to solve the non-compatible problem. In the same way ,if we make $T_2' = T_1 \wedge T_4$, $T_3' = T_1 \wedge T_5, T_4' = T_2 \wedge T_4, T_5' = T_2 \wedge T_5, T_6' = T_4 \wedge T_5$,then get $l_2', l_3', l_4', l_5', l_6'$, respectively, which can also solve the

non-compatible problem. Of course there are other combinations, here omitted.

3.4. evaluation

T_3 and $T_1' \cdots T_6'$ are different strategies to solve the non-compatible problem .The following is to evaluate each strategy so as to select the better scheme.

(1)Define the evaluation index

To simplify the calculation, selecting efficiency, ease of processing, stability of movement as evaluation index. That is

$$SI = \{SI_1, SI_2, SI_3\}, SI_1 = (c_1, V_1) = (\text{efficiency}, V_1)$$

$$SI_2 = (c_2, V_2) = (\text{easy of processing}, V_2) \quad SI_3 = (c_3, V_3) = (\text{stability of movement}, V_3)$$

Efficiency is in the range of $\hat{X}$ =<0,1>;Ease of processing is divided into 5 levels, the maximum is 5, the minimum is 1;Stability of movement is divided into 5 levels, the maximum is 5, the minimum is 1.

The matter elements to be evaluated can be written as:

$$Z_1 = \begin{bmatrix} l_1', & c_1, & 0.9604 \\ & c_2, & 1 \\ & c_3, & 3 \end{bmatrix} Z_2 = \begin{bmatrix} l_2', & c_1, & 0.882 \\ & c_2, & 4 \\ & c_3, & 5 \end{bmatrix} Z_3 = \begin{bmatrix} l_3', & c_1, & 0.931 \\ & c_2, & 4 \\ & c_3, & 1 \end{bmatrix} Z_4 = \begin{bmatrix} l_4', & c_1, & 0.882 \\ & c_2, & 2 \\ & c_3, & 5 \end{bmatrix} Z_5 = \begin{bmatrix} l_5', & c_1, & 0.931 \\ & c_2, & 2 \\ & c_3, & 1 \end{bmatrix}$$

$$Z_6 = \begin{bmatrix} l_6', & c_1, & 0.855 \\ & c_2, & 5 \\ & c_3, & 2 \end{bmatrix} Z_7 = \begin{bmatrix} l_7', & c_1, & 0.8 \\ & c_2, & 3 \\ & c_3, & 4 \end{bmatrix}$$

(2)Determine the weight coefficient

$$\alpha = (\alpha_1, \alpha_2, \alpha_3) = (0.4, 0.3, 0.3)$$

(3)Initial screening

There are no indexes must to be met in the 3 evaluation indexes, so after an initial screening, all the objects to be evaluated cannot be deleted.

(4)Determine the correlation function, calculate the correlation degree

Considering the larger power of machine, in order to prevent the loss of too much energy, the efficiency of the transmission can not be too low. The acceptable range of it is X=<a, b>=<0.9,1>,maximum is at 1;to meet the requirements, the level of processing ease and move stability must be greater than or equal to 3.

The correlation function of efficiency, processing ease and move stability can be written respectively as:

$$k_1(x_1) = \begin{cases} \dfrac{x_1 - a}{b - a}, & x_1 < b \\ \dfrac{b - x_1}{b - a}, & x_1 > b \\ k(b) = 0 \vee 1 & x_1 = b \end{cases} = \begin{cases} \dfrac{x_1 - 0.9}{0.1}, & x_1 < 1 \\ \dfrac{1 - x_1}{0.1}, & x_1 > 1 \\ k(1) = 0 \vee 1 & x_1 = 1 \end{cases} k_2(x_2) = \begin{cases} 1, & x_2 = 5 \\ 0.5, & x_2 = 4 \\ 0, & x_2 = 3 \\ -0.5, & x_2 = 2 \\ -1, & x_2 = 1 \end{cases} k_3(x_3) = \begin{cases} 1, & x_3 = 5 \\ 0.5, & x_3 = 4 \\ 0, & x_3 = 3 \\ -0.5, & x_3 = 2 \\ -1, & x_3 = 1 \end{cases}$$

(5)Calculate standard correlation

If the relation degree of Z_j on SI_i can be written as $K_i(Z_j)$,then

$$k_i(Z_j) = \frac{K_i(Z_j)}{\max\limits_{x \in v} |K(x)|}$$

(6)Calculate optimal degree

$$C(Z_j) = \sum_{i=1}^{n} \alpha_i k_i(Z_j)$$

Table 1 shows the optimal degree of the object to be evaluated。

Table 1 · The results of optimal degree

strategy	K_1	K_2	K_3	k_1	k_2	k_3	C	optimal
Z_1	0.604	-1	0	0.604	-1	0	-0.0584	
Z_2	-0.18	0.5	1	-0.18	0.5	1	0.378	0.378
Z_3	0.31	0.5	-1	0.31	0.5	-1	-0.026	
Z_4	-0.18	-0.5	1	-0.18	-0.5	1	0.078	
Z_5	0.31	-0.5	-1	0.31	-0.5	-1	-0.326	
Z_6	-0.45	1	-0.5	-0.45	1	-0.5	-0.03	
Z_7	-1	0	0.5	-1	0	0.5	-0.25	

The optimal transmission scheme is $motorF \oplus involute\ cylindrical\ gearP_1 \oplus common\ V\ beltP_4$

4. Conclusions

In this paper Extenics was introduced into the project-based learning to improve students' innovation ability. The solving steps of non-compatible problem were described in detail combined with the design of a mechanical transmission device in project-based learning. Practice shows that, the applying of Extenics can make students get rid of inertial thinking and traditional way of thinking problems, expand students' mode of thinking and it is feasible to improve the college students' innovative ability and innovative thinking, train innovative talents. The research results can provide a certain reference for other teaching fields and links of universities.

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Optimization in Allocating Goods to Shop Shelves Utilizing Genetic Algorithm – An Application to the Shop Shelves for Yogurt Sales data－

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Abstract. How to allocate goods in shop shelves makes great influence to sales amount. Searching best fit allocation of goods to shelves is a kind of combinatorial problem. This becomes a problem of integer programming and utilizing genetic algorithm may be an effective method. Reviewing past researches, there are few researches made on this. Formerly, we have presented a papers concerning optimization in allocating goods to shop shelves utilizing genetic algorithm. In those papers, the problem that goods were not allowed to allocate in multiple shelves and the problem that goods were allowed to allocate in multiple shelves were pursued. In this paper, we examine the problem that allows goods to be allocated in multiple shelves and introduce the concept of sales profits and sales probabilities. Optimization in allocating goods to shop shelves is investigated. One of the TRIZ methods is extended and applied. An application to the shop shelves for yogurt is executed. Utilizing genetic algorithm, optimum solution is pursued and verified by a numerical example. Various patterns of problems must be examined hereafter.

Keywords: display, genetic algorithm, optimization, shelf

1. INTRODUCTION

Displaying method in the shop makes influence to sales amount, therefore various ideas are devised. What kind of items should be placed where in the shop, how to guide customers to what aisle in the shop are the big issues to be discussed. Searching best fit allocation of goods to shelves is also an important issue to be solved. In this paper, we seek how to optimize in allocating goods to shop shelves.

As for allocating good to shop shelves, following items are well known (Nagashima, 2005).
Shelf height is classified as follows.

・Shelf of 135cm height: Customers can see the whole space of the shop. Specialty stores often use this type.

・Shelf of 150cm height: Female customers may feel pressure to the shelf height. This height may be the upper limit to look over the shop.

・Shelf of 180cm height: It becomes hard to look over the shop. Therefore it should not be used for island display (display at the center or inside the shop).

Next, we show the following three functions of shelf for display.

1. Exhibition of goods function
2. Stock function
3. Display function

Effective range for exhibition is generally said to be 45cm-150cm. The range of 75cm-135cm is called golden zone especially. For the lower part under 45cm, goods are stocked as well as displaying.

Reviewing past papers, there are many papers concerning lay out problem. As for the problem of the distribution of equipment, we can see B. Korte *et al*. (2005), M. Gen *et al*. (1997) for the general research book. There are many researches made on this. Yamada *et al*. (2004) handles the lay out problem considering the aisle structure and intra-department material flow. Y. Wu *et al.* (2002) and Yamada *et al.* (2004) handle this problem considering aisle structure. Ito *et al.* (2006) considers multi-floor facility problem.

Although there are many researches on corresponding theme as stated above, we can hardly find researches on the problem of optimization in allocating goods to shop shelves.

Formerly, we have presented a paper concerning optimization in allocating goods to shop shelves utilizing genetic algorithm (Takeyasu *et al.*,2008). In those papers, the problem that goods were not allowed to allocate in multiple shelves and the problem that goods were allowed to allocate in

multiple shelves were pursued. In this paper, we examine the problem that allows goods to be allocated in multiple shelves and introduce the concept of sales profits and sales probabilities. Optimization in allocating goods to shop shelves is investigated with an application to the shop shelves for Yogurt in the convenience store is executed. Utilizing genetic algorithm, optimum solution is pursued and verified by a numerical example.

The rest of the paper is organized as follows. Problem description is stated in section 2. Genetic Algorithm is developed in section 3. Numerical example is exhibited in section 4 which is followed by the remarks of section 5. Section 6 is a summary.

2. PROBLEM DESCRIPTION

Shelf model is constructed as Figure 1. There are five sh elf positions. Shelf position 1 is mainly to put big and heavy g oods including stock function. Shelf position 3, 4 at the heigh t of the range 75cm to 135cm are the space of golden zone. T hus, we can use shelves properly by assuming these shelves. I n numerical example, we examine using these five shelves. Fi rst of all, we make problem description in the case there is onl y one shelf (case 1). Then we expand to the case there are mul tiple shelves (case 2).

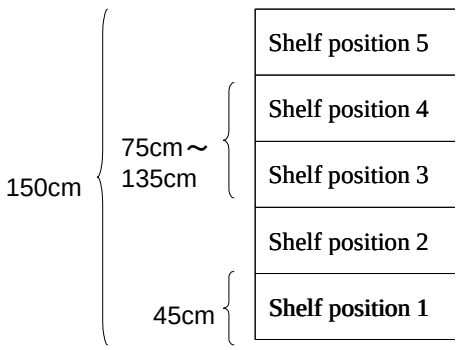

Figure 1: Shelf Model

(1)Case 1: The case that there is only one shelf

Although there are few cases that there is only one shelf, it makes the foundation for multiple shelves case. Therefore we pick it up as a fundamental one. Suppose shelf position k is from 1 to L (Figure 2).

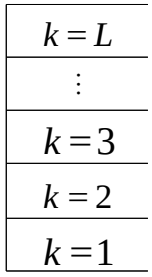

Figure 2: Shelf Position

Suppose there are N amount of goods $(i=1,\cdots,N)$. Set sales profit of goods i as H^i.
Table 1 shows the sales probabilities when each goods i s placed at each shelf position. The values in this table are written for example.

Table 1: Sales probability for each goods

Day of the Week	Time Zone(t)	Shelf $j=1$			Shelf $j=2$			…	Shelf $j=m$		
		Shelf Position			Shelf Position			…	Shelf Position		
		$k=1$	…	$k=L_1$	$k=1$	…	$k=L_2$	…	$k=1$	…	$k=L_m$
(Mon.)	0-1($t=1$)	0.01	…								
	1-2($t=2$)	0.02									
	…										
	23-24($t=24$)	0.03									
(Tue.)	0-1($t=25$)	0.02									
	1-2($t=26$)	0.02									
	…										
	23-24($t=48$)	0.03									
…	…	…	…	…	…	…	…	…	…	…	…
(Sun.)	0-1($t=145$)	0.02									
	1-2($t=146$)	0.03									
	…										
	23-24($t=168$)	0.04									

Suppose goods are sold in the period from t_1 to t_n. In addition, a new goods i is replenished when goods i is sold out.

Set the accumulated sales probability of goods i in time zone t, shelf j, and shelf position k in the table as $HK^i_{t,j,k}$.

Then, the sales probability $K^{i,j,k}_{t_1/t_n}$ of goods i in the period will be described as follows.

$$K^{i,j,k}_{t_1/t_n} = \sum_{t=1}^{n} HK^i_{t,j,k}$$

This can take the value more than 1. For example, the value 2 means that 2 amount of goods were sold during the period.

Set Benefit in the sales period from t_1 to t_n as $P^{i,j,k}_{t_1/t_n}$ $(i=1,\cdots,N)(j=1,\cdots,m)(k=1,\cdots,L)$ when goods i is placed at shelf j and shelf position k.

Where Benefit means:

$$\text{Benefit} = \text{SalesProbability} \times \text{SalesProfit}$$

Therefore, this equation is represented as follows.

$$P^{i,j,k}_{t_1/t_n} = K^{i,j,k}_{t_1/t_n} \cdot H^i \tag{1}$$

where j =1 because one shelf case is considered here.

Set $x_{i,k}$ as:

$x_{i,k} = 1$: Goods i is placed at shelf position k.

$x_{i,k} = 0$: Else

Suppose only one goods can be placed at one shelf position and also suppose that goods is allowed to allocate in multiple shelf positions. Then constraints are described as follows.

$$x_{i,k} = 1,0 \ (i=1,\cdots,N)\ (k=1,\cdots,L) \tag{2}$$

$$\sum_{i=1}^{N} x_{i,k} = 1 \ (k=1,\cdots,L) \tag{3}$$

Under these constraints,

$$J = \sum_{k=1}^{L} \sum_{i=1}^{N} P_{t_1/t_n}^{i,j,k} x_{i,k} \rightarrow Max \tag{4}$$

(2) Case 2: The case that there are m shelves

Suppose there are m shelves (Figure 3). Set Benefit as $P_{t_1/t_n}^{i,j,k}$ $(i=1,\cdots,N)$, $(j=1,\cdots,m)$, $(k=1,\cdots,L_j)$ where goods i is placed at shelf position k of shelf j. The sales period is the same with above stated (1).

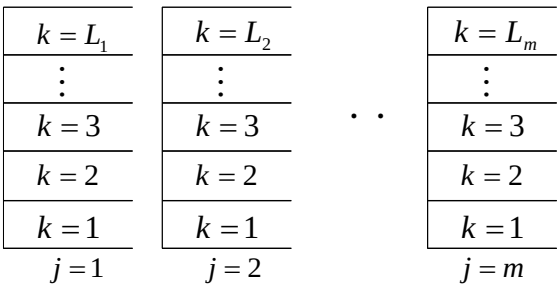

Figure 3: Shelf Position under multiple shelves

Set $x_{i,j,k}$ as:

$x_{i,j,k} = 1$: Goods is placed at shelf position k of shelf j

$x_{i,j,k} = 0$: Else

Suppose only one goods can be placed at one shelf position and also suppose that goods is allowed to allocate in multiple shelf positions. Then constraints are described as follows. The sales period is the same with before.

$$x_{i,j,k} = 1,0 \ (i=1,\cdots,N) \ (j=1,\cdots,m) \ (k=1,\cdots,L_j) \tag{5}$$

$$\sum_{i=1}^{N} x_{i,j,k} = 1 \ (j=1,\cdots,m) \ (k=1,\cdots,L_j) \tag{6}$$

Under these constraints,

$$J = \sum_{i=1}^{N} \sum_{j=1}^{m} \sum_{k=1}^{L_j} P_{t_1/t_n}^{i,j,k} x_{i,j,k} \rightarrow Max \tag{7}$$

3. ALGORITHM

We can make problem description as stated above, although these are somewhat under restricted cases. As far as only these are considered as they are, there is little difference between these and the conventional optimization problems. However, as soon as the number of involved shelves becomes larger, the number of variables dramatically grows greater, to which the application of Genetic Algorithm solution and Neural Network solutions may be appropriate. There are various means to solve this problem. When that variable takes the value of 0 or 1, the application of genetic algorithm would be a good method. As is well known, the calculation volume reaches numerous or even infinite amounts in these problems when the number of variables increases. It is reported that GA is effective for these problems (Gen et al. (1995), Lin et al. (2005), Zhang et al. (2005)).

A. The Variables

Suppose the number of goods, shelf position, and shelf a re 25,3,6 respectively.

For the convenience of handling we suppose 1 goods i s placed in one shelf.

Then the number of variables becomes 450.

$$x_{i,j,k} = 1,0 \ (i=1,\cdots,25) \ (j=1,\cdots,6) \ (k=1,2,3)$$

Therefore, set chromosome as follows.

$$\begin{aligned} X = (& x_{1,1,1}, x_{2,1,1}, x_{3,1,1}, \cdots, x_{25,1,1}, \\ & x_{1,1,2}, x_{2,1,2}, x_{3,1,2}, \cdots, x_{25,1,2}, \\ & \vdots \\ & x_{1,1,3}, x_{2,1,3}, x_{3,1,3}, \cdots, x_{25,1,3}, \\ & x_{1,6,1}, x_{2,6,1}, x_{3,6,1}, \cdots x_{25,6,1}, \\ & x_{1,6,2}, x_{2,6,2}, x_{3,6,2}, \cdots, x_{25,6,2} \\ & \vdots \\ & x_{1,6,3}, x_{2,6,3}, x_{3,6,3}, \cdots, x_{25,6,3}) \end{aligned} \tag{8}$$

B. Initialize population

Initialization of population is executed. The number of initial population is M. Here set $M = 100$. Set gene at random and choose individual which satisfies constraints.

C. Selection

In this paper, we take elitism while selecting. Choose P individuals in the order which take maximum score of objective function.

Here, set $P = 20$

D. Crossover

Here, we take uniform crossover.

Set crossover rate as:

$$P_c = 0.7 \tag{9}$$

E. Mutation

Set mutation rate as:

$$P_m = 0.01 \tag{10}$$

Algorithm of GA is exhibited at Table 2.

Table 2: Algorithm of multi-step tournament selection me thod

Step 1：Set maximum No. as $g_{\max}$, population size as P, crossover rate as p_c, mutation rate as p_m.
Step 2：Set $t=1$ for generation No. and generate initial solution matrix $x_p(t)=\left(x_{i,j,k}^{p}\right)$ $(p=1,\cdots,M)$.
Step 3：Calculate Objective function $J\left(x_p(t)\right)$ for all solution matrix $x_p(t)$ $(p=1,\cdots,P)$ in generation t.
Step 4：Set $t=t+1$ until $t>g_{\max}$.
Step 5：Crossover Generate new individual by crossover utilizing the method of above stated *D*.
Step 6：Mutation Reproduce by mutation utilizing the method of above stated *E*.
Step 7：Calculate objective function for reproduction of generation t.
Step 8：Selection Next generation is selected by elitism. Go to Step 4.

Introducing the variable y_s such that:

$$y_s = i \tag{11}$$

where

$$s = k+(j-1)\cdot 3 \tag{12}$$

when

$$x_{i,j,k} = 1$$

then (8) is expressed as:

$$Y=\left(y_1, y_2, \cdots, y_{18}\right) \tag{13}$$

4. NUMERICAL EXAMPLE

Now, we execute numerical example using POS sales data. Numerical example is executed in "Case 2" of 2 (2). Suppose the sales period is 5 days for Monday through Friday. Table 3 shows the unit sales profit H^i of each goods.

Table 3: Unit Sales Price and Sales Profit of each goods

Lot i	Sales Price	H^i
1	126	21
2	148	20
3	138	23
4	198	33
5	108	23
6	90	20
7	132	22
8	158	20
9	92	20
10	95	21
11	110	30
12	148	30
13	148	30
14	128	20
15	128	20
16	158	33
17	168	36
18	158	20
19	116	20
20	105	25
21	126	20
22	126	20
23	105	30
24	126	21
25	126	26

Supposing a general daytime retail store, we set opening time to be 10 through 21 o'clock. Table 4 shows the sales probabilities of lot i as an example.

Table 5 shows the sales probability by shelf for each shelf

position. Table 6 shows the value in which Table 4 and Table 5 are multiplied. Table 7 shows the benefit Table in which accumulated probability of Table 6 and Sales Profit of Table 3 are multiplied.

Table 4: Sales Probability of Lot i (Time Zone)

Day of the Week	Time Zone(t)	Sales Probability
(Mon.)	10-11	1.6
	11-12	1.6
	12-13	1.6
	13-14	1.1
	14-15	1.1
	15-16	1.1
	16-17	1.3
	17-18	1.3
	18-19	1.3
	19-20	1.0
	20-21	1.0
…	…	…
(Sun.)	10-11	1.1
	11-12	1.1
	12-13	1.1
	13-14	0.7
	14-15	0.7
	15-16	0.7
	16-17	0.9
	17-18	0.9
	18-19	0.9
	19-20	0.7
	20-21	0.7

Table 5: Sales Probability of Lot i (Shelf Position)

		Shelf					
		j=1	j=2	j=3	j=4	j=5	j=6
Shelf Position	k =1	0.9	1	1.1	1.1	1	0.9
	k =2	0.95	1.05	1.15	1.15	1.05	0.95
	k =3	1	1.1	1.2	1.2	1.1	1

Yogurt was placed at the upper 3 shelf position in the 8 shelf position. Therefore lowest one is near the golden zone of shelf position.

Consumers can easily focus on the main part of shelves.

Table 6: Sales Probability of Lot i

Day of the Week	Time Zone(t)	Sales Probability						
		Shelf Position			…	Shelf Position		
		j =1			…	j =6		
		k =1	k =2	k =3	…	k =1	k =2	k =3
(Mon.)	10-11	1.44	1.52	1.6		1.44	1.52	1.6
	11-12	1.44	1.52	1.6		1.44	1.52	1.6
	12-13	1.44	1.52	1.6		1.44	1.52	1.6
	13-14	0.99	1.05	1.1		0.99	1.05	1.1
	14-15	0.99	1.05	1.1		0.99	1.05	1.1
	15-16	0.99	1.05	1.1		0.99	1.05	1.1
	16-17	1.17	1.24	1.3		1.17	1.24	1.3
	17-18	1.17	1.24	1.3	…	1.17	1.24	1.3
	18-19	1.17	1.24	1.3		1.17	1.24	1.3
	19-20	0.9	0.95	1.0		0.9	0.95	1.0
	20-21	0.9	0.95	1.0		0.9	0.95	1.0
…	…	…	…	…		…	…	…

(Sun.)	10-11	0.99	1.05	1.1		0.99	1.05	1.1
	11-12	0.99	1.05	1.1		0.99	1.05	1.1
	12-13	0.99	1.05	1.1		0.99	1.05	1.1
	13-14	0.63	0.67	0.7		0.63	0.67	0.7
	14-15	0.63	0.67	0.7		0.63	0.67	0.7
	15-16	0.63	0.67	0.7		0.63	0.67	0.7
	16-17	0.81	0.86	0.9		0.81	0.86	0.9
	17-18	0.81	0.86	0.9		0.81	0.86	0.9
	18-19	0.81	0.86	0.9		0.81	0.86	0.9
	19-20	0.63	0.67	0.7		0.63	0.67	0.7
	20-21	0.63	0.67	0.7	…	0.63	0.67	0.7

Table 7 shows the benefit when each goods is placed at each shelf position of each shelf.

Table 7: Benefit Table

	Shelf 1			Shelf 2			Shelf 3		
	Shelf Position			Shelf Position			Shelf Position		
Lot i	1	2	3	1	2	3	1	2	3
1	850	950	1050	1050	1150	1250	1250	1450	1550
2	1600	1700	1800	1800	1900	2000	2000	2100	2300
3	2200	2200	2250	2250	2300	2400	2400	2600	2800
4	800	900	1000	1000	1100	1200	1200	1400	1500
5	900	1000	1100	1100	1200	1300	1300	1500	1600
6	378	399	420	420	441	462	462	483	504
7	1800	1900	2000	2000	2200	2200	2200	2400	2500
8	2106	2223	2340	2340	2457	2574	2574	2691	2808
9	1400	1500	1600	1600	1700	1800	1800	1900	2100
10	1100	1200	1300	1300	1400	1500	1500	1600	1800
11	1700	1800	1900	1900	2000	2100	2100	2300	2400
12	1000	1100	1200	1200	1300	1400	1400	1500	1700
13	1050	1150	1250	1250	1350	1450	1450	1550	1750
14	1950	2150	2250	2250	2400	2500	2500	2700	2800
15	2000	2100	2200	2350	2600	2650	2600	2600	2700
16	1500	1600	1700	1700	1800	1900	1900	2000	2200
17	1450	1550	1650	1650	1750	1850	1850	2050	2150
18	1750	1850	1950	1950	2050	2150	2150	2350	2450
19	1200	1300	1400	1400	1500	1600	1600	1700	1900

20	700	800	900	900	1000	1100	1100	1300	1400
21	1950	2130	2330	2450	2650	2600	2550	2550	2600
22	1900	2100	2300	2500	2500	2600	2600	2800	2750
23	1550	1650	1750	1750	1850	1950	1950	2150	2250
24	1650	1750	1850	1850	1950	2050	2050	2250	2350
25	1300	1400	1500	1500	1600	1700	1700	1800	2000

	Shelf 4			Shelf 5			Shelf 6		
	Shelf Position			Shelf Position			Shelf Position		
Lot i	1	2	3	1	2	3	1	2	3
1	1250	1450	1550	1050	1150	1250	850	950	1050
2	2000	2200	2300	2800	1900	2000	1600	1700	1800
3	2400	2600	2800	2250	2300	2400	2200	2200	2250
4	1200	1400	1500	1000	1100	1200	800	900	1000
5	1300	1500	1600	1100	1200	1300	900	1000	1100
6	462	483	504	420	441	462	378	399	420
7	2200	2400	2500	2000	2100	2200	1800	1900	2000
8	2574	2691	2808	2340	2457	2574	2106	2223	2340
9	1800	2000	2100	1600	1700	1800	1400	1500	1600
10	1500	1600	1800	1300	1400	1500	1100	1200	1300
11	2100	2300	2400	1900	2000	2100	1700	1800	1900
12	1400	1500	1700	1200	1300	1400	1000	1100	1200
13	1450	1550	1750	1250	1350	1450	1050	1150	1250
14	2500	2700	2800	2250	2400	2500	1950	2150	2250
15	2400	2600	2700	2200	2300	2400	2000	2100	2200
16	1900	2100	2200	1900	1800	1900	1500	1600	1700
17	1850	2050	2150	1650	1750	1850	1450	1550	1650
18	2150	2350	2450	1950	2050	2150	1750	1850	1950
19	1600	1700	1900	1400	1500	1600	1200	1300	1400
20	1100	1300	1400	900	1000	1100	700	800	900
21	2600	2700	2700	2500	2600	2600	2400	2100	2100
22	2600	2800	2750	2300	2500	2260	1900	2100	2300
23	1950	2150	2250	1750	1850	1950	1550	1650	1750
24	2050	2250	2350	1850	1950	2050	1650	1750	1850
25	1700	1800	2000	1500	1600	1700	1300	1400	1500

Experimental results are as follows. The expression Eq. (8) is complicated. Therefore we use expression by Eq. (13). A sample set of initial population is exhibited in Table 8.

Table 8: A Sample Set of Initial Populatio

$Y_1 =$	(18	10	13	20	5	20	21	2	8	9	23	2	21	22	17	23	22	14)
$Y_2 =$	(14	13	11	2	9	22	18	12	10	25	22	16	4	5	25	13	12	1)
$Y_3 =$	(15	4	18	13	11	3	23	19	9	15	10	13	20	17	20	25	15	17)
					⋮													
$Y_{98} =$	(7	17	13	13	15	17	18	1	24	15	21	23	18	20	9	15	10	23)
$Y_{99} =$	(25	19	4	20	16	20	6	18	5	5	15	19	19	18	22	9	13	13)
$Y_{100} =$	(2	25	6	21	7	19	2	8	11	8	20	9	13	6	13	14	19	7)

The problem is simple, so combination of genotype for crossover saturates in the 143th generation. Genotype in which objective function becomes maximum is as follows.

$$Y = (\ 3,\ 8,\ 8,\ 8,\ 21,\ 21,\ 22,\ 22,\ 3,\ 21,\ 22,\ 8,\ 21,\ 21,\ 8,\ 21,\ 3,\ 8\ )$$

This coincides with the result of optimal solution by the calculation of all considerable cases, therefore it coincides with a theoretical optimal solution. We take up simple problem and we can confirm the effectiveness of GA approach. Further study for complex problems should be examined hereafter.

5. REMARKS

As there are few papers made on this theme, we constructed prototype version before (Takeyasu et al.,2008). In this paper, we examined the problem that allowed goods to be allocated in multiple shelves and introduced the concept of sales profits and sales probabilities. An application to the shop with POS sales data was executed. We can see that genetic algorithm is effective for this problem.

In practice, following themes occur.

1. Sales probabilities should be arranged correctly.
2. There are various types of shelves corresponding to goods characteristics (For example, cold storage goods).
3. Furthermore, genotype must be devised in construction when there are huge number of goods and shelves.

For these issues, expanded version of the paper will be built hereafter consecutively. As for 1, constraints are relaxed than those of this paper. As for 2, expansion is easy to make. As for 3, constructing genotype from the shelf side would bear much more simple expression.

6. CONCLUSION

How to allocate goods in shop shelves makes great influence to sales amount. Searching best fit allocation of goods to shelves is a kind of combinatorial problem. This becomes a problem of integer programming and utilizing genetic algorithm may be an effective method. Reviewing past researches, there were few researches made on this. Formerly, we had presented papers concerning optimization in allocating goods to shop shelves utilizing genetic algorithm. In those papers, the problem that goods were not allowed to allocate in multiple shelves and the problem that goods were allowed to allocate in multiple shelves were pursued. In this paper, we examined the problem that allowed goods to be allocated in multiple shelves and introduced the concept of sales profits and sales probabilities. Optimization in allocating goods to shop shelves was investigated. An application to the shop with POS sales data was executed. Utilizing genetic algorithm, optimum solution was pursued and verified by a numerical example. Various patterns of problems should be examined hereafter.

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A Hybrid Method to Improve Forecasting Accuracy in the Case of the Processed Cooked Rice

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Abstract - In industries, how to improve forecasting accuracy such as sales, shipping is an important issue. There are many researches made on this. In this paper, a hybrid method is introduced and plural methods are compared. Focusing that the equation of exponential smoothing method(ESM) is equivalent to (1,1) order ARMA model equation, a new method of estimation of smoothing constant in exponential smoothing method is proposed before by us which satisfies minimum variance of forecasting error. Generally, smoothing constant is selected arbitrarily. But in this paper, we utilize the above stated theoretical solution. Firstly, we make estimation of ARMA model parameter and then estimate the smoothing constant. Thus theoretical solution is derived in a simple way and it may be utilized in various fields. Furthermore, combining the trend removing method with this method, we aim to improve forecasting accuracy. An approach to this method is executed in the following method. Trend removing by the combination of linear and 2nd order non-linear function and 3rd order non-linear function is executed to the original production data of two kinds of bread. Genetic Algorithm is utilized to search the optimal weight for the weighting parameters of linear and non-linear function. For the comparison, monthly trend is removed after that. Theoretical solution of smoothing constant of ESM is calculated for both of the monthly trend removing data and the non monthly trend removing data. Then forecasting is executed on these data. The new method shows that it is useful for the time series that has various trend characteristics and has rather strong seasonal trend. The effectiveness of this method should be examined in various cases.

Keywords: minimum variance, exponential smoothing method, forecasting, trend, bread

1. INTRODUCTION

Many methods for time series analysis have been presented such as Autoregressive model (AR Model), Autoregressive Moving Average Model (ARMA Model) and Exponential Smoothing Method (ESM)[1]−[4]. Among these, ESM is said to be a practical simple method.

For this method, various improving method such as adding compensating item for time lag, coping with the time series with trend[5], utilizing Kalman Filter[6], Bayes Forecasting[7], adaptive ESM[8], exponentially weighted Moving Averages with irregular updating periods [9], making averages of forecasts using plural method [10] are presented. For example, Maeda[6] calculated smoothing constant in relationship with S/N ratio under the assumption that the observation noise was added to the system. But he had to calculate under supposed noise because he could not grasp observation noise. It can be said that it doesn't pursue optimum solution from the very data themselves which should be derived by those estimation. Ishii[11] pointed out that the optimal smoothing constant was the solution of infinite order equation, but he didn't show analytical solution. There are some papers utilizing Neural Network. Miki (1996) [14] generated time series data by non-linear system. But it is a stationary one and do not have significant trend. Ogasawara et al. (2009) [15] utilized Hybrid Neural Network for prediction. It searches neural neighbors which has a similar typed data and utilize them as a forecast. But it needs huge data. Therefore it cannot be used in the case we are trying to make forecast in which we handle monthly data. Tkakaho et al. (2002) [16] used pre data handling such as low/high pass filter. It may be a kind of trend removing. Based on these facts, we proposed a new method of estimation of smoothing constant in ESM before[13]. Focusing that the equation of ESM is equivalent to (1,1) order

ARMA model equation, a new method of estimation of smoothing constant in ESM was derived.

In this paper, utilizing above stated method, a revised forecasting method is proposed. In making forecast such as production data, trend removing method is devised. Trend removing by the combination of linear and 2nd order non-linear function and 3rd order non-linear function is executed to the original production data of two kinds of bread. Genetic Algorithm (GA) is utilized to search the optimal weight for the weighting parameters of linear and non-linear function. For the comparison, monthly trend is removed after that. Theoretical solution of smoothing constant of ESM is calculated for both of the monthly trend removing data and the non-monthly trend removing data. Then forecasting is executed on these data. This is a revised forecasting method. Trend removal and GA are not used in [13]. Variance of forecasting error of this newly proposed method is assumed to be less than those of the previously proposed method. The rest of the paper is organized as follows. In section 2, ESM is stated by ARMA model and estimation method of smoothing constant is derived using ARMA model identification. The combination of linear and non-linear function is introduced for trend removing in section 3. The Monthly Ratio is referred in section 4. Forecasting is executed in section 5, and estimation accuracy is examined.

2. DESCRIPTION OF ESM USING ARMA MODEL

In ESM, forecasting at time $t+1$ is stated in the following equation.

$$\hat{x}_{t+1} = \hat{x}_t + \alpha(x_t - \hat{x}_t) \tag{1}$$

$$= \alpha x_t + (1-\alpha)\hat{x}_t \tag{2}$$

Here,

$\hat{x}_{t+1}$: forecasting at $t+1$

x_t : realized value at t

α : smoothing constant $(0 < \alpha < 1)$

(2) is re-stated as

$$\hat{x}_{t+1} = \sum_{l=0}^{\infty} \alpha(1-\alpha)^l x_{t-l} \tag{3}$$

By the way, we consider the following (1,1) order ARMA mo del.

$$x_t - x_{t-1} = e_t - \beta e_{t-1} \tag{4}$$

Generally, (p,q) order ARMA model is stated as

$$x_t + \sum_{i=1}^{p} a_i x_{t-i} = e_t + \sum_{j=1}^{q} b_j e_{t-j} \tag{5}$$

Here,

$\{x_t\}$: Sample process of Stationary Ergodic Gaussian Process $x(t)$ $t = 1,2,\cdots,N,\cdots$

$\{e_t\}$: Gaussian White Noise with 0 mean σ_e^2 variance

MA process in (5) is supposed to satisfy the convertibility condition. Utilizing the relation that

$$E[e_t | e_{t-1}, e_{t-2}, \cdots] = 0$$

we get the following equation from (4).

$$\hat{x}_t = x_{t-1} - \beta e_{t-1} \tag{6}$$

Operating this scheme on $t+1$, we finally get

$$\begin{aligned} \hat{x}_{t+1} &= \hat{x}_t + (1-\beta)e_t \\ &= \hat{x}_t + (1-\beta)(x_t - \hat{x}_t) \end{aligned} \tag{7}$$

If we set $1-\beta = \alpha$, the above equation is the same with (1), i.e., equation of ESM is equivalent to (1,1) order ARMA model, or is said to be (0,1,1) order ARIMA model because 1st order AR parameter is -1. Comparing with (4) and (5), we obtain

$$\begin{cases} a_1 = -1 \\ b_1 = -\beta \end{cases}$$

From (1), (7),

$$\alpha = 1 - \beta$$

Therefore, we get

$$\begin{cases} a_1 = -1 \\ b_1 = -\beta = \alpha - 1 \end{cases} \tag{8}$$

From above, we can get the estimation of smoothing constant after we identify the parameter of MA part of ARMA model. But, generally MA part of ARMA model become non-linear equations which are described below.

Let (5) be

$$\tilde{x}_t = x_t + \sum_{i=1}^{p} a_i x_{t-i} \tag{9}$$

$$\tilde{x}_t = e_t + \sum_{j=1}^{q} b_j e_{t-j} \tag{10}$$

We express the autocorrelation function of $\tilde{x}_t$ as $\tilde{r}_k$ and from (9), (10), we get the following non-linear equations which

are well known.

$$\left\{\begin{array}{ll} \tilde{r}_k = \sigma_e^2 \sum_{j=0}^{q-k} b_j b_{k+j} & (k \le q) \\ 0 & (k \ge q+1) \\ \tilde{r}_0 = \sigma_e^2 \sum_{j=0}^{q} b_j^2 & \end{array}\right\} \quad (11)$$

For these equations, recursive algorithm has been developed. In this paper, parameter to be estimated is only b_1, so it can be solved in the following way.
From (4) (5) (8) (11), we get

$$\left.\begin{array}{l} q = 1 \\ a_1 = -1 \\ b_1 = -\beta = \alpha - 1 \\ \tilde{r}_0 = \left(1 + b_1^2\right)\sigma_e^2 \\ \tilde{r}_1 = b_1 \sigma_e^2 \end{array}\right\} \quad (12)$$

If we set

$$\rho_k = \frac{\tilde{r}_k}{\tilde{r}_0} \quad (13)$$

the following equation is derived.

$$\rho_1 = \frac{b_1}{1 + b_1^2} \quad (14)$$

We can get b_1 as follows.

$$b_1 = \frac{1 \pm \sqrt{1 - 4\rho_1^2}}{2\rho_1} \quad (15)$$

In order to have real roots, ρ_1 must satisfy

$$|\rho_1| \le \frac{1}{2} \quad (16)$$

From the invertibility condition, b_1 must satisfy

$$|b_1| < 1$$

From (14), using the next relation,

$$(1 - b_1)^2 \ge 0$$
$$(1 + b_1)^2 \ge 0$$

(16) always holds.
As

$$\alpha = b_1 + 1$$

b_1 is within the range of

$$-1 < b_1 < 0$$

Finally we get

$$\left.\begin{array}{l} b_1 = \dfrac{1 - \sqrt{1 - 4\rho_1^2}}{2\rho_1} \\ \alpha = \dfrac{1 + 2\rho_1 - \sqrt{1 - 4\rho_1^2}}{2\rho_1} \end{array}\right\} \quad (17)$$

which satisfy above condition. Thus we can obtain a theoretical solution by a simple way. Focusing on the idea that the equation of ESM is equivalent to (1,1) order ARMA model equation, we can estimate the smoothing constant after estimating ARMA model parameter. It can be estimated only by calculating 0th and 1st order autocorrelation function.

3. TREND REMOVAL METHOD

As trend removal method, we describe the combination of linear and non-linear function.

[1] Linear function
We set

$$y = a_1 x + b_1 \quad (18)$$

as a linear function.

[2] Non-linear function
We set

$$y = a_2 x^2 + b_2 x + c_2 \quad (19)$$

$$y = a_3 x^3 + b_3 x^2 + c_3 x + d_3 \quad (20)$$

as a 2nd and a 3rd order non-linear function. (a_2, b_2, c_2) and (a_3, b_3, c_3, d_3) are also parameters for a 2nd and a 3rd order non-linear functions which are estimated by using least square method.

[3] The combination of linear and non-linear function
We set

$$y = \alpha_1(a_1x + b_1) + \alpha_2(a_2x^2 + b_2x + c_2) + \alpha_3(a_3x^3 + b_3x^2 + c_3x + d_3) \quad (21)$$

$$0 \le \alpha_1 \le 1, 0 \le \alpha_2 \le 1, 0 \le \alpha_3 \le 1, \alpha_1 + \alpha_2 + \alpha_3 = 1 \quad (22)$$

as the combination linear and 2nd order non-linear and 3rd order non-linear function. Trend is removed by dividing the original data by (21). The optimal weighting parameter $\alpha_1, \alpha_2, \alpha_3$,are determined by utilizing GA. GA method is precisely described in section 6.

4. MONTHLY RATIO

For example, if there is the monthly data of L years as stated bellow:

$$\{x_{ij}\} \ (i = 1, \cdots, L) \ (j = 1, \cdots, 12)$$

Where, $x_{ij} \in R$ in which j means month and i means year and x_{ij} is a production data of i -th year, j -th month. Then, monthly ratio $\tilde{x}_j$ $(j = 1, \cdots, 12)$ is calculated as follows.

$$\tilde{x}_j = \frac{\frac{1}{L}\sum_{i=1}^{L} x_{ij}}{\frac{1}{L} \cdot \frac{1}{12}\sum_{i=1}^{L}\sum_{j=1}^{12} x_{ij}} \quad (23)$$

Monthly trend is removed by dividing the data by (23). Numerical examples both of the monthly trend removal case and the non-removal case are discussed in 7.

5. FORECASTING ACCURACY

Forecasting accuracy is measured by calculating the variance of the forecasting error. Variance of the forecasting error is calculated by:

$$\sigma_\varepsilon^2 = \frac{1}{N-1}\sum_{i=1}^{N}(\varepsilon_i - \bar{\varepsilon})^2 \quad (24)$$

Where, the forecasting error is expressed as:

$$\varepsilon_i = \hat{x}_i - x_i \quad (25)$$

$$\bar{\varepsilon} = \frac{1}{N}\sum_{i=1}^{N}\varepsilon_i \quad (26)$$

6. SEARCHING OPTIMAL WEIGHTS UTILIZING GA

6.1 Definition of the problem

We search $\alpha_1, \alpha_2, \alpha_3$ of (21) which minimizes (24) by utilizing GA. By (22), we only have to determine α_1 and α_2. ${\sigma_\varepsilon}^2$ ((24)) is a function of α_1 and α_2, therefore we express them as $\sigma_\varepsilon^2(\alpha_1, \alpha_2)$. Now, we pursue the following:

$$\text{Minimize: } \sigma_\varepsilon^2(\alpha_1, \alpha_2)$$
$$\text{subject to: } 0 \le \alpha_1 \le 1, 0 \le \alpha_2 \le 1, \alpha_1 + \alpha_2 \le 1 \quad (27)$$

We do not necessarily have to utilize GA for this problem which has small member of variables. Considering the possibility that variables increase when we use logistics curve etc. in the near future, we want to ascertain the effectiveness of GA.

6.2 The structure of the gene

Gene is expressed by the binary system using {0,1} bit. Domain of variable is [0,1] from (22). We suppose that variables take down to the second decimal place. As the length of domain of variable is 1-0=1, seven bits are required to express variables. The decimal number, the binary number and the corresponding real number in the case of 7 bits are expressed in Table 6-1.

Table 6-1: Corresponding table of the decimal number, the binary number and the real number

The decimal number	The binary number							The Corresponding real number
	Position of the bit							
	6	5	4	3	2	1	0	
0	0	0	0	0	0	0	0	0.00
1	0	0	0	0	0	0	1	0.01
2	0	0	0	0	0	1	0	0.02
3	0	0	0	0	0	1	1	0.02
4	0	0	0	0	1	0	0	0.03
5	0	0	0	0	1	0	1	0.04
6	0	0	0	0	1	1	0	0.05
7	0	0	0	0	1	1	1	0.06

8	0	0	0	1	0	0	0	0.06
…								…
126	1	1	1	1	1	1	0	0.99
127	1	1	1	1	1	1	1	1.00

1 variable is expressed by 7 bits, therefore 2 variables needs 14 bits. The gene structure is exhibited in Table 6-2.

Table 6-2: The gene structure

α_1							α_2						
Position of the bit													
13	12	11	10	9	8	7	6	5	4	3	2	1	0
0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1

6.3 The flow of Algorithm

The flow of algorithm is exhibited in Figure 6-1.

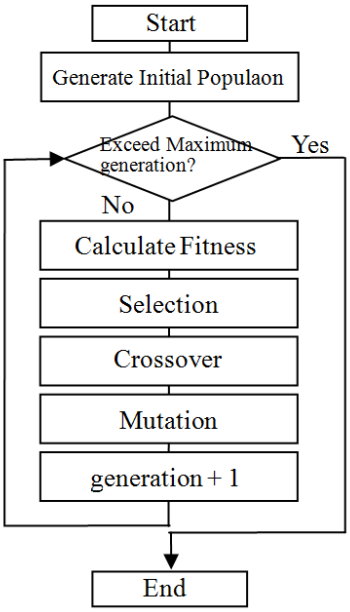


Figure 6-1: The flow of algorithm

A. Initial Population

Generate M initial population. Here, $M = 100$. Generate each individual so as to satisfy (22).

B. Calculation of Fitness

First of all, calculate the forecasting value. There are 36 monthly data for each case. We use 24 data(1st to 24th) and remove trend by the method stated in section 3. Then we calculate monthly ratio by the method stated in section 4. After removing monthly trend, the method stated in section 2 is applied and Exponential Smoothing Constant with minimum variance of the forecasting error is estimated. Then 1 step forecast is executed. Thus, data is shifted to 2nd to 25th and the forecast for 26th data is executed consecutively, which finally reaches forecast of 36th data. To examine the accuracy of forecasting, variance of the forecasting error is calculated for the data of 25th to 36th data. Final forecasting data is obtained by multiplying monthly ratio and trend. Variance of the forecasting error is calculated by (24). Calculation of fitness is exhibited in Figure 6-2.

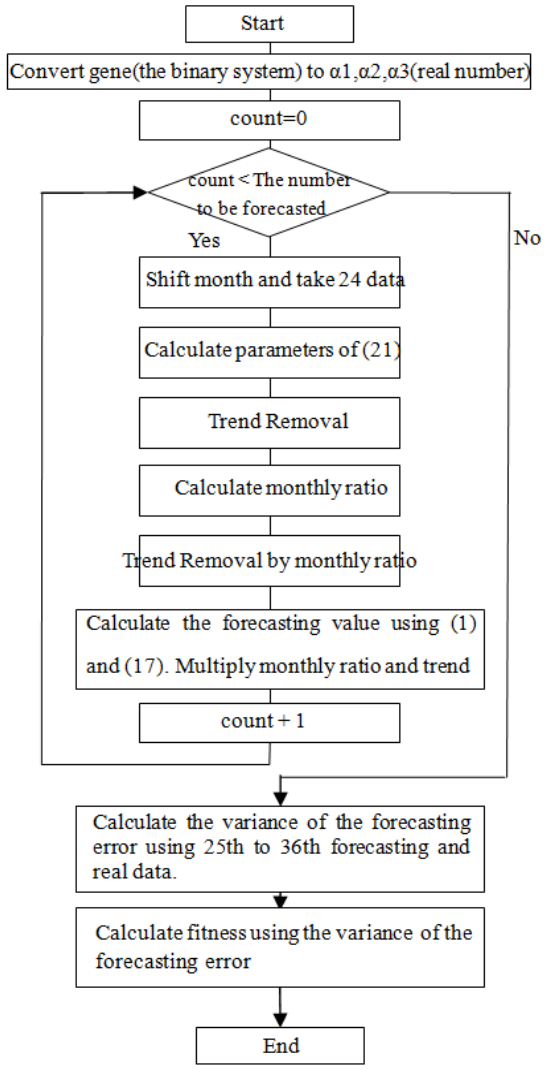


Figure 6-2:The flow of calculation of fitness

Scaling[15] is executed such that fitness becomes large when the variance of forecasting error becomes small. Fitness is defined as follows.

$$f(\alpha_1,\alpha_2)=U-\sigma_\varepsilon^{\ 2}(\alpha_1,\alpha_2) \tag{30}$$

Where U is the maximum of $\sigma_\varepsilon^{\ 2}(\alpha_1,\alpha_2)$ during the past W generation. Here, W is set to be 5.

C. Selection

Selection is executed by the combination of the general elitist selection and the tournament selection. Elitism is executed until the number of new elites reaches the predetermined number. After that, tournament selection is executed and selected.

D. Crossover

Crossover is executed by the uniform crossover. Crossover rate is set as follows.

$$P_c=0.7 \tag{31}$$

E. Mutation

Mutation rate is set as follows.

$$P_m=0.05 \tag{32}$$

Mutation is executed to each bit at the probability P_m, therefore all mutated bits in the population M becomes $P_m \times M \times 14$.

We have examined one point crossover, two points of crossover and uniform crossover and found that unifo rm crossover was best in convergence. Therefore we too k uniform crossover in this case. We have varied mutati on rate and found that this value was best in performan ce [17].

7. NUMERICAL EXAMPLE

7.1 Application to the original production data of pro cessed cooked rice

The original production data of processed cooked rice for 2 cases (Data of Chilled Cooked Rice and those of Frozen Cooked Rice: Annual Report of Statistical Research, Ministry of Agriculture, Forestry and Fisheries, Japan) from January 2008 to December 2010 are analyzed. Furthermore, GA results are compared with the calculation results of all considerable cases in order to confirm the effectiveness of GA approach. First of all, graphical charts of these time series data are exhibited in Figure 7-1, 7-2.

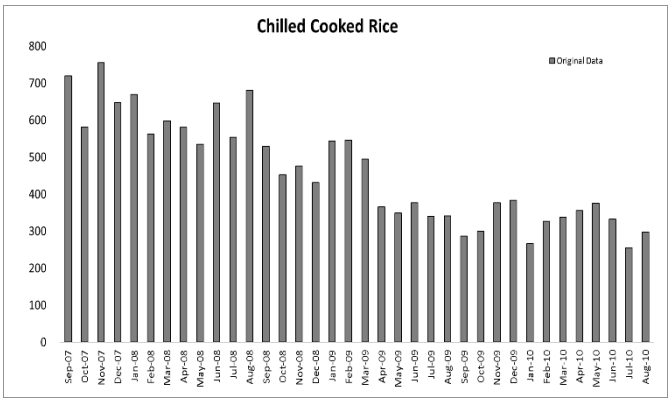


Figure 7-1: Data of Chilled Cooked Rice

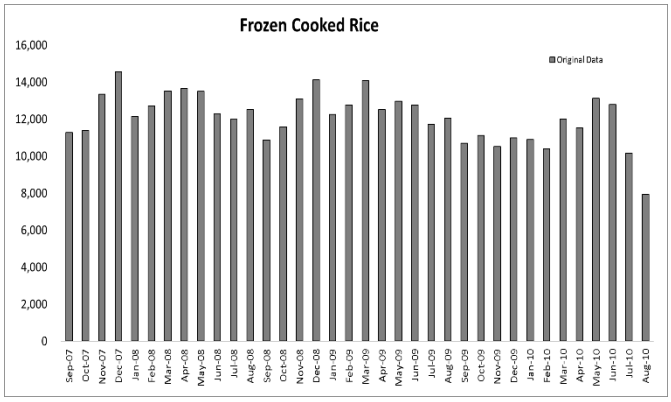


Figure 7-2: Data of Frozen Cooked Rice

7.2 Execution Results

GA execution condition is exhibited in Table 7-1.

Table7-1: GA Execution Condition

GA Execution Condition	
Population	100
Maximum Generation	50
Crossover rate	0.7
Mutation ratio	0.05
Scaling window size	5
The number of elites to retain	2
Tournament size	2

We made 10 times repetition and the maximum, average, minimum of the variance of the forecasting error and the average of convergence generation are exhibited in Table 7-2 and 7-3.

Table7-2: GA execution results(Monthly ratio is not used)

Food No	The variance of the forecasting error			Average of convergence generation
	Maximum	Average	Minimum	
Chilled Cooked Rice	3,138.70168	3,138.70168	3,138.70168	8.9
Frozen Cooked Rice	1,893,350.37	1,893,350.37	1,893,350.37	13.1

Table7-3: GA execution results(Monthly ratio is used)

Food No	The variance of the forecasting error			Average of convergence generation
	Maximum	Average	Minimum	
Chilled Cooked Rice	4,026.15041	4,026.15041	4,026.15041	9.5
Frozen Cooked Rice	1,640,686.337	1,640,686.337	1,640,686.337	12.2

The case monthly ratio is not used is smaller than the case monthly ratio is used concerning the variance of forecasting error for Frozen Cooked Rice. It may be because Frozen Cooked Rice does not have definite seasonal trend in general.

The minimum variance of forecasting error of GA coincides with those of the calculation of all considerable cases and it shows the theoretical solution. Although it is a rather simple problem for GA, we can confirm the effectiveness of GA approach. Further study for complex problems should be examined hereafter.

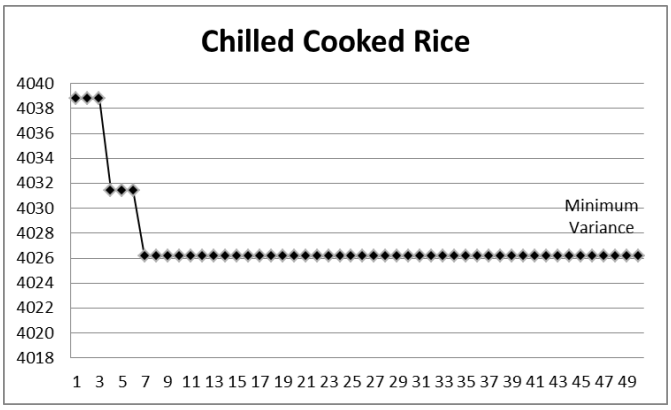
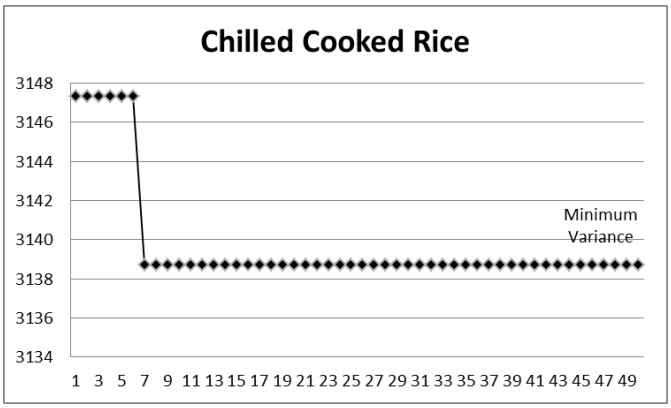


Figure7-3: Convergence Process in the case of Chilled Cooked Rice (Monthly ratio is not used)



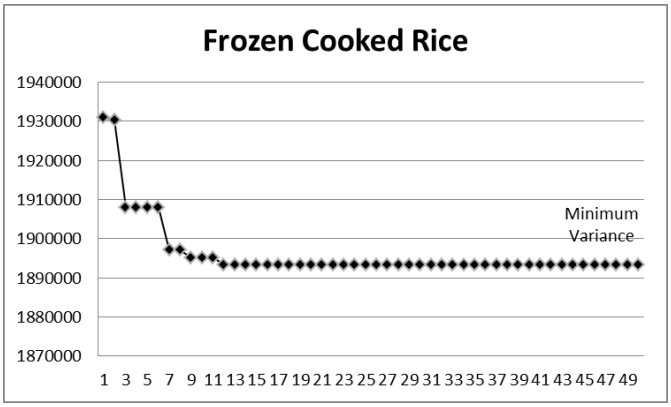


Figure7-5: Convergence Process in the case of Frozen Cooked Rice (Monthly ratio is not used)

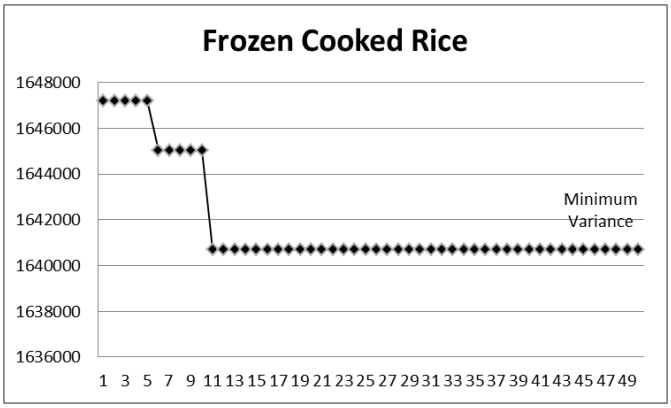


Figure7-6: Convergence Process in the case of Frozen Cooked Rice (Monthly ratio is used)

Next, optimal weights and their genes are exhibited in Table 7-4,7-5.

Table7-4: Optimal weights and their genes (Monthly ratio is not used)

Data	α_1	α_2	position of the bit													
			13	12	11	10	9	8	7	6	5	4	3	2	1	0
Chilled Cooked Rice	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
Frozen Cooked Rice	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0

Table7-5: Optimal weights and their genes (Monthly ratio is used)

Data	α_1	α_2	position of the bit													
			13	12	11	10	9	8	7	6	5	4	3	2	1	0
Chilled Cooked Rice	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
Frozen Cooked Rice	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0

In the case monthly ratio is not used, the linear function model is best in both cases. In the case monthly ratio is us ed, the linear function model is best in both cases. Parameter estimation results for the trend of equation (21) using le ast square method are exhibited in Table 7-6 for the case of 1st to 24th data.

Table7-6: Parameter estimation results for the trend of equation (21)

Data	a_1	b_1	a_2	b_2	c_2	a_3	b_3	c_3	d_3
Chilled Cooked Rice	-14.96	718.93	-0.33	-6.72	683.21	-0.03	0.80	-18.22	709.60
Frozen Cooked Rice	-1.79	12671.35	-4.11	101.05	12225.71	0.40	-19.11	254.09	11874.78

Trend curves are exhibited in Figure 7-7 and 7-8.

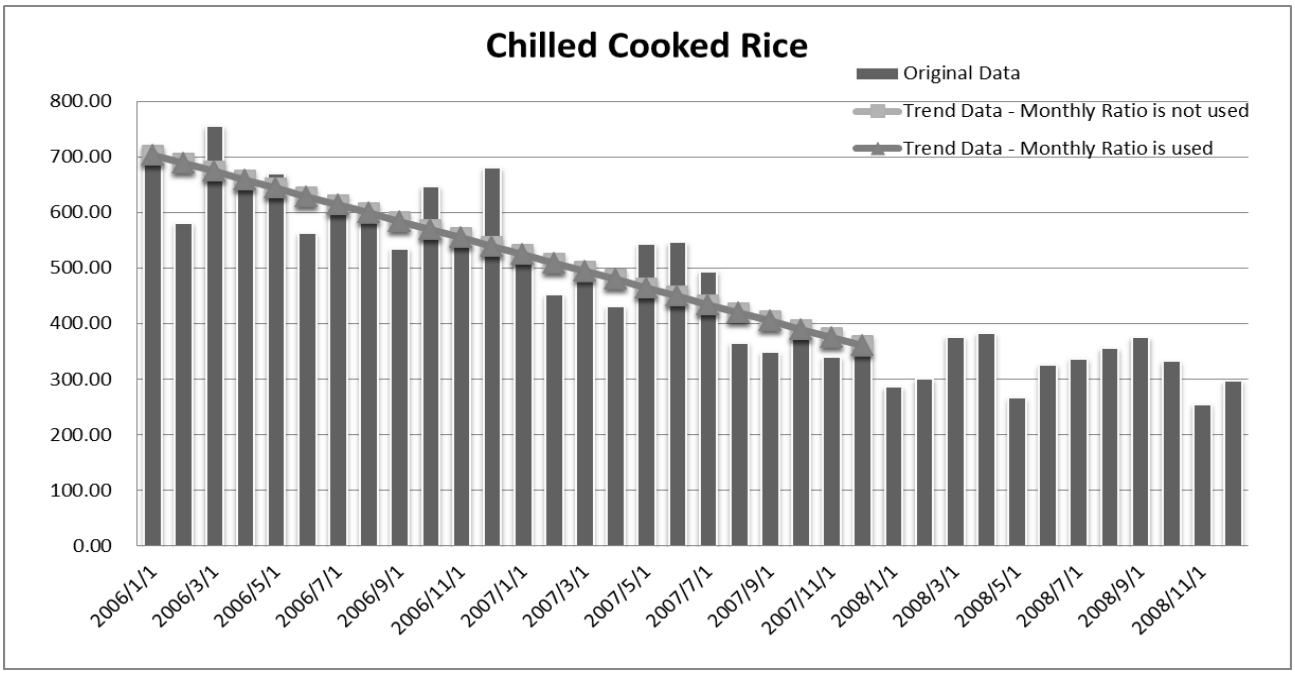


Figure7-7:Trend of Chilled Cooked Rice

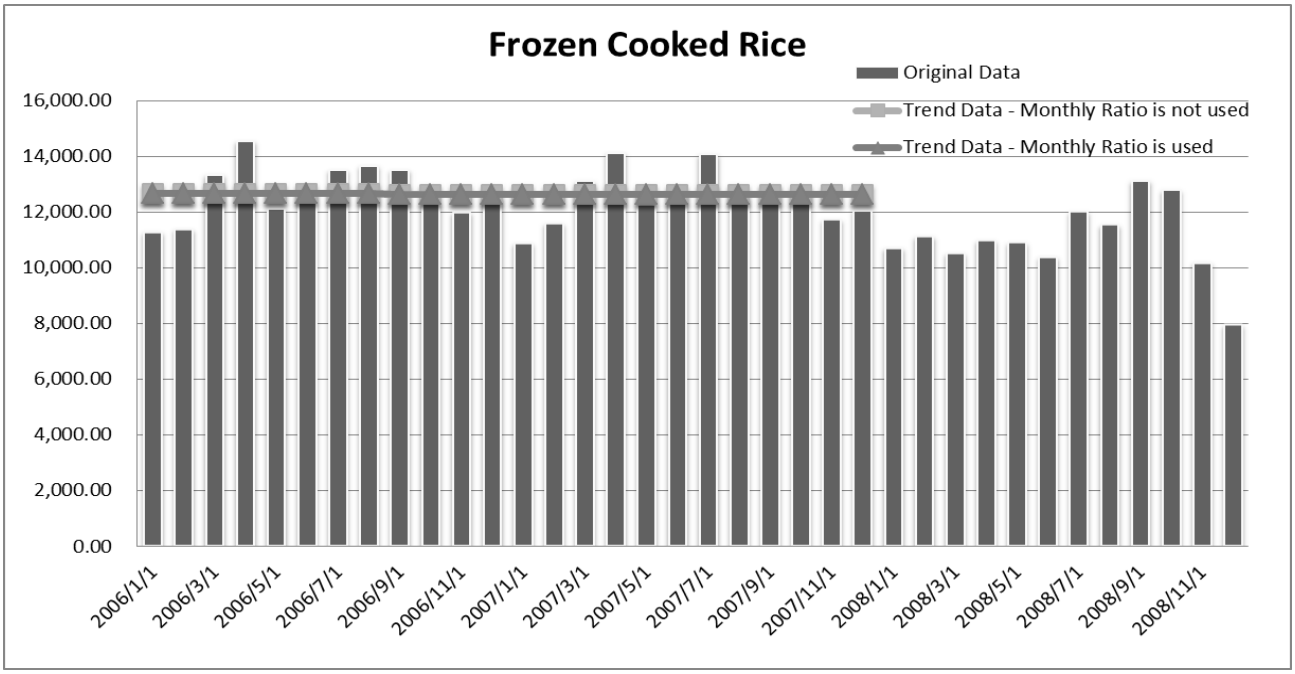


Figure7-8:Trend of Frozen Cooked Rice

Calculation results of Monthly ratio for 1st to 24th data are exhibited in Table 7-7.

Table7-7: Parameter Estimation result of Monthly ratio

Date.	1	2	3	4	5	6	7	8	9	10	11	12
Chilled Cooked Rice	1.02	0.87	1.04	0.94	1.10	1.05	1.06	0.92	0.89	1.05	0.95	1.11
Frozen Cooked Rice	0.87	0.91	1.04	1.13	0.96	1.01	1.09	1.03	1.05	0.99	0.94	0.97

Estimation result of the smoothing constant of minimum variance for the 1st to 24th data are exhibited in Table 7-8 and 7-9.

Table 7-8:Smoothing constant of Minimum Variance of equation (17) (Monthly ratio is not used)

Date	ρ1	α
Chilled Cooked Rice	-0.429544	0.431757
Frozen Cooked Rice	-0.179138	0.814712

Forecasting results are exhibited in Table 7-9 and 7-10.

Table 7-9:Smoothing constant of Minimum Variance of equation (17) (Monthly ratio is used)

Date,	ρ1	α
Chilled Cooked Rice	-0.118693	0.879586
Frozen Cooked Rice	-0.179721	0.814066

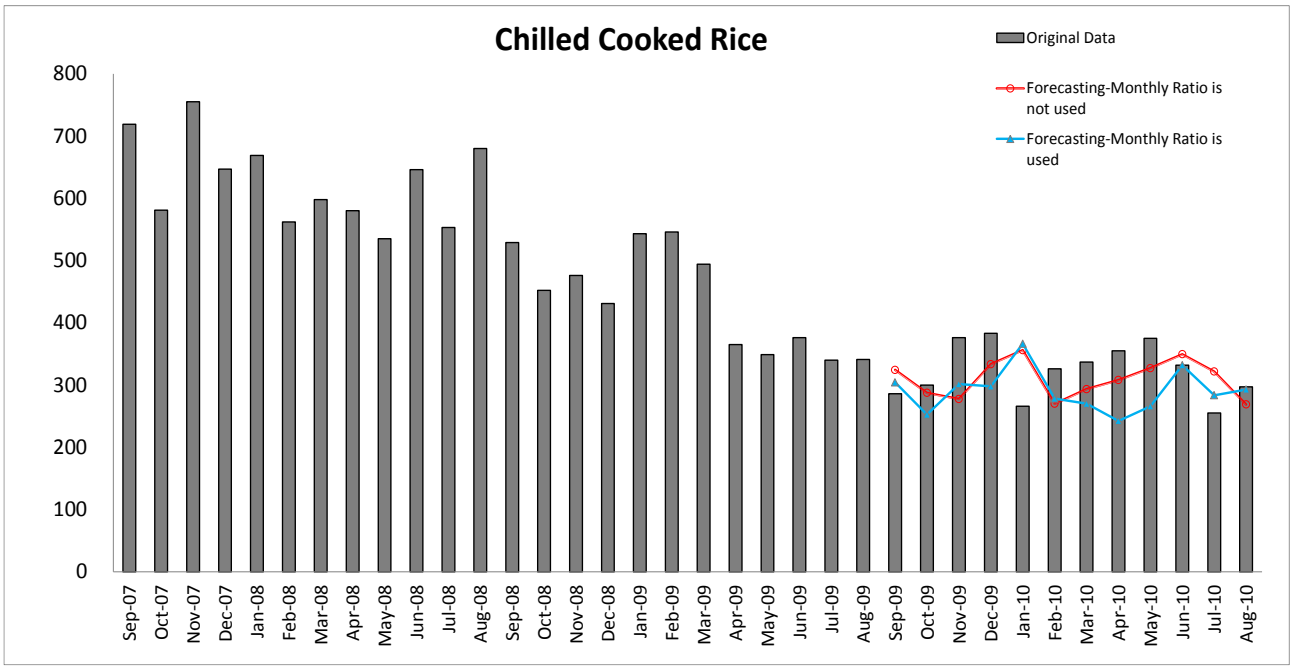


Figure 7-9: Forecasting Result of Chilled Cooked Rice

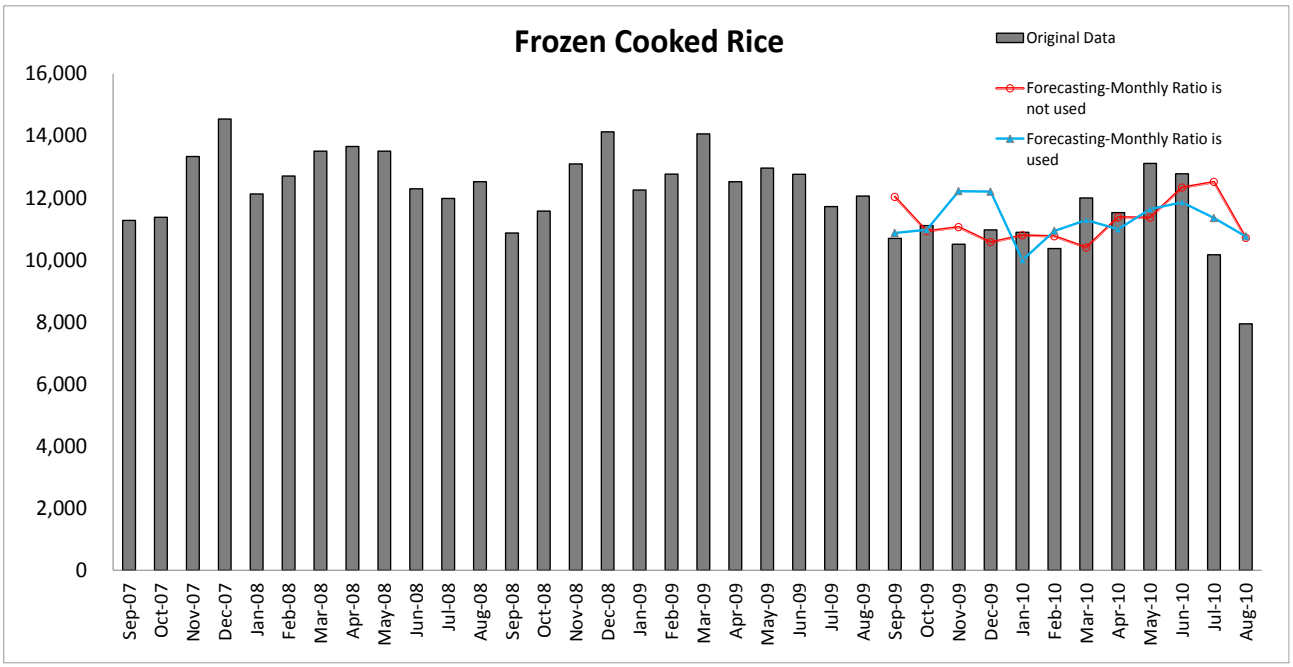


Figure 7-10: Forecasting Result of Frozen Cooked Rice

7.3 Remarks

In the case of Chilled Cooked Rice, that monthly ratio was not used had a better forecasting accuracy. On the other hand, Frozen Cooked Rice had a better forecasting accuracy in the case monthly ratio was used. Both cases had a good result in the linear function model.

The minimum variance of forecasting error of GA coincides with those of the calculation of all considerable cases and it shows the theoretical solution. Although it is a rather simple problem for GA, we can confirm the effectiveness of GA approach. Further study for complex problems should be examined hereafter.

8. CONCLUSION

Focusing on the idea that the equation of exponential smoothing method(ESM) was equivalent to (1,1) order ARMA model equation, a new method of estimation of smoothing constant in exponential smoothing method was proposed before by us which satisfied minimum variance of forecasting error. Generally, smoothing constant was selected arbitrarily. But in this paper, we utilized the above stated theoretical solution. Firstly, we made estimation of ARMA model parameter and then estimated the smoothing constant. Thus theoretical solution was derived in a simple way and it might be utilized in various fields.

Furthermore, combining the trend removal method with this method, we aimed to improve forecasting accuracy. An approach to this method was executed in the following method. Trend removal by a linear function was applied to the original production data of processed cooked rice. The combination of linear and non-linear function was also introduced in trend removal. Genetic Algorithm was utilized to search the optimal weight for the weighting parameters of linear and non-linear function. For the comparison, monthly trend was removed after that. Theoretical solution of smoothing constant of ESM was calculated for both of the monthly trend removing data and the non monthly trend removing data. Then forecasting was executed on these data. The new method shows that it is useful for the time series that has various trend characteristics. The effectiveness of this method should be examined in various cases.

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Research on Petri Nets Model of Concept Design

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Abstract

Function Analysis is an important step in the process of Product Conceptual Design. In the past, the expression of Function Analysis was captured in the form of voluminous text descriptions. In order to lead this expression to the process of computerization, the following works have been done. Firstly, we analyzed the existing Petri nets model of functional structure of mechanical and electrical products. Secondly, we bring in the knowledge of fuzzy Petri nets following by the knowledge of function tree, and we established a function model based on Petri nets. Thirdly, we have given out the definition of the model, description of behavior as well as the basic steps of establishing this model. Fourthly, based on the established model and object-oriented technology, we have given the expression model of technical contradictions. At last, we took the fabric printing and dyeing equipment for example, then we established the Petri nets function model and the technical contradictions expression model, which verify the feasibility of these models.

Keywords: concept design, fuzzy Petri nets, Petri nets function model, technical contradictions expression model

1. Introduction

Conceptual design is the key point to the process of product design, and it is a design process for function. The basic task for concept design is to define the principle solutions that satisfy the requirements. Therefore, the analysis of the function is an indispensable part of design. For function analysis, establishing a relevant model brings intuitive convenience for the analysis. Function model is a description of the product or the process. According to this description, the combination of the basic functions can meet the demands of the overall function or the final purpose (Runhua Tan, 2010).

The definition of Petri nets is first introduced by Dr. Carl A. Petri in 1962 in his doctoral dissertation. It is used to describe the causal relationship between events in a computer system. With constant enrichment and development, it has been widely used in the field of computer, automation, communication, transportation, electricity and electronics, services and manufacturing, etc (Chongyi

Yuan, 1998). In terms of Petri nets modeling, Claude Girault described the technique of establishment and analysis of Petri nets based on the performance of a machine (Claude and Ruduger, 2003). In terms of function modeling based on Petri nets, Zhou Xiaoyong established the function model and function decomposition unit model respectively from the black box method and function tree (Xiaoyong Zhou and Tuanjie Li, 2005) (Xiaoyong Zhou and Pin Li, 2003). However, all these function models reckon without the assignment, which should be considered in the variable elements and state elements in the actual flow. What's more, there hasn't had a model to express the technical contradictions in a product.

In order to solve this no assignment, we introduced the knowledge of fuzzy Petri nets in this paper. A fuzzy Petri net is the blurring of a traditional Petri net (Xingui He, 1994). It is put forward by He Xingui. Every variable element of Fuzzy Petri net has a nonnegative real value threshold limit, which is called τ. On every input link and output link there has a rated input or a rated output and their bonding strength (Xingui He, 1994). In order to express the technical contradictions, we bring in the conception of Object-Oriented.

2. Function model of concept design

▪2.1 Definition of function model of concept design

Function analysis is indispensable and vital in concept design. Function analysis including the analysis of the material-information-energy flow relationship between various functional units, the statements of the system elements when they are working, the influence of various functional units which effected by product environmental information, the analysis of resources in system, etc. In order to lead the approach of function analysis to a more specified and computerized way, we build the functional model with the knowledge of Petri nets.

(1) Variable element: on behalf of all sorts of functions in the product concept design. T is the variable element. T = { T0 , T1 , T2 , … , Tx }.

Functions in model can be divided into two forms: the operating function and the testing function.

Operating function: it is defined by the function units of the function tree, which is on the bottom. The ignition of the operating function needs definite information of the status of the system, the condition of resources and so on. Besides, it can be valued by a threshold limit τ, which should be a nonnegative real number. This τ can be the needed number of resources of the ignition of function, the needed time, the needed speed or the extreme value of pressure, etc.

Testing function: the function, which only has two states "satisfied" and "not satisfied", is defined as the testing function. In the process of computerization, "satisfied" valued as "1", "not satisfied" valued as "0".

(2) State element: on behalf of environment information of product or restrictions of the implementation of variable elements in concept design. P is the state element. P = { P0, P1, P2, ... , Px }. There are two state elements, the intermediate state element and the limited state element.

Intermediate state element: it presents the middle state of two related state elements. The “token” carries the state information.

Limited state element: it is a state element used for restricting the ignition of operating function. The “token” carries the condition information.

(3) Arc: it is a one-way arrow, connecting the variable element with the state element. It presents the direction of the token’s flow. The arc can be valued by real number αand β which represents the consumption of resources, the speed or the pressure in process.

(4) Token: it is a the black dot in state element which will carries information. It can be valued and dyeing. After ignition, the “token” in the foregoing-variable-element state element flows into the posterior-variable-element state element. The properties of “token” vary with the change of the system state.

▪2.2 Behavior description of Petri nets function model

In Petri nets model, the flow of “token” can dynamically describes the executive state of each function. First of all, in the initial state, “token” is in the corresponding P, and the system is in the initial state. The flow of “token” shows the follow-up state. Only when every P, which has been set up before this T, has at least one “oken”, do this T can be ignited. After ignition, the P, which has been set up foregoing, loses a “token” and the P, which is set up posterior, gets the corresponding “token”.

In this established Petri nets model, the ignition of an operating function T is decided by the state of the foregoing P. Only when the value of “token” in this P meets the threshold limit, can this T be ignited. Conversely, this T is inactivated. The ignition of a testing function T is decided by the state of the foregoing P too. When it is assigned with a value "1", it means there has “token” in this P. That means this T can be ignited. If it is assigned with a value "0", it means there has no “token” in this P. That means this T can not be ignited.

▪2.3 the establishing of a Petri nets function model

The model varies from the experience and knowledge reserves of different designers. In order to regulate the establishment of a Petri nets function model, the process model of the establishing of a Petri nets function model is given below.

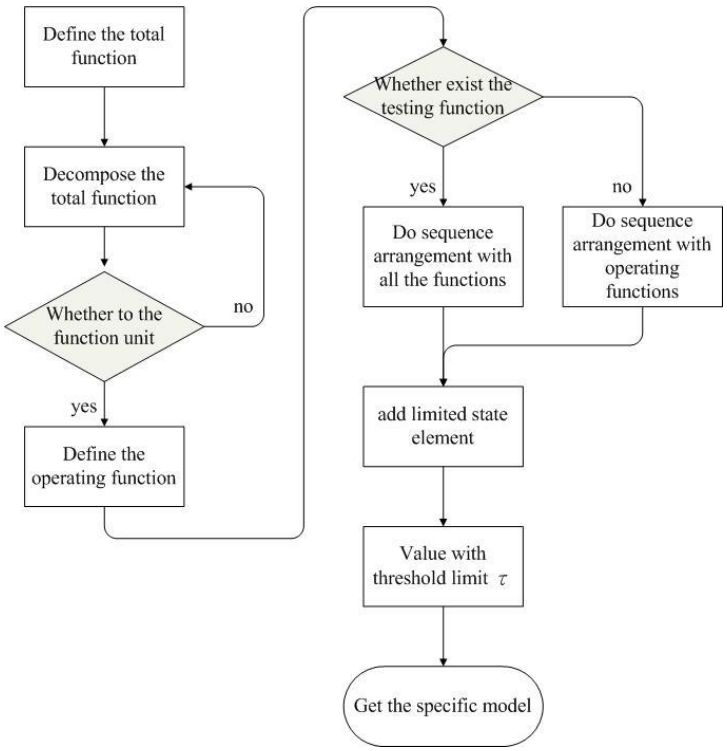

Figure 1.Process Model of the Establishing of Petri Nets Function Model.

Firstly: we should establish the function tree of this product. Decompose the total function into function units. Define every function unit as a specific operating function directly. Then do simple sequence arrangement with the operating functions in the working process. Then define every operating function as a T, and do pre-analysis with this Petri nets model.

Secondly: in the process of pre-analysis, find out the testing functions. Define every testing function as a T. Then do sequence arrangement with both operating functions and testing functions. Then establish the Petri nets function model.

Thirdly: according to every actual situation, add limited state element before the operating variable element.

Fourthly: value every specific operating function with a threshold limit τ. Then value the "token" in limited state element and value arcs, which should be set up between limited state element and operating function according to the actual situation. Get the specific final model.

▪2.4 Petri nets expression of technical contradictions

G. S. Altshuller divided contradictions into three forms: management contradiction, physical contradiction and technical contradiction (Runhua Tan, 2010). The traditional description of technical contradiction is called matter-field model. The matter-field model is based on graphic description. However, this matter-field model is short of the corresponding analysis, and its verification means are also absence as well as its powerful tools of mathematics. So the introduction of the knowledge of Petri nets has its necessity. The work (Darui Zhang, 2009) given four new definition of contradiction, which is based on Petri nets, based on the existing contradiction definition and based on the new forms of contradiction that have already been shown in the process of product design. But this expression is so single. In order to get over the singleness of this expression and expand the means of expression, we introduce the knowledge of object-oriented Petri nets.

In the design process, we can see that a function is composed of many different structures or is affected by many environment factors. Therefore, in the Petri nets model we can consider a function as a subsystem. In other words, this subsystem can be regarded as an object in the object-oriented Petri nets. This package of the subsystem will expand the ability of expression of traditional Petri nets.

In the expression of technical contradictions, the P which has contradictions will be replaced by a dotted line frame. Under this circumstance, it means it is an object. The oval sign in dotted line frame is called the information gate. It must be set between T and P. It can be illustrated in the following figure 2. There has been contradiction between T2 and T3. So T2 is replaced by object1 and T3 is replaced by object 2. The three ovals on the dotted line frame are called the information gates. In figure 2, the contradiction between T2 and T3 is P5. In addition, we can value T4 and T5 with threshold limit τs which carrying the information of influence degree and so on.

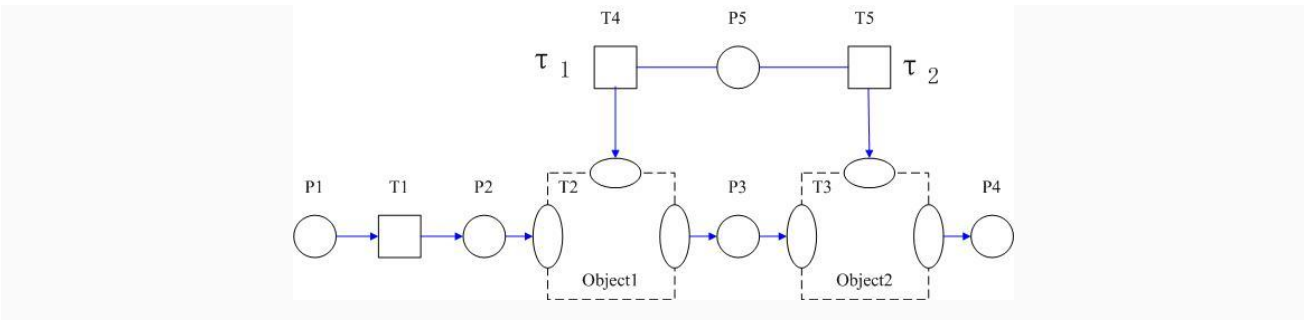

Figure 2.Object-oriented Petri net.

3. Example

▪3.1 Function Petri nets model

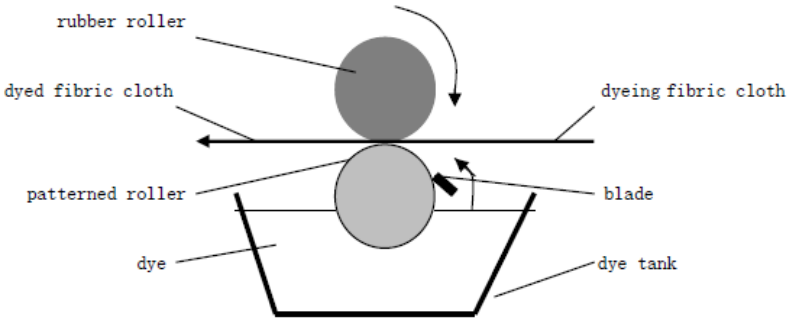

Figure 3.the fabric printing and dyeing equipment.

The fabric printing and dyeing equipment consists of rubber roller, patterned roller, dye, dye tank and the blade. Rubber roller and patterned roller are in the condition of rotating and they drive the fabric cloth to move. When the fabric cloth is in the interval between rubber roller and patterned roller, the pressure leads to the vacuum on the patterned. This vacuum pushes dye on the fabric cloth which completes the dyeing of fabric cloth.

Firstly, we should establish a function tree of this device.

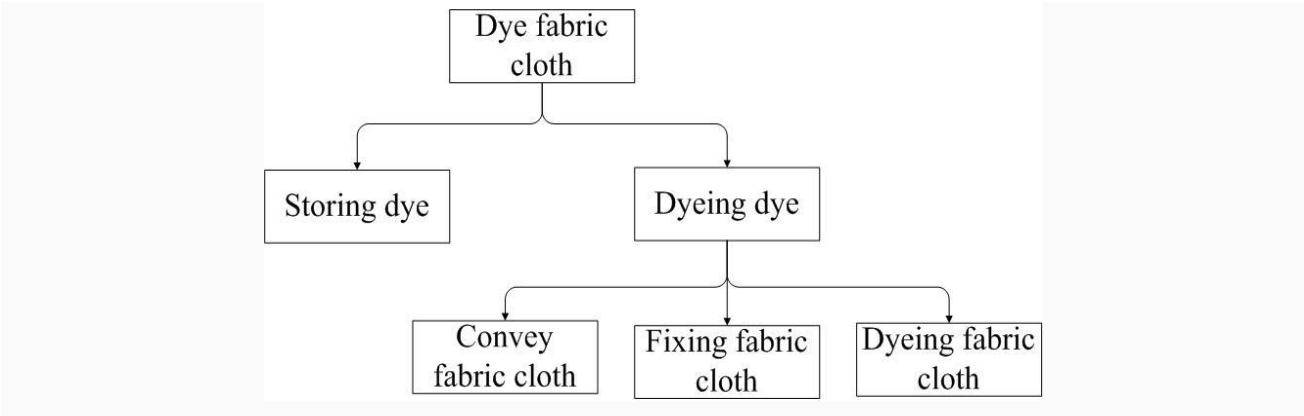

Figure 4.the function tree of the fabric printing and dyeing equipment.

According to the figure 4, Storing Dye, Convey Fabric Cloth, Fixing Fabric Cloth and Dyeing Fabric Cloth are the function units of this device. The operating functions are these function units in this function tree. The corresponding between operating functions and T is expressed in table 1.

Table 1. The corresponding between operating functions and T.

T0	Storing dye
T1	Convey fabric cloth
T2	Fixing fabric cloth
T3	Dyeing fabric cloth

Testing function is obtained from the analysis of working process in the modeling. Obviously, T4 is derived from T0, T5 is derived from T1. The corresponding between testing functions and T is expressed in table 2.

Table 2. The corresponding between testing functions and T.

T4	Testing dye
T5	Testing fabric cloth

Determine the sequences of these Ts.

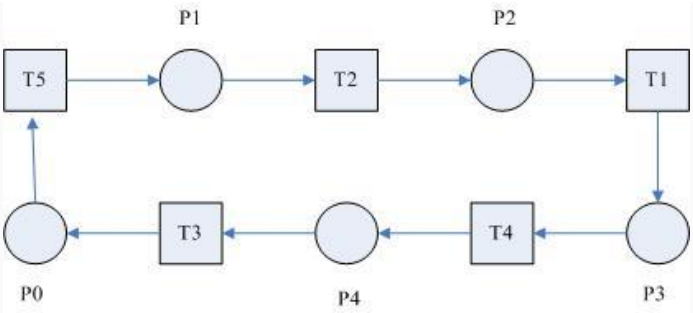

Figure 5.the Petri nets functional model of the fabric printing and dyeing equipment.

With further analysis, we recognize that, in order to ignite T1, there must be a “token” of Linear Velocity, and in order to ignite T3, there must be a “token” of Pressure. Add restrictions of these two “token”. Then we get the improved Petri nets function model. As figure 6 shows.

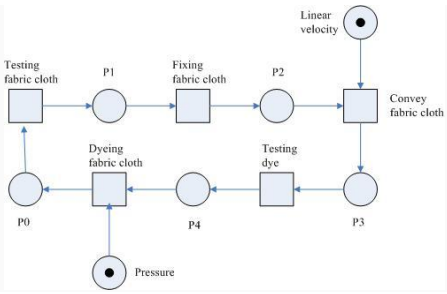

Figure 6.the improved Petri nets function model of the fabric printing and dyeing equipment.

For dynamic analysis, you just need to add “token” in P0, P1, P2, P3 and P4.

The last but not the least, we can add fuzzy elements into the model of figure 6, which means value the original Petri nets. Add threshold limit onto the corresponding T. T1 is valued with τ1 and T3 is valued with τ2. In here, the physical meaning of τ1 is that, only when the Linear Velocity is equal to or greater than the value of τ1, then T1 can be ignited. The physical meaning of τ2 is that, only when the Pressure is equal to or greater than the value of τ2, then T2 can be ignited. What's more, add rated input or output on the corresponding arcs in the original Petri nets function model. The physical meaning of α1 means the information of Linear Velocity which P5 can provided. The physical meaning of β1 means the information of Pressure which P6 can provided. Figure 7 is the improved fuzzy Petri nets function model.

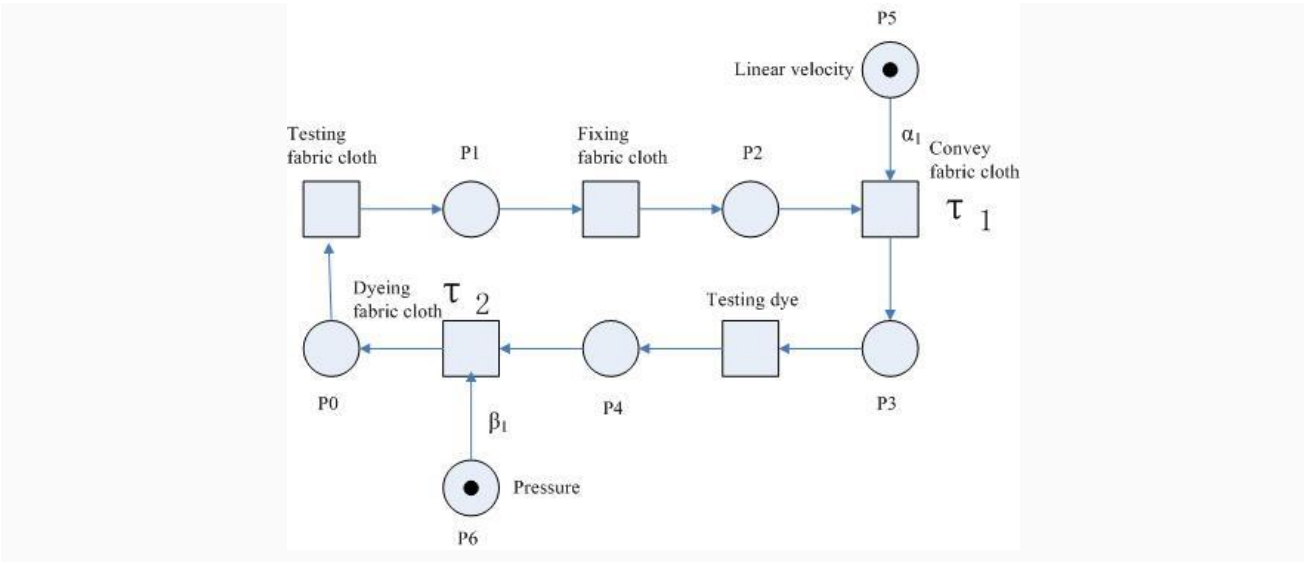

Figure 7.the improved fuzzy Petri nets function model of the fabric printing and dyeing equipment.

▪3.2 Petri nets expression of technical contradiction

From the working characteristics of the fabric printing and dyeing equipment, we can conclud that the cost of dyeing fabric cloth has a direct relationship with the linear velocity. The higher linear velocity is, the higher productivity can be. Nevertheless, the higher linear speed is, the more color will be on the cloth. Which means the quality of the dyed fabric cloth can not be guaranteed. This problem leads to a technical contradiction. And this certain technical contradiction is between the T of Convey Fabric Cloth and the T of Dyeing Fabric Cloth.

As figure 8 shows, when expressing the technical contradiction, package the P of Convey Fabric Cloth and the P of Dyeing Fabric Cloth. What's more, add two factors, Pressure and Linear Velocity, between them respectively. The threshold limit τ1、τ2、τ3 and τ4 represent the influence degree of the factors to corresponding object.

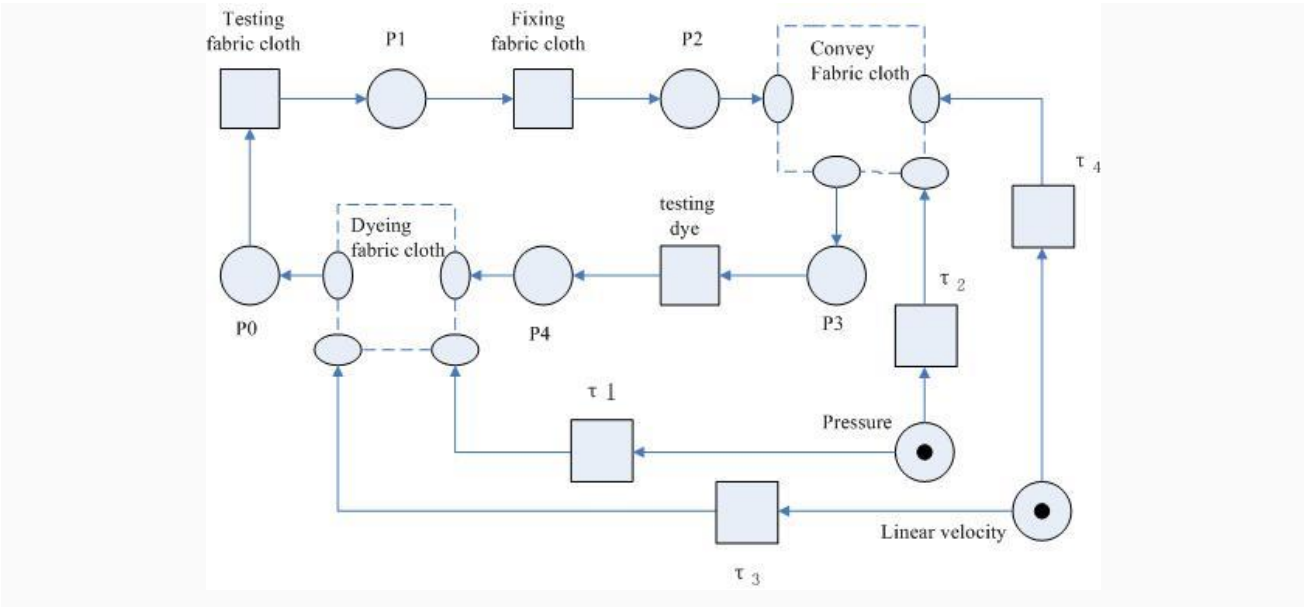

Figure 8.the technical contradictions expression model of the fabric printing and dyeing equipment.

4. Conclusion

With the analysis of the process of concept design and from the knowledge of function tree, in this paper we established the Petri nets function model which is based on the knowledge of Petri nets and fuzzy Petri nets. Then, we defined the basic elements of Petri nets function model and the expression of its dynamic behavior. And the basic steps of modeling are presented in this paper too. In the last part of this paper, the expression of technical contradiction is illustrated with the technology of object-oriented Petri nets. Using this model, we can not only analyze the structural characteristics of a product, but also be able to analyze the dynamic characteristics of this product. Furthermore, within the advantages of Petri nets, this model has great graphical visual expression mode and a rigorous mathematical theory which would be in my following research plan. And equally important, it provides support for the computerizing of analysis of function structure. This model is the basis for the subsequent design model.

Acknowledge

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Questionnaire Investigation on SNS and its Sensitivity Analysis Utilizing Bayesian Network

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Abstract

Social Networking Service (SNS) is prevailing rapidly in Japan in recent years. Facebook, mixi and Twitter are the popular one. These are utilized in various field of life together with the convenient tool such as smart- phone. In this paper, a questionnaire investigation is executed in order to clarify the current usage condition, issues and desired function etc. More than 1000 samples are gathered. Bayesian Network is utilized for this analysis. After executing the sensitivity analysis, useful results are obtained. One of the TRIZ methods is extended and applied. Difference of usage objective and SNS site is made clear by the attributes and preference of SNS users. It can be utilized effectively for marketing by clarifying the target customer though the sensitivity analysis.

Keywords: SNS, questionnaire investigation, Bayesian Network

1. Introduction

Social Networking Service (SNS) is prevailing rapidly in recent years. Facebook, mixi and Twitter are the popular one. Big Disaster happened at 11/March/2011 in the east part of Japan. It is well known that Facebook played important role in communication under the condition that telephone and/or cellular phone connected with Internet could not make link. Google launched forth into SNS by the name Google+ at June 2011. Thus, it has become a hot business spot and it makes great influence upon society and economy. In this paper, a questionnaire investigation is executed in order to clarify the current usage condition, issues and desired function etc.

Difference of objective usage and SNS site would be made clear by the attributes and preference of SNS users.

For these purposes, we created a questionnaire investigation of user attitudes to SNS. In recent years, Bayesian Network is highlighted because it has the following good characteristics (Neapolitan, R.E., 2004).

●Structural Equation Modeling requires normal distribution to the data in the analysis. Therefore it

has a limitation in making analysis. But Bayesian Network does not require specific distribution type to the data. It can handle any distribution type.

●It can handle the data which include partial data.

●Expert's know-how can be reflected in building Bayesian Network model.

●Sensitivity analysis can be easily executed by settling evidence. We can estimate and predict the prospective purchaser by that analysis.

●It is a probability model having network structure. Related items are connected with directional link. Therefore understanding becomes easy by its visual chart.

In this research, it is suitable to utilize Bayesian Network to analyze SNS users' current usage condition, issues and desired function etc. because each variable does not necessarily have normal distribution. Reviewing past researches, there are some related researches as follows. Tsuji et al. (2008) made analysis concerning preference mining on future home energy consumption. There are some papers concerning purchase behavior in the shop (Tatsuoka et al.,2008-a, Tatsuoka et al., 2008-b). But there is no research for the SNS users utilizing Bayesian Network.

Bayesian Network is utilized for this analysis. One of the TRIZ methods is extended and applied. After executing the sensitivity analysis, useful results are obtained. Difference of usage objective and SNS site is made clear by the attributes and preference of SNS users. It can be utilized effectively for marketing by clarifying the target customer though the sensitivity analysis.

The rest of the paper is organized as follows. Extended analysis method is stated in section 2. Outline of questionnaire research is stated in section 3. In section 4, an analysis by cross tabulation is executed. In section 5, Bayesian Network analysis is executed which is followed by the sensitivity analysis in section 6. Section 7 is a summary.

2. Extended Analysis Method

The function "Moves" is a fundamental function of TRIZ [2], [3].

We can further develop this concept as shown in Figure 2.1.

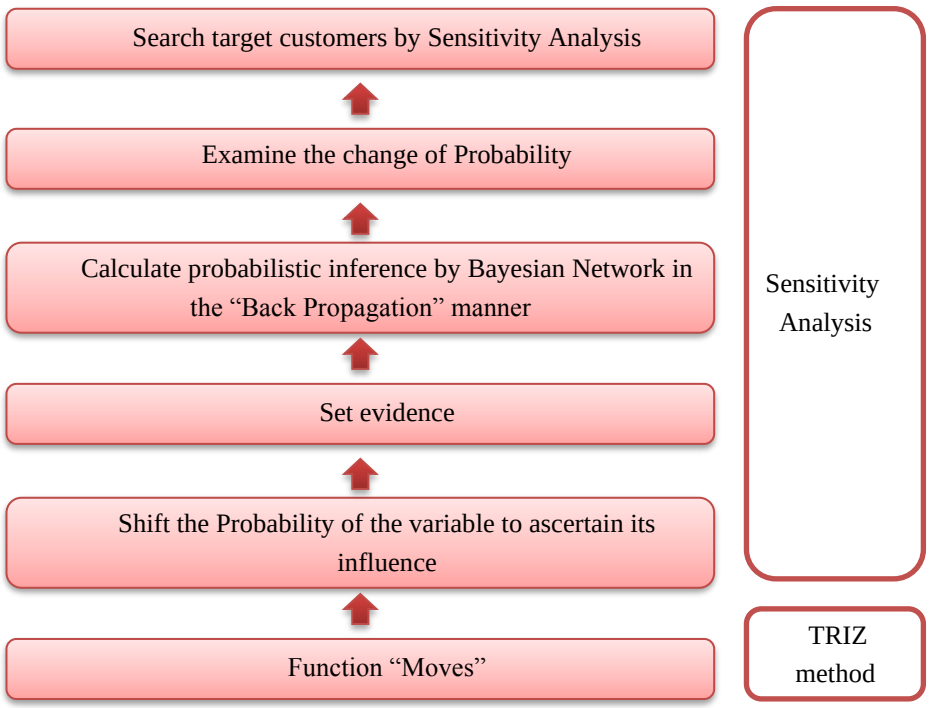

Figure 2.1. Extended Analysis Method

Based on the TRIZ method, sensitivity analysis is developed utilizing Bayesian Network. Applying "Moves" function, shift the probability of the variable to ascertain its influence. Set evidence to, for example, "1.0" to the variable, calculate probabilistic inference by Bayesian Network in the "Back Propagation" manner. Then, examine the change of probability.

These are the process of "Sensitivity Analysis" based upon TRIZ "Moves" method. Detailed inspection is executed in section 6.

3. Outline of Questionnaire Research and Examinees

▪3.1 Outline of Questionnaire Research

We make a questionnaire investigation concerning the SNS. Outline of questionnaire research is as follows.

(1)Scope of investigation：Student, Government Employee and Company Employee etc., Japan

(2)Period　　：April/26/2012～June/6/2012

(3)Method　　：Mail, online and self-writing

(4)Collection　　：Number of distribution 1,500

Number of collection 1,197 (collection rate 79.8%)

Valid answer 1,098

Analysis methods are as follows.

Questionnaire results are analyzed in three methods. First, analysis by Hypothesis testing is executed in section 3 in order to confirm hypotheses. Second, analysis by Bayesian Network is executed in section 4 in order to clarify and visualize the causal relationship among the items. Third, analysis by sensitivity analysis is executed in section 5 in order to predict the prospective purchaser as is shown in Table 3.1.

Table 3.1. Analysis Procedure

Step	Aim of analysis	Used Method
①	Confirm hypotheses	Hypothesis testing
②	Build Bayesian Network in order to clarify and visualize the causal relationship among items	Bayesian Network Analysis
③	Predict the prospective purchaser	Sensitivity Analysis

▪3.2 Outline of Examinees

Table 3.2. Major single variable summary results

Q1. Use the SNS	Use	792	72.1%
	Do not use	306	27.9%
Q13. Gender	Male	650	59.2%
	Female	448	40.8%
Q14. Age	—20	196	17.9%
	—30	328	29.9%
	—40	299	27.2%
	—50	194	17.7%
	—60	73	6.6%
	60—	8	0.7%
Q15. Occupation	Student	295	26.9%
	Government Employee	15	1.4%
	Company Employee	595	54.2%
	School Teacher/Staff	43	3.9%
	Clerk of Organization	19	1.7%
	Independents	45	4.1%
	Temporary Employee	15	1.4%
	Part-timers	53	4.8%

	Miscellaneous	18	1.6%
Q16. Residence	Hokkaido	22	2.0%
	Tohoku Region	49	4.5%
	Kanto Region	157	14.3%
	Chubu Region	176	16%
	Kansai Region	400	36.4%
	Chugoku Region	110	10.0%
	Shikoku Region	105	9.6%
	Kyushu Region	79	7.2%

4. The Results of Statistical Hypothesis Testing

▪4.1 Outline of Questionnaire Research

$\chi 2$ hypothesis Testing is executed for about users' SNS consciousness. Hypotheses are built based upon the following viewpoints (Table 4.1).

Table 4.1. Hypothesis Building Viewpoints (Source: P.Kotler and K.Keller-Revised by the writer)

	Characteristics	Example
Consumers' characteristics	Demographic characteristics	Sex, Age, Family, Occupation
	Geographic characteristics	Urban City, Rural City, Tokyo/Osaka
	Psychographic characteristics	Life-style, Personality
	Usage condition	Daily use, Business use
Consumers' Response	Benefit Response	Quality, Endurance, After sales service, Economical, Convenience, Swiftness
	Usage Ration Response	Big user etc.
	Type of users	Non-user, Former user, First user, Regular user etc.
	Frequency	Light user, Heavy user etc.
	Royalty	Absolute, Non etc.
	Attitude towards products	Fanatic, Negative etc.

1. Difference of evaluation between user and non-user for SNS

2. Difference of evaluation by attribute

3. Difference of evaluation by residential area

4. Difference of usage by each SNS

5. Difference of Psychographic characteristics between user and non-user for SNS

As it takes so much pages, we omit 3. stated above. We set 6 themes as follows. These are extracted from the discussion of the authors.

Theme 1: In Integrated genre SNS such as Facebook, users feel interests by sharing the information of current condition with friends.

Theme 2: Young people use SNS more frequently and dispatch much more information than senior.

Theme 3: Company employee mainly use Integrated genre SNS such as Facebook while students often use Game genre SNS such as GREE.

Theme 4: Single wants to build new network by utilizing SNS.

Theme 5: Female use Facebook more frequently than male, so does the mixi and You Tube.

Theme 6: Those who like acting at outdoor spread the information much more than those of indoor type.

▪4.2 The results of statistical hypothesis testing

The results of statistical hypothesis testing are as follows.

Theme 1: In Integrated genre SNS such as Facebook, users feel interests by sharing the information of current condition with friends.

Null Hypothesis: It cannot necessarily be said that users feel interests by sharing the information of current condition with friends in Integrated genre SNS such as Facebook.

Table 4.2. Cross Tabulation result 1

		Q4 (%)			
		Facebook	mixi	Twitter	Google+
Q6 ①	Think so very much	0.537	0.195	0.170	0.011
	Slightly think so	0.434	0.139	0.132	0.021
	Ordinary level	0.167	0.064	0.115	0.064
	Slightly not think so	0.294	0.000	0.088	0.088
	Do not think so	0.087	0.087	0.174	0.043
Sum		0.439	0.150	0.147	0.024

	YouTube	Niconico β	Ustream	GREE

Think so very much	0.025	0.014	0.000	0.005
Slightly think so	0.128	0.011	0.000	0.011
Ordinary level	0.179	0.051	0.000	0.000
Slightly not think so	0.147	0.206	0.000	0.059
Do not think so	0.174	0.087	0.000	0.087
Sum	0.087	0.027	0.000	0.012

	Mobage	Hangame	Ameba	Taberogu
Think so very much	0.016	0.000	0.008	0.005
Slightly think so	0.021	0.011	0.028	0.021
Ordinary level	0.115	0.000	0.013	0.064
Slightly not think so	0.059	0.000	0.000	0.029
Do not think so	0.043	0.043	0.043	0.043
Sum	0.031	0.005	0.017	0.019

	KAKAKU.com	Ameba pico	myspace
Think so very much	0.003	0.000	0.000
Slightly think so	0.011	0.004	0.000
Ordinary level	0.077	0.013	0.000
Slightly not think so	0.029	0.000	0.000
Do not think so	0.043	0.000	0.000
Sum	0.015	0.003	0.000

	foursquare	Orkut	PowerLink
Think so very much	0.000	0.000	0.000
Slightly think so	0.000	0.000	0.000
Ordinary level	0.000	0.000	0.000
Slightly not think so	0.000	0.000	0.000
Do not think so	0.000	0.000	0.000
Sum	0.000	0.000	0.000

	Life Shot	Miscellaneous	Total
Think so very much	0.000	0.011	1.000
Slightly think so	0.000	0.028	1.000
Ordinary level	0.000	0.077	1.000
Slightly not think so	0.000	0.000	1.000
Do not think so	0.000	0.043	1.000

Sum	0.000	0.024	1.000

Real number	Integrated SNS	Miscellaneous	Sum
Important	537	109	646
Not important	25	32	57

Expectation	Integrated SNS	Miscellaneous	Sum
Important	516.4	129.6	646
Not important	45.6	11.4	57

*"Integrated SNS" is Facebook, mixi, Twitter and Google+. "Miscellaneous" is the other SNS.

Statistic (χ^2 value)	50.627
Rejection region (1% significance level)	Z > 6.635

Rejection region is over 6.635 for 1% significance level and 3.841 for 5% significance level by 1 degree of freedom.

The null hypothesis is rejected with 1% significance level. It can be said that in Integrated genre SNS such as Facebook, users feel interests by sharing the information of current condition with friends. It can generally be said that Integrated SNS is the most suitable tool for communication compared with other genre SNS.

Theme 2: Young people use SNS more frequently and dispatch much more information than senior.

Null Hypothesis: Young people use SNS as frequently as senior and also dispatch information similarly.

Table 4.3. Cross Tabulation result 2-1

		Q14 (%)			
		—20	—30	—40	—50
Q2	More than 5 times a day	0.383	0.338	0.197	0.076
	Around 3~ 4 times a day	0.197	0.421	0.243	0.112
	Around 1~ 2 times a day	0.112	0.341	0.324	0.176
	Around 4~ 5 times a week	0.135	0.173	0.346	0.269
	Around 2~ 3 times a week	0.157	0.196	0.373	0.275
	Around 1 times a week	0.061	0.303	0.303	0.212
	Around 2~ 3 times a month	0.000	0.444	0.333	0.111
	Around 1 times a month	0.000	0.167	0.583	0.167
	Less than that	0.059	0.294	0.412	0.118
Sum		0.226	0.331	0.271	0.139

	—60	60—	Total
More than 5 times a day	0.007	0.000	1.000
Around 3~ 4 times a day	0.026	0.000	1.000
Around 1~ 2 times a day	0.047	0.000	1.000
Around 4~ 5 times a week	0.077	0.000	1.000
Around 2~ 3 times a week	0.000	0.000	1.000
Around 1 times a week	0.121	0.000	1.000
Around 2~ 3 times a month	0.111	0.000	1.000
Around 1 times a month	0.083	0.000	1.000
Less than that	0.118	0.000	1.000
Sum	0.033	0.000	1.000

Real number	—40	40—	Sum
More than once a day	529	83	612
Else	122	52	174

Expectation	—40	40—	Sum
More than once a day	506.9	105.1	612
Else	144.1	29.9	174

Statistic (χ^2 value)	25.335
Rejection region (1% significance level)	Z > 6.635

Table 4.4. Cross Tabulation result 2-2

		Q14 (%)			
		—20	—30	—40	—50
Q8	Every time	0.304	0.304	0.278	0.101
	Frequently	0.251	0.371	0.246	0.114
	Sometimes	0.213	0.362	0.253	0.129
	Scarcely	0.152	0.273	0.303	0.235
	Never	0.231	0.212	0.385	0.115
Sum		0.221	0.333	0.271	0.140

	—60	60—	Total
Every time	0.013	0.000	1.000
Frequently	0.017	0.000	1.000

Sometimes	0.043	0.000	1.000
Scarcely	0.038	0.000	1.000
Never	0.058	0.000	1.000
Sum	0.034	0.000	1.000

Real number	—40	40—	Sum
Frequently	222	32	254
Else	139	45	184

Expectation	—40	40—	Sum
Frequently	209.3	44.7	254
Else	151.7	32.3	184

Statistic (χ^2 value)	10.436
Rejection region (1% significance level)	Z > 6.635

The null hypothesis is rejected with 1% significance level. It can be said that young people use SNS more frequently and dispatch much more information than senior. SNS market is growing owing to the prevailing smartphone for one reason. Com Score in USA released that the smart-phone users in Japan consist of the following division of generation:
18-24: 19.4%, 25-34: 25.6%, 35-44 : 22.7%, 45-54 : 12.5%, 55-64 :8.6%
in which 45% are 18-35 generation.

Theme 3: Company employee mainly use Integrated genre SNS such as Facebook while students often use Game genre SNS such as GREE.

Null Hypothesis: It cannot necessarily be said that company employee mainly use Integrated genre SNS such as Facebook while students often use game genre SNS such as GREE.

Table 4.5. Cross Tabulation result 3

		Q4 (%)			
		Facebook	GREE	mixi	Twitter
Q15	Student	0.188	0.020	0.270	0.223
	Company Employee	0.800	0.000	0.100	0.100
	Government Employee	0.530	0.010	0.080	0.134
	School Teacher/Staff	0.667	0.000	0.111	0.000
	Clerk of Organization	0.500	0.000	0.286	0.071
	Independents	0.725	0.000	0.075	0.025

	Temporary Employee	0.636	0.000	0.091	0.000
	Part-timers	0.500	0.000	0.088	0.059
	Miscellaneous	0.615	0.000	0.154	0.077
Sum		0.438	0.011	0.148	0.145

	Google+	YouTube	Niconico β
Student	0.031	0.105	0.063
Company Employee	0.000	0.000	0.000
Government Employee	0.023	0.088	0.013
School Teacher/Staff	0.000	0.074	0.000
Clerk of Organization	0.000	0.071	0.000
Independents	0.000	0.125	0.000
Temporary Employee	0.000	0.091	0.000
Part-timers	0.118	0.088	0.000
Miscellaneous	0.000	0.000	0.000
Sum	0.027	0.092	0.027

	Ustream	Mobage	Hangame	Ameba
Student	0.000	0.035	0.012	0.012
Company Employee	0.000	0.000	0.000	0.000
Government Employee	0.000	0.034	0.003	0.008
School Teacher/Staff	0.000	0.000	0.000	0.000
Clerk of Organization	0.000	0.071	0.000	0.000
Independents	0.000	0.000	0.000	0.025
Temporary Employee	0.000	0.091	0.000	0.000
Part-timers	0.000	0.000	0.000	0.118
Miscellaneous	0.000	0.000	0.000	0.154
Sum	0.000	0.030	0.005	0.016

	Taberogu	KAKAKU.com	Ameba pico
Student	0.004	0.000	0.008
Company Employee	0.000	0.000	0.000
Government Employee	0.028	0.021	0.000
School Teacher/Staff	0.074	0.074	0.000
Clerk of Organization	0.000	0.000	0.000
Independents	0.000	0.025	0.000
Temporary Employee	0.091	0.000	0.000
Part-timers	0.000	0.029	0.000

Miscellaneous	0.000	0.000	0.000
Sum	0.019	0.015	0.003

	myspace	foursquare	Orkut	PowerLink
Student	0.000	0.000	0.000	0.000
Company Employee	0.000	0.000	0.000	0.000
Government Employee	0.000	0.000	0.000	0.000
School Teacher/Staff	0.000	0.000	0.000	0.000
Clerk of Organization	0.000	0.000	0.000	0.000
Independents	0.000	0.000	0.000	0.000
Temporary Employee	0.000	0.000	0.000	0.000
Part-timers	0.000	0.000	0.000	0.000
Miscellaneous	0.000	0.000	0.000	0.000
Sum	0.000	0.000	0.000	0.000

	Life Shot	Miscellaneous	Total
Student	0.000	0.031	1.000
Company Employee	0.000	0.000	1.000
Government Employee	0.000	0.028	1.000
School Teacher/Staff	0.000	0.000	1.000
Clerk of Organization	0.000	0.000	1.000
Independents	0.000	0.000	1.000
Temporary Employee	0.000	0.000	1.000
Part-timers	0.000	0.000	1.000
Miscellaneous	0.000	0.000	1.000
Sum	0.000	0.024	1.000

Real number	Integrated SNS	Miscellaneous	Sum
Company Employee	297	90	387
Miscellaneous	303	102	405

Expectation	Integrated SNS	Miscellaneous	Sum
Company Employee	293.2	93.8	387
Miscellaneous	306.8	98.2	405

*"Integrated SNS" includes Facebook, mixi, Twitter and Google+, and "Miscellaneous" includes other SNS stated above.

Statistic (χ^2 value)	0.397
Rejection region (5% significance level)	Z > 3.841

Real number	Game genre SNS	Miscellaneous	Sum
Student	17	239	256
Miscellaneous	20	516	536

Expectation	Game genre SNS	Miscellaneous	Sum
Student	12.0	244.0	256
Miscellaneous	25.0	511.0	536

*"Game genre SNS" includes GREE, Mobage and Hangame, and "Miscellaneous" includes other SNS stated above.

Statistic (χ^2 value)	3.235
Rejection region (5% significance level)	Z > 3.841

The null hypothesis is not rejected. It cannot necessarily be said that company employee mainly use Integrated genre SNS such as Facebook while students of the use game genre SNS such as GREE. We can observe that Facebook, which is one of the Integrated genre SNS, is used by the people of various type occupation.

Theme 4: Single wants to build new network by utilizing SNS.

Null Hypothesis: Single does not necessarily want to build new network by utilizing SNS.

Table 4.6. Cross Tabulation result 4

		Q12② (%)					
		Think so very much	Slightly think so	Ordinary level	Slightly not think so	Do not think so	Total
Q17	Married	0.182	0.350	0.239	0.145	0.084	1.000
	Single	0.201	0.343	0.271	0.122	0.063	1.000
Sum		0.193	0.346	0.258	0.131	0.071	1.000

Real number	Important	Not important	Sum
Married	202	311	513
Single	87	106	193

Expectation	Important	Not important	Sum
Married	210	303	513
Single	79	114	193

Statistic (χ^2 value)	1.888

Rejection region (5% significance level)	Z > 3.841

The null hypothesis is not rejected. It can be said that single does not necessarily want to build new network by utilizing SNS.

By another analysis, we could get the result that those who esteem getting acquaintance with the friend of the opposite sex by SNS were rather few. It has few relationships who esteem building new network by SNS whether they are single or married.

Theme 5: Female use Facebook more frequently than male, so does the mixi and You Tube.

Null Hypothesis: Female do not necessarily use Facebook more frequently than male, nor so does the mixi and You Tube.

Table 4.7. Cross Tabulation result 5

		Q4 (%)				
		Facebook	mixi	Twitter	Google+	YouTube
Q13	Male	0.462	0.124	0.117	0.025	0.108
	Female	0.408	0.178	0.181	0.029	0.072
Sum		0.438	0.148	0.145	0.027	0.092

	Niconico β	Ustream	GREE	Mobage	Hangame
Male	0.034	0.000	0.016	0.045	0.009
Female	0.017	0.000	0.006	0.011	0.000
Sum	0.027	0.000	0.011	0.030	0.005

	Ameba	Taberogu	KAKAKU.com	Ameba pico
Male	0.007	0.011	0.023	0.000
Female	0.029	0.029	0.006	0.006
Sum	0.016	0.019	0.015	0.003

	myspace	foursquare	Orkut	PowerLink
Male	0.000	0.000	0.000	0.000
Female	0.000	0.000	0.000	0.000
Sum	0.000	0.000	0.000	0.000

	Life Shot	Miscellaneous	Total
Male	0.000	0.020	1.000
Female	0.000	0.029	1.000
Sum	0.000	0.024	1.000

Real number	Integrated Genre's and Moving Picture Genre's SNS	Miscellaneous	Sum
Student	354	90	444
Miscellaneous	283	65	348

Expectation	Integrated Genre's and Moving Picture Genre's SNS	Miscellaneous	Sum
Student	357.1	86.9	444
Miscellaneous	279.9	68.1	348

*"Integrated Genre's and Moving Picture Genre's SNS" includes Facebook, mixi, Twitter, Google+, You Tube, Niconico β and Ustream. "Miscellaneous" is the other SNS.

Statistic (χ^2 value)	0.313
Rejection region (5% significance level)	$Z > 3.841$

The null hypothesis is not rejected. Female do not necessarily use Facebook more frequently than male, nor so does the mixi and You Tube.

Theme 6: Those who like acting at outdoor spread the information much more than those of indoor type.

Null Hypothesis: It cannot necessarily be said that those who like acting at outdoor spread the information much more than those of indoor type.

Table 4.8. Cross Tabulation result 6

		Q8 (%)		
		Every time	Frequently	Sometimes
Q21	Outdoor	0.093	0.195	0.472
	Indoor	0.101	0.237	0.430
	Cannot choose either	0.106	0.235	0.426
Sum		0.101	0.223	0.441

	Scarcely	Never	Total
Outdoor	0.183	0.057	1.000
Indoor	0.158	0.075	1.000
Cannot choose either	0.165	0.068	1.000
Sum	0.168	0.066	1.000

Real number	Frequently	Else	Sum
Outdoor	71	77	148

Indoor	59	53	112

Expectation	Frequently	Else	Sum
Outdoor	74	74	148
Indoor	56	56	112

Statistic (χ^2 value)	0.565
Rejection region (5% significance level)	Z > 3.841

The null hypothesis is not rejected. It cannot necessarily be said that those who like acting at outdoor spread the information much more than those of indoor type. Indoor typed person would handle SNS by PC.

5. Bayesian Network Analysis

▪5.1 Confirmation of Hypothesis by Utilizing Bayesian Network

Now, we examine the probabilistic inference of Bayesian Network by picking up Hypothesis 1 stated above. Set "Facebook" as a parent node and "Relationship" as a child node.

Figure 5.1. Node and Parameter (Hypothesis 1)

As a result, we can see rather high value in Conditional Probability Table (CPT) (Posterior Probability in Table 5.2) for Facebook "Use" and Relationship "Important". This means that users of Facebook are the majority in this questionnaire answerers and they think it important for having relationship.

In the next section, we see more in detail. Building the model with Demographic, Geographic and Psychographic items, we show that it can be utilized for further effective marketing.

Table 5.2. Built Model

Node	Parameter	Prior Probability	Posterior Probability
			Facebook

Facebook	Use	0.6335	1.0000
	Not use	0.3665	0.0000
Relationship	Important	0.8242	0.8942
	Ordinary level	0.1019	0.0679
	Not important	0.0739	0.0379

▪5.2 Model Structure

In constructing Bayesian Network, it is required to set an outline of the model reflecting the causal relationship among groups of items. Concept chart in this case is exhibited in Figure 5.3.

Haga (2005) restricted the range of search to the following 5 stages while building model.

①Selection of variables

②Grouping the variables

③Setting the search range for variable groups

④Setting the search range within the variable group

⑤Building the total structure

She found that it makes possible to interpret easily and to forecast effectively.

We refer this sample and build model.

Where cause and effect relationship is assumed by the order of（Ⅰ）Purchaser⇒（Ⅱ）Extroversion、Usage condition⇒(Ⅲ) Purpose for Usage⇒(Ⅳ)SNS. This means that (Ⅲ) Purpose for Usage for (Ⅳ)SNS is influenced by（Ⅱ）Extroversion and Usage condition, and one's sense of value for these is influenced by the（Ⅰ）Purchaser.

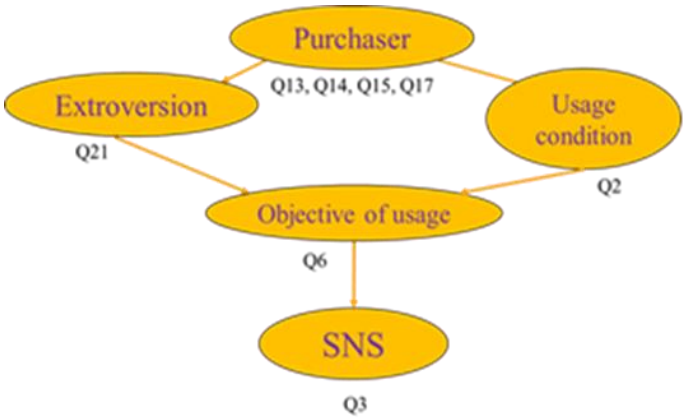

Figure 5.3. Node and Parameter (Source: Takahashi et al, 2008 - Revised by the writer)

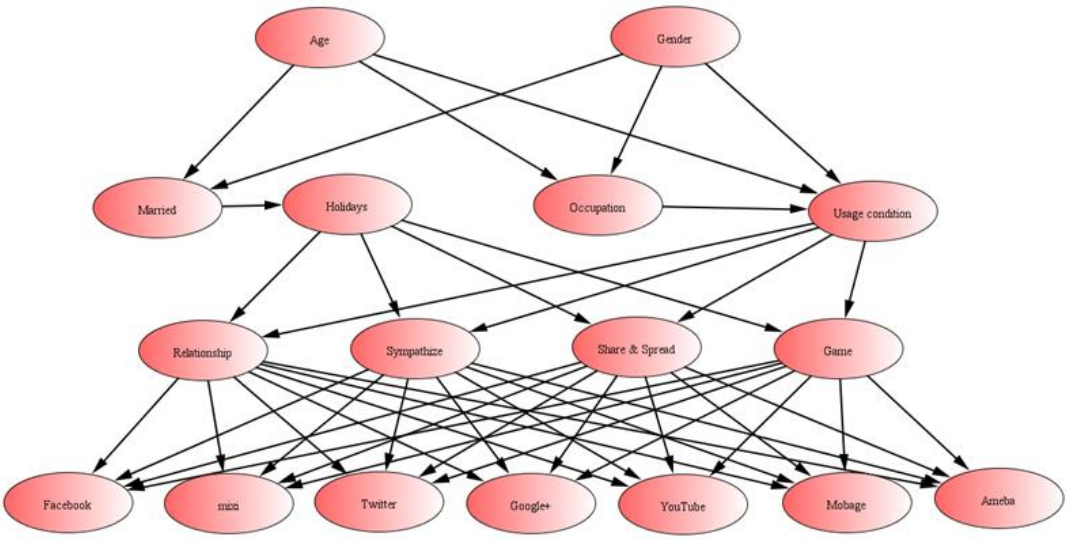

Figure 5.4. Built Model

We used BAYONET software (http://www.msi.co.jp/BAYONET/). When plural nodes exist in the same group, it occurs that causal relationship is hard to set a priori. In that case, BAYONET system set the sequence automatically utilizing AIC standard. Node and parameter of Figure 5.4 are exhibited in Table 5.5.

Table 5.5. Node and Parameter

Group Name	Node in Group	Parameter					
		1	2	3	4	5	6
Purchaser	Gender	Male	Female				
	Age	—30	—50	50—			
	Occupation	Student	Company Employee	School Teacher/Staff	Independents	Part-timers	Others
	Married	Married	Single				
Usage condition	Usage condition	More than 5 times a day	More than 1 times a day	More than 1 times a week	Less than that		
Purpose for Usage	Relationship, Sympathize, Share & Spread, Game	Important	Ordinary level	Not important			
Extroversion	Holidays	Outdoor	Indoor	Cannot choose either			
SNS	Facebook, mixi,	Use	Do not				

	Twitter, Google+, You Tube, Mobage, Ameba	use

To decrease the number of node, "Think so very much" and "Slightly think so" is condensed into one. So does the "Do not think so" and "Slightly not think so". We have chosen 4 sites from Integrated Genre's SNS and each 1 site from Blog Genre SNS, Moving Picture Genre SNS, genre SNS and game genre SNS..

6. Sensitivity Analysis

Bayesian Network calculates Conditional Probability Table (CPT) after inputting the data. Sensitivity analysis of Bayesian Network is executed mainly by the following two methods.

A. Change the value in CPT

Set the certain value in CPT and calculate again. Then the back propagation is executed and Posterior Probability is calculated. From the difference of Prior Probability and Posterior Probability, its influence can be observed.

B. Add new input

If the data is repeatedly inputted, then it becomes a kind of reinforcement learning, in which repeated data I stressed. Posterior Probability is calculated the new coming data (repeated data). Then influence can be observed by comparing Prior Probability with Posterior Probability.

We use A. method and set evidence 1.0 to "Use" for each node in group (Facebook, mixi, Twitter, Google+, You Tube, Mobage, Ameba), then calculate by back propagation method. After that, we obtain Posterior Probability shown in Table 6.1. If it goes up compared with Prior Probability, then we can see the positive influence by "Use" as we have set evidence to the utmost 1.0. If it goes down, then we can see that it has a negative influence in "Use", i.e., "do not use" would increase.

The result of Hypothesis testing for Hypothesis 1 is as follows. "It can be said that in Integrated Genre SNS such as Facebook, users feel interests by sharing the information of current condition with friends." In the Bayesian Network analysis, Evidence 1.0 is set to "Use" in the item of "Facebook" and to "Important" in those of "Relationship". Prior Probability and Posterior Probability is shown in Table 6.1, 6.2.

Hatched parts are the items where Posterior Probability has increased. From the result, we can observe the following feature and/or characteristics.

"Outdoor typed Single male of Student/School Teacher/Independents/Part-timers who like Facebook under 30 use mixi/ Twitter/ Google+/ Mobage/ Ameba more than 1 time a week and make importance of "Share & Spread".

But it includes subtle changes. Therefore we calculate Odds ratio. It is often seen that the change of the probability becomes small when the hierarchical data cluster is distant. Posterior Probability is calculated in the back propagation method. It is often spoken metaphorically that back propagation is a kind of wave after the collision to the wall. Therefore it decreases greatly as it apart from the “wall”. Therefore we take Common logarithm before calculating Odds ratio. Odds ratio is calculated in Table 6.1and 6.2.

Table 6.1. Odds ratio for "Use"

Node	Parameter	Prior Probability		Posterior Probability "Use"		
			Common logarithm		Common logarithm	Odds ratio
Gender	Male	0.5918	0.7642	0.5923	0.7723	1.0953
	Female	0.4082	0.6107	0.4077	0.6096	0.9908
Age	—30	0.4768	0.6776	0.4797	0.6803	1.0251
	—50	0.4487	0.6513	0.4467	0.6493	0.9826
	50—	0.0745	0.8722	0.0735	0.8663	0.9014
Occupation	Student	0.2672	0.4265	0.2699	0.4298	1.0273
	Company Employee	0.5417	0.7324	0.5175	0.7135	0.8280
	School Teacher/Staff	0.0399	0.601	0.0421	0.6232	1.2057
	Independents	0.0417	0.6201	0.0459	0.6618	1.4372
	Part-timers	0.0489	0.6893	0.0580	0.7634	2.1151
Married	Married	0.4236	0.6235	0.4172	0.6201	0.9715
	Single	0.5764	0.7513	0.5828	0.7649	1.1599
Usage condition	More than 5 times a day	0.3679	0.5647	0.3120	0.4942	0.5673
	More than 1 times a day	0.4083	0.6107	0.3882	0.5888	0.8332
	More than 1 times a week	0.1745	0.2405	0.1940	0.2878	1.6286
Relationship	Important	0.8242	0.9159	0.8361	0.9222	1.1846
Sympathize		0.3852	0.5885	0.3309	0.5185	0.5670
Share & Spread		0.6140	0.7882	0.6217	0.7931	1.0610
Game		0.2538	0.4031	0.1972	0.2945	0.3821
Holidays	Outdoor	0.3106	0.4914	0.3148	0.4969	1.0450
	Indoor	0.2687	0.4281	0.2594	0.4133	0.8856
Facebook	Use	0.6335	0.8014	1.0000	—	—
mixi		0.4950	0.6946	0.5310	0.7251	1.3450
Twitter		0.4219	0.6243	0.4556	0.658	1.3406
Google+		0.1423	0.1523	0.2056	0.3118	6.3593
You Tube		0.5617	0.7490	0.5369	0.7292	0.8143
Mobage		0.1159	0.0607	0.1730	0.238	23.3601
Ameba		0.1486	0.1703	0.2220	0.3464	6.6672

Table 6.2. Odds ratio for "Important"

Node	Parameter	Prior Probability		Posterior Probability "Important"		
			Common logarithm		Common logarithm	Odds ratio
Gender	Male	0.5918	0.7642	0.5932	0.7731	1.1053
	Female	0.4082	0.6107	0.4068	0.6085	0.9817
Age	—30	0.4768	0.6776	0.4931	0.6928	1.1514
	—50	0.4487	0.6513	0.4364	0.6395	0.9020
	50—	0.0745	0.8722	0.0705	0.8482	0.6703
Occupation	Student	0.2672	0.4265	0.2771	0.4425	1.1391
	Company Employee	0.5417	0.7324	0.516	0.7126	0.8207
	School Teacher/Staff	0.0399	0.6010	0.0409	0.6117	1.0938
	Independents	0.0417	0.6201	0.0441	0.6444	1.2325
	Part-timers	0.0489	0.6893	0.0557	0.7459	1.7507
Married	Married	0.4236	0.6235	0.4095	0.6117	0.9049
	Single	0.5764	0.7513	0.5905	0.7709	1.2407
Usage condition	More than 5 times a day	0.3679	0.5647	0.3443	0.5366	0.7968
	More than 1 times a day	0.4083	0.6107	0.3979	0.5988	0.9052
	More than 1 times a week	0.1745	0.2405	0.1703	0.2304	0.8938
Relationship	Important	0.8242	0.9159	1.0000	—	—
Sympathize		0.3852	0.5885	0.3729	0.5705	0.8626
Share & Spread		0.6140	0.7882	0.5921	0.7723	0.8307
Game		0.2538	0.4031	0.2485	0.3945	0.9308
Holidays	Outdoor	0.3106	0.4914	0.3136	0.4955	1.0333
	Indoor	0.2687	0.4281	0.2651	0.4232	0.9607
Facebook	Use	0.6335	0.8014	0.6593	0.8189	1.2557
mixi		0.4950	0.6946	0.5578	0.7459	1.6658
Twitter		0.4219	0.6243	0.468	0.6702	1.4956
Google+		0.1423	0.1523	0.1878	0.2718	4.3160
You Tube		0.5617	0.7490	0.5421	0.7340	0.8551
Mobage		0.1159	0.0607	0.1592	0.2014	15.2297
Ameba		0.1486	0.1703	0.2092	0.3201	5.2613

When Evidence is set to 1.0 for “Use” in “Facebook”, Odds ratio parts for more than 2.0 are “Part-timers”, “Google+”, “Mobage” and “Ameba”. These have strong correlation for the users of “Facebook”.

When Evidence is set to 1.0 for "Important" in "Relationship", Odds ratio parts for more than 2.0 are "Google+", "Mobage" and "Ameba". These have strong correlation for those who make importance in relationship. These have a similarity in having or constructing relationship with friends.

As is stated before, the change of the probability becomes small when the hierarchical data cluster is distant.

To this point, reinforcement learning, for example, may be one of an improving method to cope with this. As stated before, if the data is repeatedly inputted, then it becomes a kind of reinforcement learning, in which repeated data is stressed. The decrease is improved by this reinforcement learning and we can observe its influence more clearly. For another improving method is to make shallow the depth of the hierarchy of the model.

Thus, utilizing the sensitivity analysis, we can make clear the difference of usage objective and SNS site by the attributes and preference of SNS users. It can be utilized effectively for marketing by clarifying the target customer through the sensitivity analysis.

7. Conclusion

Social Networking Service (SNS) is prevailing rapidly in Japan in recent years. Facebook, mixi and Twitter are the popular one. These are utilized in various field of life together with the convenient tool such as smart-phone.

In this paper, a questionnaire investigation was executed in order to clarify the current usage condition, issues and desired function etc. One of the TRIZ methods was extended and applied. Difference of objective usage and SNS site was made clear by the attributes and preference of SNS users. It can be utilized effectively for marketing by clarifying the target customer though the sensitivity analysis.

Various cases should be examined hereafter.

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Appendix: Questionnaire concerning the SNS

Please answer the following questions. Please write down ○ to the answering items. Plural selection is allowed for the Question 3, 5, 7, 9, 10. Select ①～⑤ of the right column for the Question 6, 11, 12.

1. Do you use the SNS?

Q1 ①YES ②NO * If you answer "②NO", then proceed to Q11, please.

2. How often do you use the SNS?

Q2 ①More than 5 times a day ②Around 3~ 4 times a day ③Around 1~ 2 times a day ④Around 4~ 5 times a week ⑤Around 2~ 3 times a week ⑥Around 1 times a week ⑦Around 2~ 3 times a month ⑧Around 1 times a month ⑨Less than that

3. What kind of the SNS do you use?

Q3 ①Facebook ②mixi ③Twitter ④Google+ ⑤YouTube ⑥Niconico β ⑦Ustream ⑧GREE ⑨Mobage ⑩Hangame ⑪ Ameba ⑫ Taberogu ⑬ KAKAKU.com ⑭ Ameba pico ⑮ myspace ⑯ foursquare ⑰ Orkut ⑱ PowerLink ⑲Life Shot ⑳Miscellaneous ( )

4. What kind of the SNS do you use the most?

( )

5. Why is it?

Q5 ①Able to communicate with friends and acquaintances
②Able to seek old friends and acquaintances
③Able to seek new friends and acquaintances
④Able to agree with/ appreciate the valuable information
⑤Able to collect special and delightful information
⑥Able to browse artists/ celebrities' comments
⑦Able to apply for the campaign
⑧Able to collect/ put out the company's services and service information
⑨Able to collect/ put out hobby and interesting information
⑩Able to post diary, tweets, moving images and photos
⑪Able to play the game (including the online game)
⑫Miscellaneous ( )

6. What are the SNS's interesting and fascinating points?

Importance	Think so very much	Slightly think so	Ordinary level	Slightly not think so	Do not think so
Q6 ①Able to communicate with each other by diary and tweets ②Obtained much opportunities to contact with friends and acquaintances who were under rare contact ③Able to find new friend who has the same hobby and interest via the Net ④Able to get a feeling of intimacy by browsing artists/ celebrities' comments ⑤Able to collect news and information efficiently ⑥Able to share sympathy by joining a group ⑦Able to share hobby and interests with friends and acquaintances ⑧Able to let others know about myself well ⑨Able to control the information for public, which is different from blog ⑩Able to retain the thinking of our own opinion and to make the record ⑪Rich online game ⑫Good for killing time ⑬Miscellaneous ( )	①	②	③	④	⑤

7. How did you come to use the SNS?

Q7 ①To create a new network
②Agree with/ appreciate the valuable information
③To collect information
④Utilize to my business

⑤To apply for the campaign
⑥To Put out and share the information
⑦Sound like fun by posting everything
⑧More easy to handle than those by phone and e-mail
⑨Suggestion by the friends and acquaintances
⑩Acquaintances and friends use them
⑪Became current topics
⑫Miscellaneous ( )

8. How often do you reply to the comments or share photos and news?

Q8 ①Every time ②Frequently ③Sometimes ④Scarcely ⑤Never

9. What kind of the SNS are you going to continue to use?

Q9 ①Facebook ②mixi ③Twitter ④Google+ ⑤YouTube ⑥Niconico β ⑦Ustream ⑧GREE ⑨Mobage ⑩Hangame ⑪ Ameba ⑫ Taberogu ⑬ KAKAKU.com ⑭ Ameba pico ⑮ myspace ⑯ foursquare ⑰ Orkut ⑱ PowerLink ⑲Life Shot ⑳Miscellaneous ( )

10. Why is it?

Q10 ①Want to enrich communication with friends and acquaintances
②Want to seek old friends and acquaintances
③Want to seek new friends and acquaintances
④Want to agree with/ appreciate the valuable information
⑤Want to collect beneficial and delightful information
⑥Want to browse artists/ celebrities' comments
⑦Want to apply for the campaign
⑧Want to collect/ put out the company's services and service information
⑨Want to collect/ put out hobby and interesting information
⑩Want to continue posting diary, tweets, moving images and photos
⑪Want to play the new game (including the online game)
⑫Miscellaneous ( )

11. Why don't you use the SNS?

Importance	Think so very much	Slightly think so	Ordinary level	Slightly not think so	Do not think so
Q11 ①Do not have interest ②Interesting but do not know how to use ③Anxious about security concerning individual information ④Anxious about fee ⑤Surrounding people do not use them ⑥Become poor in human communication ⑦Will waste a lot of time ⑧Feel uneasy how friends and acquaintances make response ⑨Cannot continue because it is too bothering ⑩Likely to increase the spam e-mail ⑪Miscellaneous ( )	①	②	③	④	⑤

12. What do you expect the SNS in the future?

Importance	Think so very much	Slightly think so	Ordinary level	Slightly not think so	Do not think so

Q12 ①Make full communication with friends and acquaintances ②Want to seek old friends, acquaintances and new friends ③Encounter the friend/lover of opposite sex ④Provide the valuable information ⑤Enrich the collection of information ⑥Have a space/ field for exchanging opinion about goods, service and politics ⑦Gather interesting information ⑧To disclose the information of himself ⑨To make perfect the security of individual information ⑩Easiness in using ⑪Restrict the writing in board by others ⑫Interconnection among SNS functions ⑬Miscellaneous ( )	①	②	③	④	⑤

About yourself

Q13 <Gender> ①Male ②Female
Q14 <Age> ( ) years old
Q15 <Occupation> ①Student ②Government Employee ③Company Employee ④School Teacher/Staff ⑤Clerk of Organization ⑥Independents ⑦Temporary Employee ⑧Part-timers ⑨Miscellaneous ( )
Q16<Address> Prefecture : ( ) City : ( )
Q17<Are you married?> ①Married ②Single
Q18<How many children do you have?> ( )
Q19<Are you positive to do anything?> ①Positive ②Somewhat positive ③Ordinary level ④Somewhat passive ⑤Not positive
Q20< Do you like to play with many others?>①Think so very much ②Slightly think so ③Ordinary level ④Slightly not think so ⑤Do not think so
Q21<How do you spend holidays?> ①Outdoor ②Indoor ③Cannot choose either
Q22<What is the most important thing to you?> ① Affection ② Safety and security ③ Honor ④ Clothes/Eating/House⑤Self-realization ⑥Contribution to society ⑦Recognized from others ⑧Miscellaneous ( )

The figure below is an on-line data gathering Form for Questionnaire Investigation.

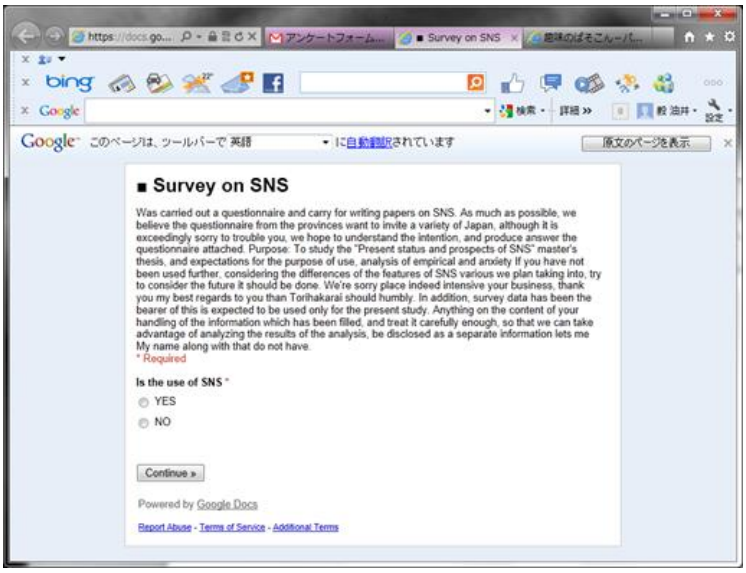

Figure. On-line data gathering Form for Questionnaire Investigation, https://docs.google.com

Paper ID: 30

Based on TRIZ Functional Analysis for Utility Model Patents Design Around

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Abstract

Utility model patent, which provides the new technical solution by refer to the product's shape, structure or the combination of its shape and structure, is commonly known as "petty patent". Within the framework of the principle of legal infringement, utility model patent design around is proposed according to the characteristics of utility model patent, by using of the functional analysis of TRIZ theory in this paper. Firstly, the principle of the utility model patent design around is introduced. Secondly, the six steps of the proposed patent design around process are deduced. Thirdly, an example for the utility model patent design around is to be validated the proposed patent design around method, and the result indicates the proposed patent around method can be used for utility model patents.

Keywords: Utility model patent, patent design around, TRIZ, functional analysis

1. Introduction

Utility model patent, which proposes the new technical solution by refer to the product's shape, structure or the combination of its shape and structure, is commonly known as "petty patent". Utility model patent, which is regarded as an independent part of the object protected by intellectual property, encourages the low-cost and short cycle innovation activities, serves the company's intellectual property strategic target as the peripheral patent, to improve the competitiveness of enterprises with other core patents.

SCHECHTER(2003) defined the patent around as an enterprise develops the new design process to avoid other competitor's patents' attacks or hinges. Integrating the TRIZ innovative methods with the legal avoidance strategy is a new research direction, attracted by many researchers in recent years. Shangzhi Liu (1998) combined a range of methods with the legal strategy to patent design around. Xiangtang Zhang (2006) used the patent technical matrix and TRIZ method to find the key components to patent design around. The patent law of China defines several kinds of patents, such as pioneering invention, combination invention, selection invention, and so on, what's more, there are product patent and method patent in invention patents. Though the different types of patents have different

characteristics, the patent design around process by using of TRIZ theory does not distinguish them.

According to the characteristics of utility model patent, the patent design around is proposed in this paper. Within the framework of the principle of legal infringement, a patent design around, which is different with the target patent, is proposed by using of the functional analysis of TRIZ theory, and the detailed steps for utility model patent design around are introduced, and validated by an example patents in this paper.

2. The Principle of the Utility Model Patent Design around

Actually, the successful patent design around is a process, which meets the legal requirements and bypasses the patent infringement judgment of the legal principles. The mainly judgment principles of the patents infringement are the principle of comprehensive coverage, the principle of equivalents, the principle of estoppels and the principle of contribution. Utility model patents and invention patent are both applied in the same infringement judgment. Comparing with the invention patents, the patent law of China has lower requirements in creative for utility model patents, in another word, invention patents needs the characteristics of the prominent substantive feature and significant process, while, utility model patents just needs a prominent feature and progressive. The necessary technical features of the target patent are regarded as the patent design around base. And each necessary technical feature is an information base, which includes the components and the relationship between components. According to the above difference between invention patents and utility model patents, the principles of patent design around for utility model patents are as following:

1) To satisfy the principle of comprehensive coverage by reducing the number of information base.
2) The improved information base should be satisfied the substantive features. That's mean the improved technical program should include the information base, which has neither identical nor equivalent technical features with the target patent's technical program.
3) Others information bases can use of existing technology or base on the technical program, which are published into public domain for the estoppels principle and contribution principle.
4) For utility model patent, the non-equivalent technical features, which have the substantive features, may be outside of the present technique field, or may be non-apparent technical in the present technique field.

3. Utility model patents design around based on function analysis

Functional analysis originated from GE engineer L.D.Miles, who was done the value engineering analysis in 1947, and found that customer bought is not the product itself, but the functions of the product. Functional analysis is an important tool in TRIZ theoretical (Tan Runhua. 2004). The function model of product can be established by decomposing the system, and the standard, insufficient, excess and harmful functions can be obtained. And the function model can be used to determine the relationship between the parts, the main function of the system, and the contribution for the system

functions of each component, therefore, the functional analysis can be analyzed the target patent as the refine structure and the relationship between parts of the target patent.

Utility model patent is a new technical program for the shape and structure of product, the results of function analysis fit with utility model patent's features. The weaknesses or vulnerabilities in target utility model patent can be obtained by functional analysis, in this way, the utility model patent design around can be achieved.

Utility model patent design around based by functional analysis includes six steps, that are the choice of target patent, interpreting the target patent claims, the stability analysis of target patent, functional analysis model, solving the problem by using Triz theory and evaluating the designed patent, in this paper.

The detailed patent design around process is as following:

▪3.1 Choosing the target utility model patent

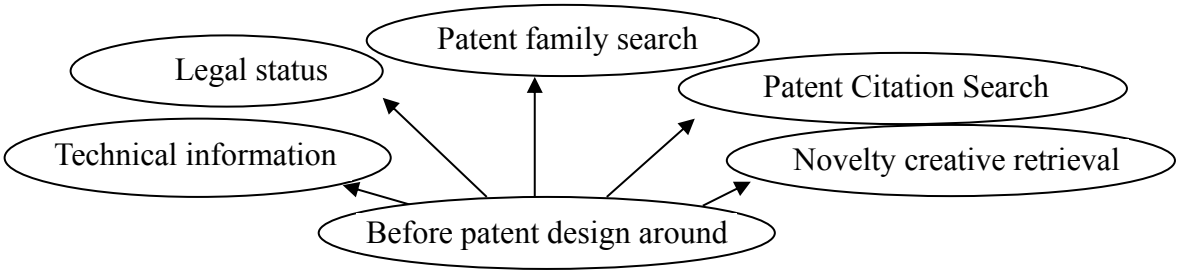

Figure 1. The search direction.

The choice of target utility model patents needs the help of patent search and analysis. Different purposes, different patent search methods, different purpose, have a different analysis strategies, the former need to develop a search strategy, the latter need to develop the patent map. The patent map can determine the specific patent, which need patent design around, within the whole patent intellectual property strategy of the enterprise. The search direction for the target patent is shown in Figure.1.

The target utility model patent can be determined by patent layout. The purpose of patent layout is to ascertain the technical heights, to investigate the geographical distribution and legal status of the target patents, then, to find the right point by combination the characteristics of enterprise itself, and provide the direction for the patent design around.

▪3.2 Interpreting the target patent claims information

Interpreting the target patent claims information is the key step to achieve the patent design around. The claims of the target patent can be explained by using of the specification, drawings,

Related claims, and the patent review the files, in accordance with the law. According to the judicial interpretation from China Supreme Court, the correct interpretation of the claim need to determine the following elements:

1) Determination of the three elements of the invention. The technical problems (implicit technical field), the technical solutions and the technical effect constitute an invention, while three elements is a unified whole, and the logic relationship exists between themself.

2) Technical characteristics contributed by the donated principle. The technical program is disclosed in the instrument, but it is not written into the claims, and it may be hidden in the embodiment example.

3) The technical features contributed by the estoppels principle. The technical programs are given up for amendment of the claims and instrument, when the patent is examined, replied, invalidated during the patent application process.

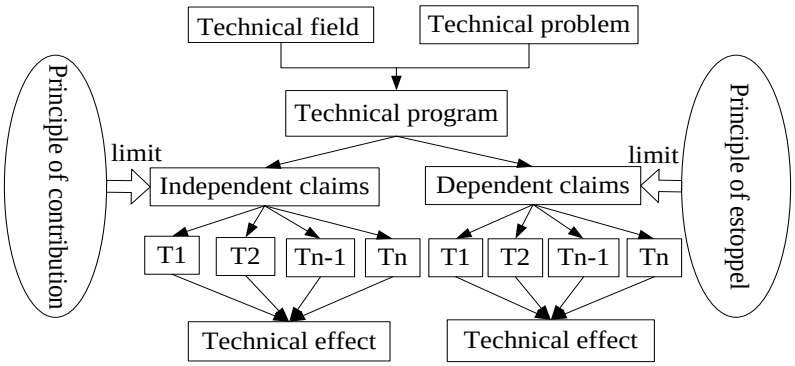

Figure 2. The interpreting process

The interpretation model for the target patent is shown in Figure.2. Firstly, the technical field of the target patent and the solved technical problems should be determined. Secondly, the technical programs, which include the technical programs not only from independent claims but also from the dependent claims, are determined to solve the technical problems. Each claim contain certain necessary technical features T_1 ,T_2 ,T_{n-1} and T_n. Each necessary technical feature is regarded as an information base, and the set of the information bases can determine the technical program to solve the technical problems. Considering the protection scope of the independent claims is the widest, so the independent claims are selected as the technical program design around. Finally, the technical effect can be determined by the set of information bases. It is notice that the technical feature disclosed in specification but not written in the claims, or the technical feature abandoned by the patentee in the patent review files can limit the technical program of the claim of the target patent.

▪3.3 Analyzing the stability of the target patent

The patent documents are rigorous technical legal document, and any errors are likely to make the patent to loss its due legal effect. The patent documents should not only comply with the legal requirement, but also have stable rights. The utility model patent in china is not carried out the real trial, therefore, according to the target patents, the effectiveness of stability analysis should be done before the patent design around.

The datura squared figure diagram can be established around for the invalid patents. The datura squared figure diagram can investigate the elements, which lead the patent to invalid. The value of the patent design around for the target patent can be evaluated by search the patents which are the similar to the target patent, and obtain a set of patents to solve the same technical question.

The exactly directions are shown in Figure.3

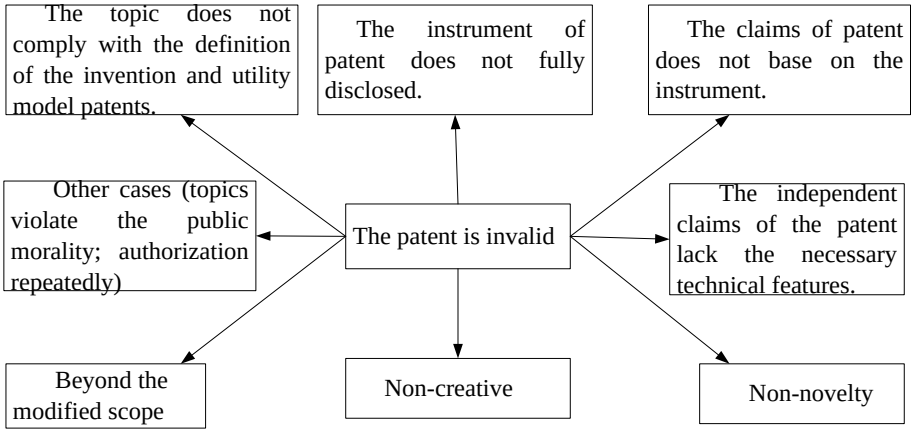

Figure.3 The stability analysis model for the target patent

The revelation of the closest technology and the patent document which can obtain the combination revelatory can be indexed by tracking and positioning the comparison files, which are got by focusing on the novelty and inventive search. The stability for the files of the target or obstacles patent is evaluated by using of the comparison files and the datura squared Figure. Once the target patent is invalidated, the invalidation procedures should be provided. After the evaluation the stability of the target patent, the stability analysis can be as the preparation for the patent design around.

▪3.4 Functional modeling and analysis

Functional analysis is carried out by functional modeling. Function model is one of the important analysis tools in TRIZ theory. The specific process is to first determine the overall function of the product, then the total function of the product can be decomposed many sub-functions. Finally, the total functions and sub-functions forms the function tree, in this way, the product functional structure can be established.

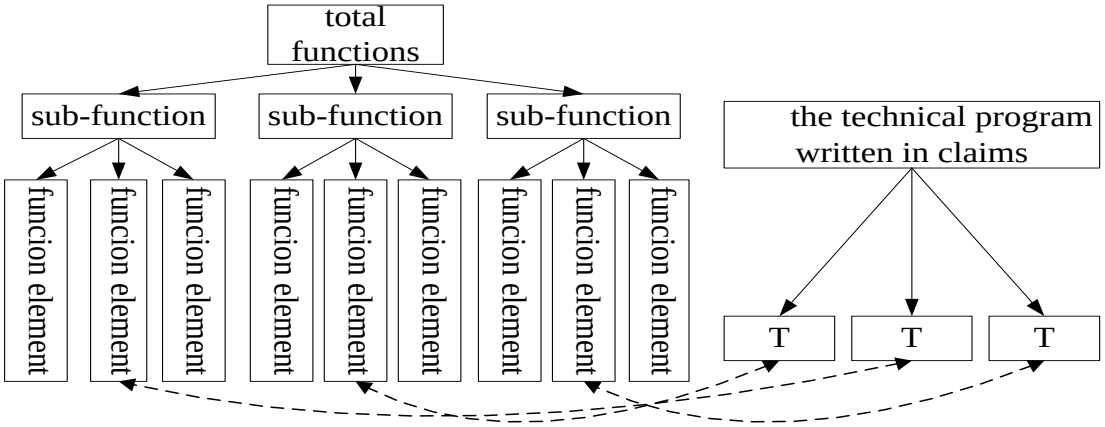

Figure.4 The match relationship between the diagrams of technical program of the patent claims

Each the necessary technical feature contains the elements and the connection relationship between the elements, which is the base for function model. The corresponding functional elements can be found in product structure diagram, then to analyze the existing problems and list the problem set. The match relationship between the diagram of technical program of the patent claims and functional tree is shown in Figure.4.

▪3.5 Solving questions by TRIZ theory

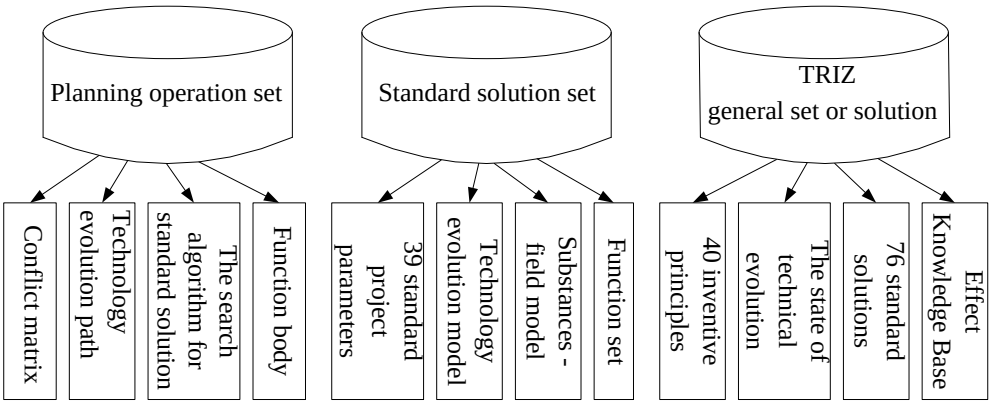

Figure.5 The standard solutions by TRIZ

The main problems confirmed in step 4 can be transferred as the TRIZ standard problems and solved by TRIZ tools. The solving problem process by classic TRIZ tool is that, the problems are transferred the TRIZ standard problem set by using of the problem analysis tool in planning operation set, then, TRIZ general set or solution can be obtained by TRIZ tool. The innovation technical program generates by analogy to the standard solution. The solving progress is shown in Figure.5

▪3.6 Evaluating the technical program

Each innovative technical program should be evaluated by according to the legal principles and evaluation index. If the case complies with the infringement judgment principles, the evaluation result

is Yes, or the result is "NO". The patents designed around can be evaluated according to the following process, and the detailed evaluation process is shown in Figure.1.

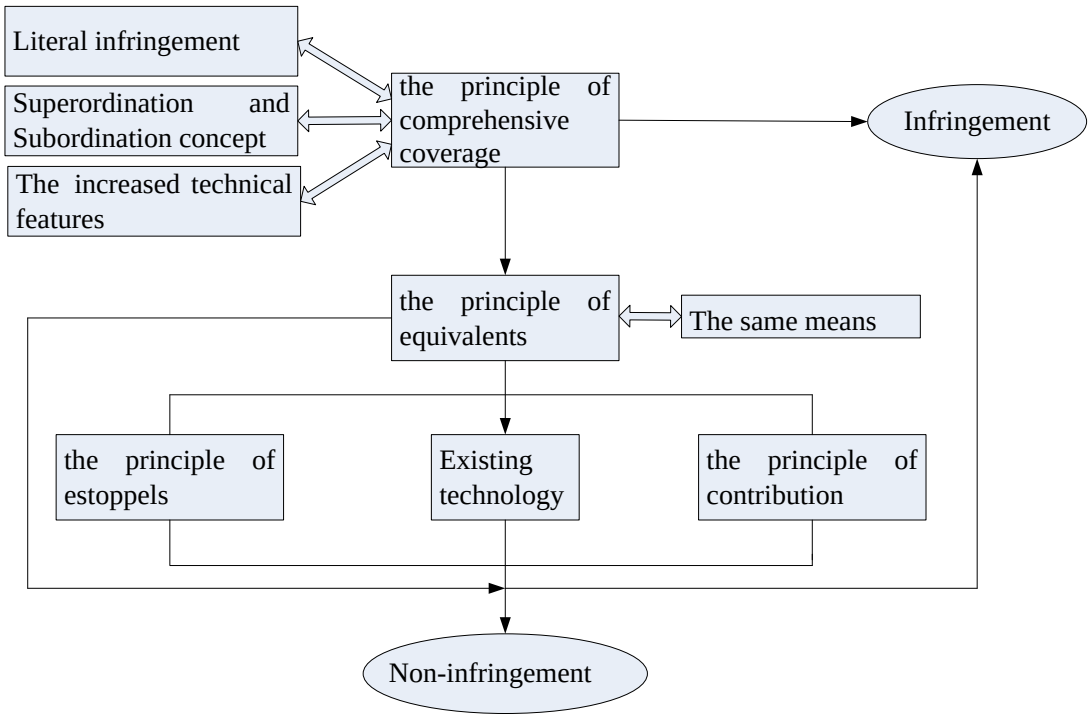

Figure.6 The evaluation process

4. The project example

▪4.1 Choosing the target patent

The utility model patent named the flour mixer used for vermicelli, its' patent number is ZL200520031671.0, is chosen as the target patent. The following steps are to illustrate the process of the utility patent design around.

▪4.2 Interpreting the claim target patent

The target utility model patent (ZL200520031671.0) can be extracted the important information, shown in Figure.7. T_1 is frame, T_2 is the driven motor, T_3 is the hopper of the inlet and outlet mounted in the upper of the frame, T_4 is the convey stirring device mounted horizontally in the hopper, and driven by the motor, T_5 is the two interlinked U-shaped mixer's buckets mounted above the feed port of the frame of the flour mixer, while the bottom of one of the U-shaped mixer's buckets is connected with the out-feed port, and T_6 is the mixing hammer located respectively up frame in each of the U-shaped bucket, and the support frame of the two mixing hammers are connected with the driven shaft of motor by the crank linkage. The limited 1 means with the dough increasing in one of the U-shaped dough bucket, the dough mixed by the mixing hammer is forced to the anther U-shaped dough bucket for the two U-shaped dough bucket linked each other. The limited 2 means the attached drawing shown

the two mixing hammers share one support frame, and the two mixing hammers mount separately on the ends of the support frame, the crank linkage drives the two mixing hammers move up-down reciprocate motion, and the crank linkage connects in the middle of the support frame.

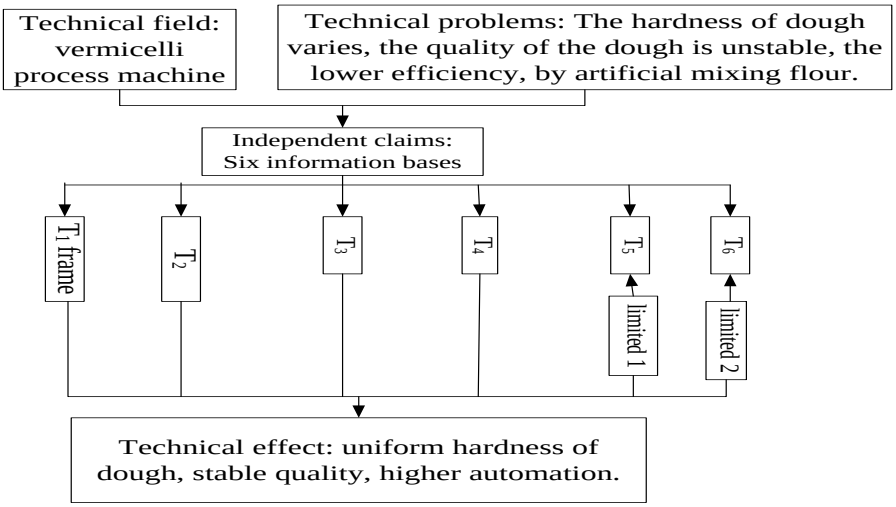

Figure.7 The evaluation process

▪4.3 Analyzing the stability of the target patent

The stability of the target patent (ZL200520031671.0) is analyzed by the stability analysis model, and each of necessary direction is listed in Figure.1.

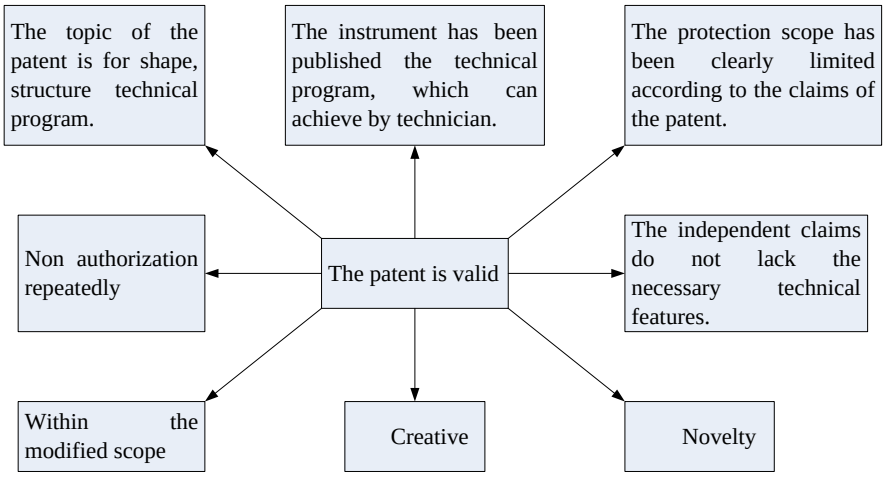

Figure.8 The evaluation process

▪4.4 Function modeling for the target patent

The total functions of the flour mixer are shown in Figure.9:

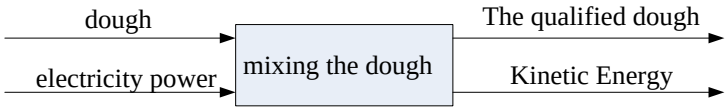

Figure.9 The evaluation process

The functional structure of the flour mixer is shown in Figure.10:

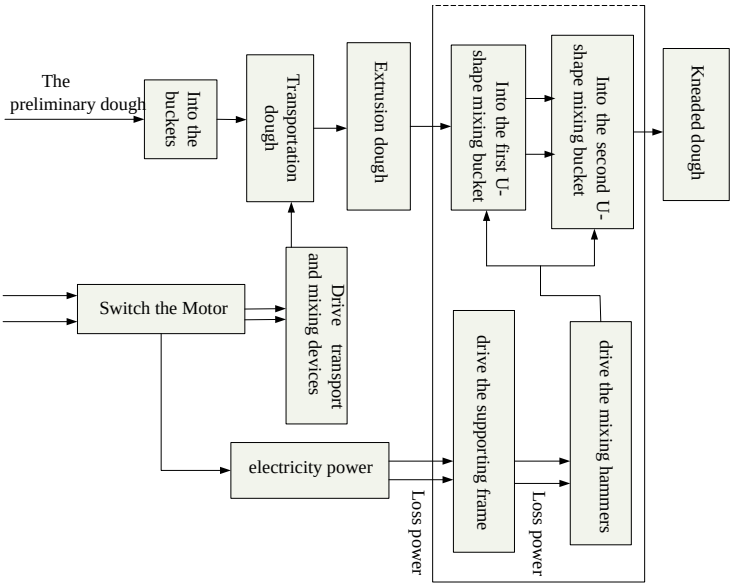

Figure.10 The evaluation process

The content in the dotted rectangle is matched with the fifth information base T5 in the patent claims. The information base T5 means the two interlinked U-shaped mixer's buckets mounted above the feed port of the frame of the flour mixer, while the bottom of one of the U-shaped mixer's buckets is connected with the out-feed port. The information from the information base T5 corresponds to the technical features reflected from the dotted rectangle in the functional model. The main problem of the system is that, the two hammers should be started simultaneously, moved in the same direction with the vertical reciprocating movement process, noise and waste power.

▪4.5 Solving the problem by TRIZ theory

The main problems of the above system can be converted it into TRIZ standard questions. The necessary improvement characteristics of the system is the time loss and the deterioration characteristics of the system is complexity and the power. The conflict matrix is used to find the solutions, and the principles of the invention are 10, 6, 20, 35 items. The 20 item, which means the continuity application effectively, is used in the patent design around.

Therefore, the ideal solution is that, each of the two hammers has a support frame, and the two frames of the two hammers are connected by a lever. And one of the frames is driven by the crank

linkage and power driven device, in this way, the two hammers can be moved with the reverse down reciprocating motion.

The patent No. 200 620 175 922, also named the flour mixer used for vermicelli, adopts the above TRIZ ideal solution.

▪4.6 Evaluating the patent design around

The technical program of the patent (No. 200 620 175 922) design around has completely different information base with the target patent (ZL200520031671.0), so the comprehensive coverage principle is not applied in the patent design around.

Comparing with the two technical programs, each of the information bases of themselves has the different techniques and program, so the effects are also different. Meantime, the technical program of the patent design around cannot be achieved without creative effort. Therefore, the equivalents principles are not applied in the patent design around. And the patent design around is successful.

5. Conclusion

Utility model patent design is a kind of innovative design to circumvent the scope of protection of utility model patents. The target patent is interpreted correctly by using of the characteristics of the utility model patent in patent law. The technical problems, which should be solved, obtained by functional model, the ideal solution is got by using of TRIZ theory, the ideal solution is also evaluated by using of the legal analysis to judge the infringement action, in this way, the ideal technical solution can be protect by the patent law to around the target patent.

The utility model patent named flour mixer for vermicelli is illustrated as the target patent, the patent design steps are analyzed, and the new better structure of the flour mixer is achieved by using the proposed innovation method.

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Idea creation system & intensive thinking activities with TRIZ in industrial company

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Abstract

In this work, TRIZ activities including training course and process of creating ideas and its adoption into problem solution which are happening in an industrial company are described. Samsung Electronics is one of those companies and there is a well-established TRIZ education system having different level courses such as beginner, practitioner, expert and professional. Employees having finished expert course can adopt TRIZ methodology to solving some real problems of their work and are also collaborating with others by consulting their projects. Moreover, intensive thinking activities with TRIZ called "Eureka" have been found to be effective and powerful to create ideas and solve problems.

Keywords: TRIZ, Eureka, Intensive thinking

1. Introduction

Since Samsung Electronics introduced TRIZ into the company about fifteen years ago (Kim et al., 2005), it has taught TRIZ to the employees to solve real problems in their work more efficiently. Samsung Electronics had already adopted a few of innovative tools before TRIZ was introduced. However, TRIZ was a different kind of methodologies to give concrete technical solutions, so it has strongly attracted a lot of attentions from many engineers. Samsung Electronics has developed TRIZ education programs to train the engineers effectively and systematically (Lee, J. -Y., 2010), which is combined with employee`s evaluation and it has been a good motivation. By the way, Samsung Electronics has owned an internal knowledge management system (KMS) and it consists of various kinds of knowledge databases. Samsung Patent Searching System (SPSS) is a patent searching system in the KMS, which it has proven to be a very strong tool when it uses for TRIZ applications. "Eureka" named after an anecdote of Archimedes is intensive thinking activities using SPSS and TRIZ, which has been generated by Device Solution (DS) division and extended to other divisions in Samsung Electronics. A lot of engineers have found Eureka effective and powerful. In this study, TRIZ education system of Samsung Electronics has been elaborated and effects of Eureka have been described.

2. TRIZ education system of Samsung Electronics

In Samsung Electronics, TRIZ education system has been established by Samsung TRIZ Association (STA) since about ten years ago. In the beginning stage, TRIZ education consisted of three courses but now there are four main education courses such as beginner, practitioner, expert and professional. Since two years ago, managing department of education has moved to the Samsung Advanced Technology Training Institute (SATTI) from STA, while some practitioner courses are managed by DS division doing semiconductor business, which is oriented toward semiconductor manufacturing and its technical problem solutions.

▪2.1 Details of TRIZ education courses

Beginner course is the first level which one is going to learn TRIZ and it is the first e-learning education for TRIZ that has ever developed in Korea. One who wants to study beginner TRIZ should sign up at an internal education website. Because it is online education, one who has registered it can study at any places where can connect to internet, no matter what it is at the offices or home. Beginner course consists of basic concepts and classical problem solving methodologies of TRIZ, which it has to be done in one month and its learning fee is supported by the employment insurance of the government. If one does not finish it in one month, he or she has penalty, which he or she has to pay its learning fee by oneself.

Next level of education after finishing beginner course is the practitioner course, which consists of four working days. SATTI is holding about ten classes during one year with twenty students in each class. Practitioner courses are mainly held at SATTI and some of them are separately held at DS division. Most of semiconductor engineers who want to join practitioner classes are registering at DS division too, which is more advantageous to them than SATTI because they have a chance to learn some examples of semiconductor technical solutions. Practitioner course consists of using basic tools of TRIZ including some quiz and practice of solving on-hands projects by group activities in the class. Finishing practitioner class, everyone has to do an assignment doing a project related to one`s work. Topics of assignments are chosen as having contradictions. A template file is given, which is covering most of basic tools of TRIZ such as function analysis, root-cause analysis (RCA), technical contradiction, physical contradiction and Su-Field models. All the assignment should be saved to an internal KMS called Samsung value creation system (SVS), which can be searched by any others and can give inspiration to them. After completion of practitioner course, they are entitled with level-1.

Expert course is for getting the level-2 certificate officially approved by the International TRIZ association (MATRIZ). An interesting thing is that the qualified as level-2 has a benefit with evaluation of the company, which they get a point for the promotion and is a good motivation. Expert courses are holding at SATTI for a couples of times in a year and each class have about fewer than twenty students. In the expert course, the students learn a lot of TRIZ concepts such as ARIZ, function oriented search (FOS) and resource analysis and how to use the Goldfire Innovator software by Invention Machine Corp. After finishing the class, one has to do an assignment and upload its results to the SVS at the

end, which is same with that of practitioner`s. At the end of every year, the assignments of expert course are reviewed for getting the certificate. The students who attended the expert courses have to present their assignments and defend themselves in front of reviewers having level-3 certificates of TRIZ in the company. After getting level-2 certificate, their employee`s evaluation points are given and they have to do at least a project to keep the point in every year. Those who have got level-2 certificates start doing roles as the TRIZ specialists, which some of them give a lecture of TRIZ to lower level classes while others do consulting internal projects.

The last education of TRIZ is professional course which is holding for getting level-3 certificate from MATRIZ. It is holding at SATTI and STA. Because its educational term is eight months long, ones who are attending the course have to leave their jobs during that period and can focus on that course. The curriculum consists of three big parts, which are creative leadership, advanced TRIZ methodologies and research activity as a specialist. In the creative leadership part, a lot of innovation skills and tools including facilitation, business innovation and creative methodologies are taught to the students. Advanced TRIZ methodologies part includes patent, modern TRIZ methodologies, IDM-TRIZ, G3:ID TRIZ, software related TRIZ and benchmarking of TRIZ technical solutions. TRIZ specialist research activities consist of consulting strategic projects of business divisions, giving lectures and researching of a topic related innovation. In October, reviews on getting level-3 certificate approval are held, which they are asked to make presentation on their paper, consulting results and other activities. Employee`s evaluation points are also given to ones who are getting the level-3 certificate. After eight months course finishes, the participants go back to their work again, and they play roles as TRIZ consultants.

Those four TRIZ education courses are summarized in Table 1.

Table 1. TRIZ education system of Samsung Electronics.

Education courses	Beginner	Practitioner	Expert	Professional
Certificate of MATRIZ	-	-	Level-2	Level-3
Education terms	1 month online learning	4 days	5 days	8 months
Education institute	STA	SATTI / DS	SATTI	SATTI
Education contents	Basic concepts of TRIZ	Classical TRIZ	ARIZ, FOS, Goldfire innovator, etc.	Innovation tools, Advanced TRIZ, Research activity
Assignments	Quiz / Test	Test / one project	Test / one project / presentation	Test / paper/ consulting/ presentation
Employee`s evaluation point	-	-	O	O

▪2.2 Trends of TRIZ education in Samsung Electronics

TRIZ education participants in DS division have been investigated. The results are found in Figure 1. When online beginner course has started in 2005, participants were under one hundred but from its next year the number of participants have increased rapidly to a few hundreds. Until 2012, cumulative participants having joined beginner course are about five thousand people. In 2012, whole number of TRIZ education participants of Samsung Electronics is also indicated in Figure 1, which beginner course is four times larger than DS.

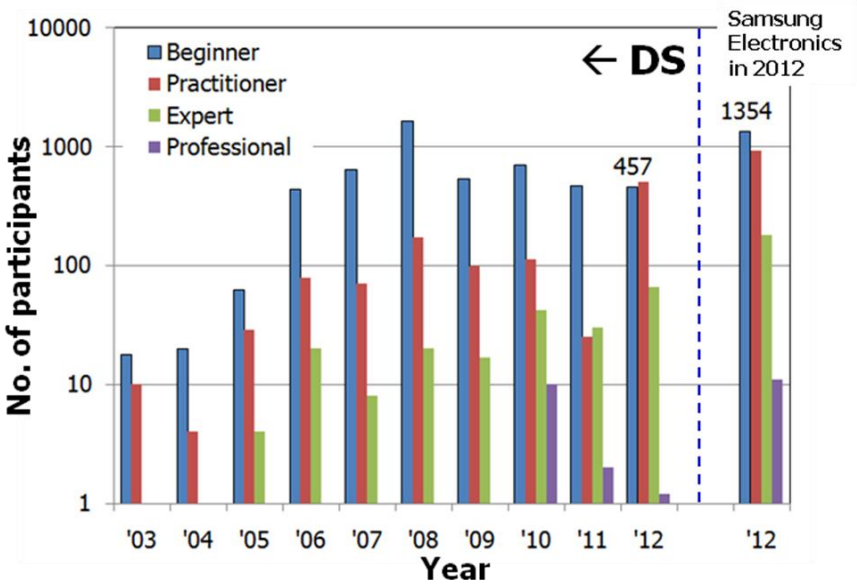


Figure 1. TRIZ education participants' trends in DS

Cumulative participants' numbers of 2012 are 22,984 of beginner course, 3,588 of practitioner course, 656 of expert course and 59 of professional course.

In Figure 2, trends of TRIZ certificates in DS are shown. From 2006, the number of level-2 is increasing, while that of level-3 is still fewer but is expected to increase because more level-2 certificates want to get level-3. Whole certicate-2 & 3 numbers of Samsung Electronics in 2012 are 196 and 11 respectively. Cumulative certificates in Samsung Electronics are 576 of level-2 and 52 of level-3 in 2012.

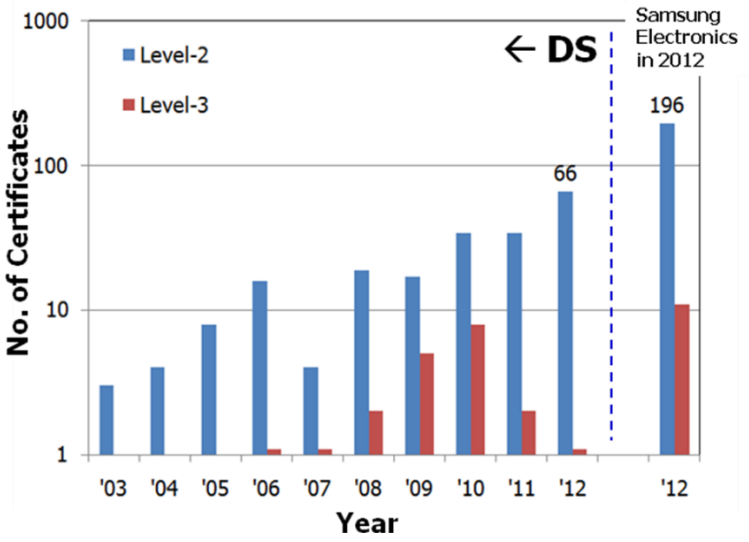
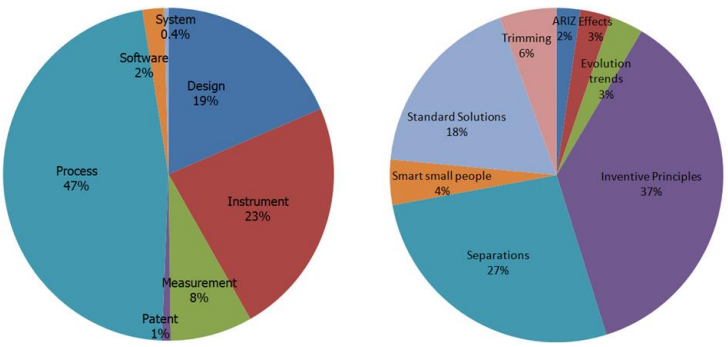


Figure 2. Trends of TRIZ certificates level-2(blue) and level-3(red) in DS

Figure 3 are showing what fields are tried and what methodologies have been used in 372 TRIZ projects performed in DS from 2010 to 2012. The biggest part of TRIZ project`s fields are 47% of process, 23% of instrument, 19% of design and 8% of measurement, which is found in Figure 3(a). As for the methodologies of TRIZ projects, 37% of inventive principles, 27% of separations and 18% of standard solutions have been used, which is found in Figure 3(b).



(a) Fields of TRIZ (b) Methodologies of TRIZ

Figure 3. 372 TRIZ projects performed in DS from 2010 to 2013 classified as in (a) fields and (b) methodologies

3. Eureka, intensive thinking activities in Samsung Electronics

Samsung Electronics is one of leading companies in semiconductor manufacturing, which semiconductor`s nano-scale process technology is critically important. In last couples of years, semiconductor process technology has dramatically developed to realize unbelievable level of shrinkage in scale, which has become more and more difficult and needed breakthrough to overcome a lot of hurdles. Recently, Semiconductor Research & Development Center (SRD) of Samsung Electronics which has made a huge role of developing critical semiconductor process technology and

had biggest number of TRIZ certificates over DS has needed a lot of innovation to go further in process technology.

Eureka is an innovation as intensive thinking activities which SRD has started for the first time in Samsung Electronics since 2012 and currently SATTI has also introduced it to its curriculum. SATTI has combined Eureka with expert course, which makes the participants to join just after the expert course. Other business divisions are also going to introduce it to their own educational programs. Eureka is named after an anecdote of Archimedes, a famous ancient Greek mathematician who found the Archimedes`s principle. Known as Archimedes`s anecdote, Eureka is intensive thinking activities for solving of technical problems. Engineers in SRD have to resolve their own projects which mostly have many technical contradictions to solve. Eureka is holding for two working days, which ones attending Eureka have to move away from their daily lives during two days and gather at a room equipped with individual personal computers. In the room, they learn some skills how to use SIMPS, Goldfire Innovator and FOS. SIMPS and Goldfire are used as tools for patent searching, scientific effects. With help of SPSS, participants search patents which are original, derivatives and referred, which they try to find new ideas with considering those patents. FOS is utilized for searching ideas which is assumed to be already realized in far area expertise. Some of the participants have joined TRIZ practitioner course already but some have not, however it does not matter. They just bring their own technical problems and define technical contradictions, and search ideas and patents using those three kinds of tools. In Table 2, the tools used in Eureka are summarized.

Table 2. Tools using in Eureka.

<table>
<tr><th>Patent / Scientific Effects</th><th>Far Area Expertise</th></tr>
<tr><td>SPSS
(Samsung IP Management System)</td><td rowspan="2">FOS
(Function Oriented Search)</td></tr>
<tr><td>Goldfire Innovator</td></tr>
</table>

Widely known as Gen3 Partners has started to do FOS, FOS is a very powerful tool to search ideas existing in other areas (Litvin, S. S., 2005), which is possible with using internet or commercial searching tools. By the way, SPSS is an internal patent searching system, which is also able to use as a searching tool for FOS. First, defining a problem of one`s project is done and then, figuring out key problems and function of a system in the project is performed. After that, generalizing of function and problem is done and some keywords for them are put in SPSS. Then, SPSS shows quite a lot of searching results. And its narrow downing step using International Patent Classification (IPC) codes is done by SPSS. Then, SPSS shows patents ranking in far area and deciding of leading ideas is done with brainstorming. As a result, a list of ideas is obtained by SPSS and creating ideas adapting to the key problems is done.

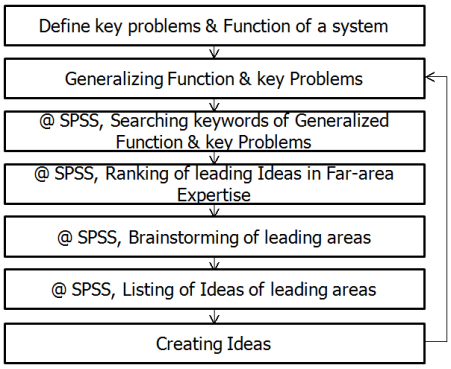


Figure 4. Procedure of FOS with SPSS

These procedures can easily repeat to find a lot of good ideas. To investigate effects of Eureka, questionnaires have been completed by the participants, which were asking about satisfaction to Eureka activities and helpful to solving technical problems. The results are described in Figure.5, which says that most participants answered satisfaction very high & high and helpful to solving technical problems very high & high.

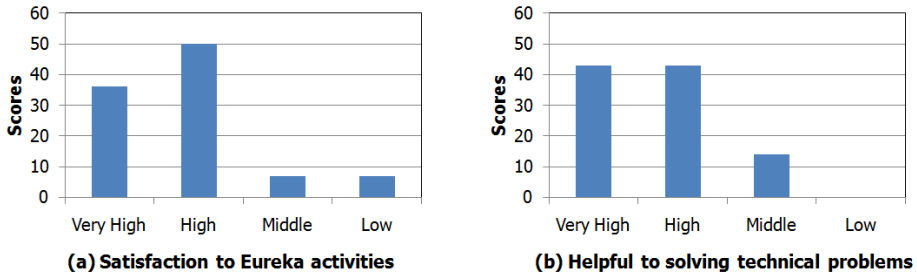


Figure 5. Effects of Eureka activities with questionnaires of (a) satisfaction to Eureka activities and (b) Helpful to solving technical problems

4. Conclusions

TRIZ education system of Samsung Electronics has been described. Some trends of TRIZ education were investigated, which TRIZ education participants and MATRIZ certificates are continuously increasing. Eureka activities pursuing technical solutions have been explained. SPSS, Goldfire and FOS are tools used in Eureka, which a procedure of FOS combining with SPSS has been shown. Results of questionnaires to Eureka participants were very satisfactory and helpful.

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An expression of ideality based on TRIZ, Extenics and Lattice Theory

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Abstract:
There are many defects in the formula of Ideality=∑[Benefits/(Costs+Harms)] in TRIZ. Firstly, it is unrealistic to calculate the ideality because of the non-unity dimension of the numerator and the denominator. Secondly, the result of the ideality always tends to be zero for there are infinite harms in almost any artifacts. Thirdly, it can be confusing to some extent when the numerator and the denominator changes in the same direction. Besides, there are only few studies that tie the formula of ideality with technology evolution theory. In order to solve this problem, based on the existing studies of the authors, this paper is going to propose a new expression by integrating Extenics and Lattice Theory. This expression can not only eliminate most of these defects, but also provide a visual relationship between the ideality and the technology evolution theory with the help of Hasse Diagram from Lattice Theory. This paper will investigate the application of this expression of ideality at different levels of an artifact, and explain the mechanism of ideality increasing in a variety of technology innovation such as disruptive innovation in more detail. The contributions of this paper contains:

a. revealing the characteristics of ideality changing at different levels of an artifact;

b. relating ideality increasing to some new technology innovation modes such as disruptive innovation.

Keywords: TRIZ; Extenics; Lattice Theory; ideality; technology evolution theory; Hasse Diagram; disruptive innovation;

1.Introduction

Ideality is one of the most important concepts in TRIZ, which considers every technology will follow the evolutionary law of ideality increasing, with the method of contradiction elimination (Cavallucci, 2001). By definition, ideality increasing means a system performing more and more useful functions(UF) with less and less costs and harmful functions(HF). In order to measure the ideality of the technologies, a formula of ideality has been proposed by many TRIZ experts(Domb, 1997; Savransky, 2000; Slocum et al, 2003):

$$\text{Ideality}=\sum[\text{Benefits}/(\text{Costs}+\text{Harms})] \quad (1)$$

Although this formula is very popular, there are three main defects in it:

Firstly, it is almost impossible to calculate with this formula, because its numerator, which is often represented by the useful functions, is significantly different from its denominator represented by costs and harmful functions in terms of metrics(Salamatov, 2002; Karasik, 2003).

Secondly, the result of this formula will always tends to be 0 since every system is faced with

almost infinite harms, so it is difficult to judge whether the ideality of a system has increased or not (Karasik, 2003). To the contrary, it will be very confusing in another theoretically extreme case that system A can perform useful functions X and Y without any costs and harms, while system B can only perform useful function X also without any costs and harms--both calculating results of this formula are infinity, but according to the general definition of ideality, the former is much more ideal than the latter.

Thirdly, it will be confusing when the numerator and the denominator become greater (or smaller) at the same time. We can compare the calculating results of this formula, but it does represent a kind of trade-off rather than contradiction solving from the basic viewpoint of TRIZ when the numerator and the denominator change in the same direction (Zhou et al, 2010).

In order to eliminate the first defect, the Buckingham's Theorem was introduced by Salamatov (2002) to unify the metrics of its numerator and denominator, while Petrov(2005) discussed and partly eliminated the third defect. Nevertheless, it is still difficult to analyze the relationship between the contradiction elimination and the changes of ideality, and little is known about how the ideality will vary on the S-curve during the evolution of a system. To explain and solve these problems, a new presentation of ideality based on the law of system evolution and Lattice Theory(Ganter and Wille, 1999) was proposed Zhou et al (2010).

Their research, however, did not discuss the possible difference of ideality between different levels of a system. This problem is the very subject of this paper, and we want to answer these questions: will the ideality of the technology increase all the time in the process of its evolution? In what way will this happen if it is true? How to explain the changes of ideality (especially the increases of ideality) in the process of contradiction elimination and disruptive innovation(Christensen, 1997)?

The rest of this paper is made up of these parts: in the second section, we want to update the presentation of ideality proposed by Zhou et al(2010) with the help of Extenics(Yang and Cai, 2007); in the third section, the difference of ideality at different levels of a system is discussed; in the last section, this model is used to explain the changes of ideality in some certain innovation activities, such as contradiction elimination and disruptive innovation.

2. An expression of ideality based on Lattice Theory and Extenics

2.1 Extenics and the expression of systems

Extenics (Yang and Cai, 2007) is a contradiction solving theory and metho created by a Chinese scholar— Cai, and it can indicate any subject with three elements-- O, C, V, where O means object, C means characteristics of the object, and V means the value of characteristics. With this method, a system P can be described as follows:

$$M=\begin{bmatrix} O, & C_{11}, & C_{11}(O) \\ & C_{12}, & C_{12}(O) \\ & \cdots & \cdots \\ & C_{21}, & C_{21}(O) \\ & C_{31}, & C_{31}(O) \\ & C_{32}, & C_{32}(O) \\ & \cdots & \cdots \end{bmatrix}=\begin{bmatrix} SystemP, & UF1, & Value11 \\ & UF2, & Value12 \\ & \cdots & \cdots \\ & Cost, & Value21 \\ & HF1, & Vaule31 \\ & HF2, & Value32 \\ & \cdots & \cdots \end{bmatrix} \quad (2)$$

And the relationship between the system and its subsystems can also be described with the following expression:

$$M=M_1 \oplus M_2 \oplus M_3 \oplus \wedge \oplus M_n \qquad (3)$$

Similarly, the subsystem Pi represented by Mi in the above equation can be described in the same way as formula (2).

In order to evaluate the ideality of the system P, we can extract an ordered series related to the indicators of UF, costs and HF from the expression (2):

$$(\underbrace{x_1,x_2,\cdots\cdots,x_{n1}}_{\text{UF indicators Of the system}},\underbrace{x_{n1+1},x_{n1+2},\cdots\cdots,x_{n2}}_{\text{Costs and HF Indicators}}) \qquad (4)$$

and in the expression (4), $x_i \in [0,+\infty)$, $i \in \{1,2,\ldots\ldots,n1\}$

$x_j \in (-\infty,0]$, $j \in \{n1+1,n1+2,\ldots\ldots,n2\}$

According to the definition of ideality increasing, the problem of ideality evaluation of the system can be transformed into a task comparing the UF indicators, costs and HF indicators of that system.

2.2 A presentation of ideality based on Extenics and Lattice Theory

It is clear that the evaluation of ideality is in fact a problem of ordering . The Lattice Theory, which is a kind of ordering method, can be used to construct a new presentation of ideality. Let system Q represent the subsequent state of the system P, then it can be concluded that the ideality of the system has increased if and only if(Zhou et al, 2010):

$$x_{lp} \leqslant x_{lq} \text{ for some } l \in \{1, 2, \cdots\cdots, n2\} \qquad (5)$$

and for all $m \neq 1$, $m \in \{1, 2, \cdots\cdots, n2\}$

$$x_{mp} \leqslant x_{mq} \qquad (6)$$

otherwise, the ideality of Q and P are incomparable.

The new expression of the ideality evaluation could be depicted with the help of Hasse Diagram from the Lattice Theory(Zhou et al, 2010):

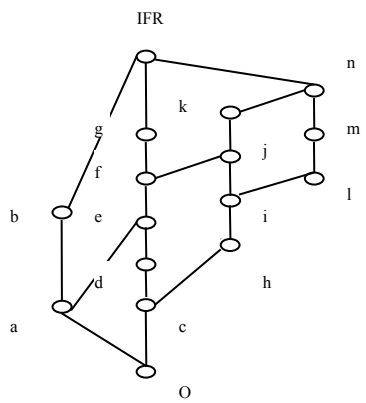

Figure 1 The description of ideality based on Hasse Diagram(Zhou et al, 2010)

In Figure 1, O stands for the original point, and IFR stands for the ideal final result of the system, with all other nodes standing for a special evolution state of the system. If there is a (are some) link(s) between two nodes in this picture, the node above possesses higher ideality, otherwise, the ideality of the two nodes could not be compared.

3. The difference of ideality between different levels of the system

Will the ideality of the system increase all the time in the process of its evolution? The answer is "no" if we pay attention to Figure 1, where the ideality of node "d" and that of node "i "are incomparable, even if the node "i" stands for the later evolution state of the system. Then, in which sense does the system evolve from the view point of the ideality increasing?

What is neglected by Zhou et al (2010) is the difference of ideality between different levels of the system. In other words, the ideality of the system could be considered from the perspective of different levels, and in those cases that it is impossible to compare the ideality of the system at the system level, it may be comparable at the subsystem level or the super-system level.

For the different states P and Q, if they are faced with the following situation:

$$\begin{cases} x_{lp} < x_{lq} & (7) \\ x_{mq} < x_{mp}, & (8) \end{cases}$$

where l, m∈{1,2,……,n2} and m≠1. it is obvious that the ideality of these two states are incomparable.

However, if there are two corresponding subsystems Pi and Qi for P and Q respectively, and these two subsystems satisfy the following conditions:

$$\begin{cases} x_{lpi} < x_{lqi} & (9) \\ x_{mpi} \leqslant xm_{qi}, \quad \text{for all } m \neq 1 & (10) \end{cases}$$

where l, m∈{1,2,……,n2'}(n2' ≤n2). Then it is clear that the ideality of the subsystem has really increased.

Take the special case which Altshuller(1984) mentioned in 1970s as an example, the speed of the modern car was much faster than the earliest, but at the same time, the former is also much more complex than the latter, so, it is difficult to judge whether the ideality of the car has increased from the level of the whole system. However, according to the equation (8) and (9), the engineer of the car has evolved with a much higher ideality. What is more, with the further development of the other subsystem, the ideality of the whole system will eventually to become much higher than its predecessors.

Similarly, in some cases where the ideality of the two states of the system are incomparable, the trend of ideality increasing at the super-system level become more and more evident. For example, there are a lot of systems which reach its evolution limit becoming a subsystem of other systems at last. Although it is difficult to compare the ideality of the systems, the super-system indeed becomes much more ideal.

4. The explanation of ideality changes in contradiction elimination and disruptive innovation

4. 1 Ideality changes in contradiction elimination

The evolution of system is realized by solving their contradictions. Nevertheless, contradiction elimination does not necessary bring a higher ideality for the system because of various secondary problems appearing in the process of solving contradiction.

But if we examine the relevant subsystems with the method proposed in the third section above, their ideality may be getting much higher than before. Moreover, the ideality of the whole system could further become much higher if the trimming process is performed after contradiction elimination. To some extent this can partly explain the changes of ideality in contradiction elimination.

4. 2 Ideality changes in disruptive innovation

It is very interesting to discuss the disruptive innovation from the perspective of ideality changes. Though the original system becomes much less complex, some useful functions also become much weaker in the process of disruptive innovation, so it is very confusing to judge the ideality changes brought by it.

However, if the system is examined from the point of Figure 1, it may become clearer: compared to the original system state "b", the new system created by disruptive innovation is system state "c". As a result, it is difficult to compare their ideality directly, from the perspective of subsystem, the ideality of "c" is much higher than the original point O, and what is more important is that the node "c" has much more evolution paths and therefore much more innovation opportunity than the node "b", which can only evolve into the theoretical ideal final result at a higher and higher cost.

5.Conclusion

The popular formula of ideality has many defects, and a new presentation based on Extenics and Lattice Theory was proposed by the authors in their last paper to eliminate most of these defects. However, the new presentation has neglected the difference of ideality between different levels of the system. This paper discusses the possibility of ideality increasing at the subsystem and super-system level even though it is difficult to compare the ideality from the perspective of system, and examines roughly the ideality changes in the process of contradiction elimination and disruptive innovation. But the method proposed still leaves to be proved by more case studies.

6. Acknowledgement

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Development of a Brainwave Consciousness-based Entertainment Toys with TRIZ-based Systematic Innovation Method

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Abstract

The theory of inventive problem solving (TRIZ) has widely adopted in diverse disciplines as an effective systematic innovation method and has revealed its promising development. In this paper, we apply the TRIZ-based systematic innovation method to analyze the problem existing in daily life for the disabled. We found some feasible solutions based on IT technology solution and evaluate their effects. The process of the proposed method was illustrated with a case study — development of a brainwave consciousness-based toys. The method proposed in this paper might provide a reference of how to develop a toy controlled by human brainwaves.

Keywords: Brain Computer Interface, the attention meters, Neurosky, mindset

1. Introduction

This study aimed at developing a Brain Computer Interface (BCI) toy. BCI, an interface between brain and real world, uses computers to analyze brains' activities to control external devices. Since brainwaves change so rapid, they are difficult to be controlled. To use brainwave to control the world is a dream of human. In this study, we use a mindset produced by NeuroSky Inc. Mindset can easily retrieve the brainwaves on forehead, and can parse them into attention meters and mediation meters (Yasui, 2009). We use TRIZ strategy to develop a brainwave-reading toy, flying-fish, and we also apply 40 inventive principles to solve technical problems (Zinovy, 1997).

2. TRIZ

TRIZ is a set of innovation processes including strategies, tools, skills, to help inventors organize their thought. TRIZ help us find a solution faster than we used to. TRIZ methods include problem hierarchy diagram, 9-windows, ideal final result (IFR), function analysis (FA) and Su-Field analysis.

3. BCI

Most BCIs, such as electroencephalography (EEG), use electrodes to record electrical activity along the scalp. Multiple electrodes can simultaneously receive data from multiple sites, but placing electrodes precisely and extracting useful information is difficult.

Many studies are based on multiple electrodes. Multiple electrodes are placed on the scalp to record the brain's electrical activity. Multiple electrodes are placed on the scalp to record the brain's electrical activity. Multiple electrodes can detect many points at the same time, but to filter out useful points and information is difficult. It is also difficult to fit many probes on the scalps at proper points. Electrodes type can also be divided into two groups, dry and wet. Wet electrodes have to be used with gel, whereas dry electrodes can simplify EEG recording.

Two types of BCI are outlined. One is steady-state visual evoked potential (SSVEP), and the other uses the Attention Meters.

Steady-state visual evoked potential (SSVEP) and attention meters are commonly used in EEG. The preparation of SSVEP requires a technician to find suitable frequency and accurate position to sense the stimulated brain wave. Also, during the process, users must keep their eyes on the screen to receive the visual stimulation. In comparison, using attention meters is simpler. First, we process the brainwaves into attention meters and mediation meters. The attention meters will rise if they receive EEG signals.

SSVEP is the EEG response to visual stimulus flashing at some predefined patterns (Gao et al., 2003). The brain will generates an electrical activity at the same frequency of the visual stimulus, as the retina is excited by a visual stimulus at presentation rates ranging from 3.5 Hz to 75 Hz. So we can give the retina some specific visual stimulus, and detect the response of the EGG to trigger the outside devices.

The method of the attention meters is simpler. First, we process the brainwaves into attention meters and mediation meters. Attention meters are used because they are simple to control. In our study, the attention meters will rise if they receive EEG signals, so we don't need extra training to learn to rise the attention meters.

Both the two methods (SSVEP and the attention meters) are used in BCI study. In our study, we prefer the attention meters.

4. Methodology

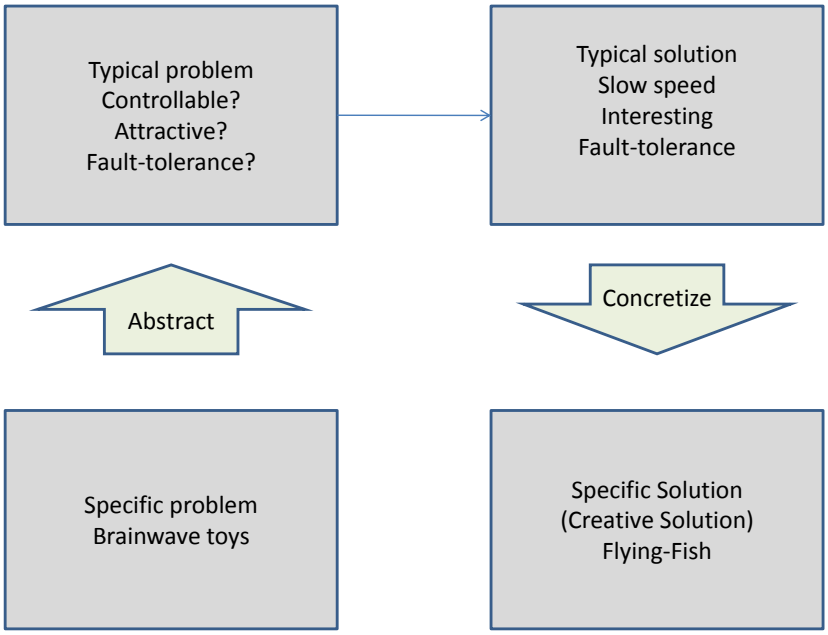

Figure 1 TRIZ process for creative problem solving

Flying-Fish

According TRIZ theory, we identify problems, figure out typical solution, and finally generate a creative solution. As shown in Figure 1, we want to develop a brainwave-reading toy, so we raise some important issues to controllability, degree of entertainment value, and of fault-tolerance. Applying 40 inventive principles to the issues, and we finally generate a solution: a flying-fish. The flying-fish is a toy of entertainment, and controllability, and it caches attention when flying.

Attention Meters

According to Keller's ARCS model (Keller, 1987), the attention meter can be used to measure the motivation of learning, because attention is the basic element of leaning. In our study, we adopt this concept to control the flying-fish. Using the MindWave, a single dry electrode, we detect the αand β waves, which can be generated easily when we focus our mind, and translate them into images (or messages) by the attention meters.

Horizontal control

We divide the attention meters into three groups, and give a command to each group (Table 1).

Table 1 The attentions meters to the movement

The Attention meters	movement
100~60	Fly forward
60~30	Turn around
0~30	Float

We also apply principle 16 of TRIZ's 40 inventive principles—partial or excessive actions—to develop horizon control. At first, we faced the difficulty that the flying-fish cannot turn around by its caudal fin, but we then found that inertia can make the flying-fish turn around as a spacecraft makes turns in outer space.

Vertical control

Attention Meters are one-dimensional, but to control the flying fish, we need to control at least two dimensions: direction and altitude. Thus, we design another device to adjust the flying-fish's altitude. According to principle 17 of TRIZ's 40 inventive principles, we fit two mercury switches horizontally to the electrode to detect the slope of the head and add another dimension. Because we can only lean our heads to the only directions, this features is a solution to the problem of exclusive of flying upward or downward. We use the direction of the slope to control the flying-fish's upward or downward movement. When the head slopes toward left, the flying-fish move downward. When the head slope toward right, the flying-fish moves upward.

Figure 2 Neurosky's Mindwave and mercury switches to convey the brainwaves

The whole system

The system architecture of our system is shown in Figure 2. Users can easily focus their mind on moving the flying-fish. The brainwaves, which are translated into messages by attention meters, are encapsulated and sent to the computer. We then decode the messages and use the attention meters to control the flying-fish's movement. The computer also sends the commands through I/O interface to the remote-controller of flying-fish, triggering the button to control the flying-fish by infrared. Eventually, users can see the flying-fish and get the visual feedback to improve the controlling process.

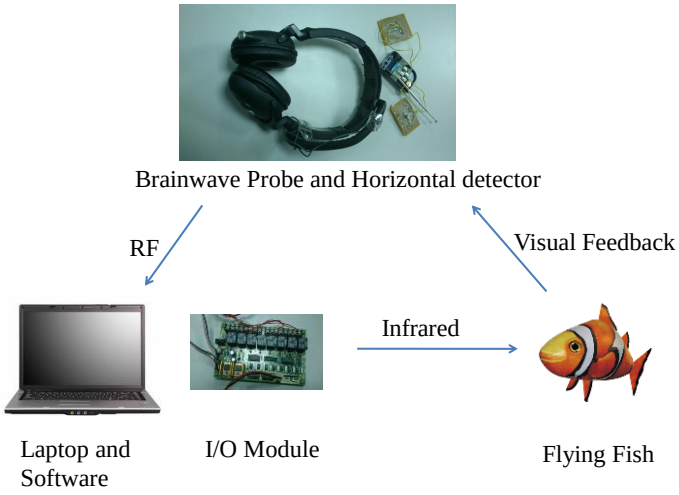

Figure 3 System Architecture

5. Experiment Result

We successfully make the flying-fish circling overhead in five minutes. With the attention meters, users do not need extra training to controlling the flying-fish. However, brainwaves change so fast that we cannot precisely predict the brainwaves' trend. Thus, in our study, we only focus on using the attention meters as the BCI.

Figure 4 Using brainwaves to control the flying-fish

6. Conclusion

In our study, we apply the theory of TRIZ to design a brainwave-reading toy, the flying-fish. TRIZ helps extending one-dimensional control of brainwaves to two-dimensional controls by adding mercury switches to control the flying-fish's movement. The attention meters control the direction and the mercury switches control the altitude. In the future, we hope to combine the attention meters and the mediation meters to control the flying-fish.

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Paper ID: 35

Design for a Balls Collector with TRIZ-based Systematic Innovation Method

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Abstract

The theory of inventive problem solving (TRIZ) has widely adopted in diverse disciplines as an effective systematic innovation method and it has revealed its promising development. In this paper, we applied the TRIZ-based systematic innovation method to analyze the problem existing in the ball collecting activities. The process of design method to analyze the problem includes many TRIZ tools such as problem hierarchy diagram, 9-windows, ideal final result (IFR), and function analysis (FA), etc. The process of the design method and several types of ball collectors were illustrated in this paper. The design method proposed in this paper might provide a reference for innovative product development.

Keywords: TRIZ, Ball Collector, Systematic Innovation, Function Analysis

1. Introduction

TRIZ has been developed over six decades and attracted a great deal of interest in industry and education. It can provide a systematic approach to analyze problems where innovation is needed and to provide strategies and methods to solve the problem. It consists of many tools such as 40 inventive principles and the matrix of contradictions, laws of technical system evolution, substance-field analysis, ARIZ (algorithm of inventive problems solving). In this paper, we applied the TRIZ-based systematic innovation method to analyze the problem existing in the ball collecting activities. The processes of this method include requirement analysis, confirmation of problem direction, problem definition, selection of TRIZ tools, generation of solutions, evaluation of solutions. The authors expect this research could provide a reference for innovative product development and education and the method proposed in this paper is general in form to be applied for the other disciplines.

2. Literature Review

TRIZ has been developed over six decades and attracted a great deal of interest in industry and education. It can provide a systematic approach to analyze problems where innovation is needed and to provide strategies and methods to solve the problem. Recently, considering the specific situations and scenario in different disciplines, many scholars have proposed some new contradiction matrices

in their researches. TRIZ can be seen as a collection of tools, a complete method, or a philosophy (Mann, 2004). It consists of many tools such as 40 inventive principles and the matrix of contradictions, laws of technical system evolution, substance-field analysis, ARIZ (algorithm of inventive problems solving).

TRIZ can also be a practical auxiliary tool for product development, there have been many research papers that integrate TRIZ and others effective design or decision-making techniques such as AHP (Chang & Chen, 2004), QFD (Li et al., 2009), Kano (Chen et al., 2008). Chang & Chen (2004) developed an Eco-Design Tool which integrated TRIZ into the eco-innovation idea and evaluated the relative importance of eco-efficiency elements with AHP. Li et al. (2009) integrated QFD and TRIZ to product conceptual design based on the consideration of customer need. As TRIZ is a powerful tool, it has been applied on many disciplines to systematically solve problem. For engineering application, Pin et al. (2011) applied TRIZ principles in crowd management and found it is a very good method for solving problems which involve contradiction. Fresner et al. (2010) developed a generic approach for option identification by using elements of the so-called TRIZ method for cleaner production projects.

In addition to engineering problem-solving application, recently, instructors have paid huge attention on TRIZ. For example, Turner (2009) proposed the 'Advanced Systematic Inventive Thinking' (ASIT) method as a problem solving strategy for education. Fulbright (2004) considered that TRIZ principles are better suited for physical, chemical, and mechanical systems, so he modified the classical TRIZ into PINE-TRIZ (Permutative Information Engineering TRIZ) and extended the inventive principles from 40 to 62. Based on aforementioned literature, we know that TRIZ have attracted the attention of industry and education disciplines. However, in order to elicit student's learning interests, TRIZ's education may need more case studies in daily life and systematic innovation method for learning reference. Therefore, This research used a daily life case study – picking balls as research topics and adopted a systematic process to design related innovative product.

3. Research Method

The process in the proposed method in this paper is shown in Figure 1. The process has five stages including problem definition, tool selection, solution generation, solution evaluation, and concept embodying. The problem definition stage includes various TRIZ tools such as Ideal Final Result (IFR), 9 windows of resources and constraints, problem explorer and Function Analysis (FA), etc. After finishing the above stage, one can select the more suitable tools to generate several solutions. The fourth stage, solution evaluation can use some methods such as AHP or radar plot, etc. In order to assimilate the innovation concept, we propose the fifth stage, concept embodying, used to transform concept to real prototype with hands-on practices.

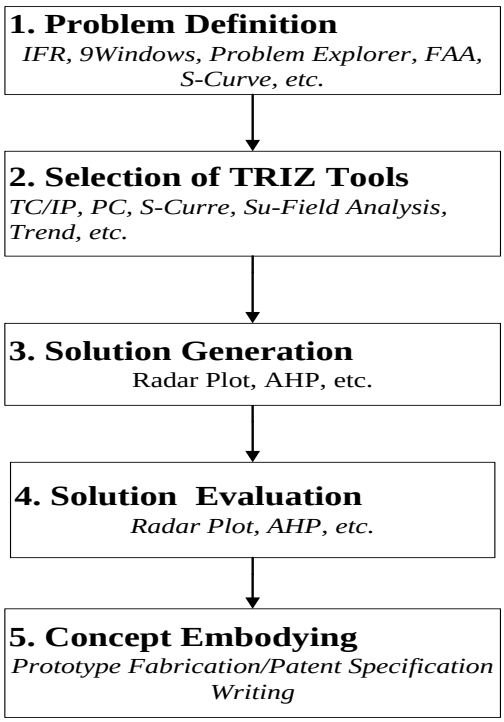

Figure 1. Process of TRIZ-based systematic innovation method in this paper.

4. Case Study

In this section, an example implemented by a topic research project was demonstrated for illustrating the proposed method in previous section. Through a series of survey and discussion, a scenario description of the problem in the ball collecting activities was listed as below:

Problem- Scenario description

- *It is inefficient and easy to cause spinal pain and backache when people pick balls with improper postures.*
- *It is easy to give rise to a lot of dust when a person picks table-tennis balls with a broom so as to cause the discomfort of the nose.*
  - *Is there any ways to resolve these problems?*

Some tools used in problem analysis and definition were shown in Figure 2-4. Figure 2 shows the stakeholders benefit analysis. Figure 3 shows problem hierarchy analysis and Figure 4 shows functional analysis diagram in the ball collecting activities. From the function analysis diagram, one will analyze harmful/insufficient/excessive/missing/effective functions between components of the product so that he/she can focus on the key-points of the problem.

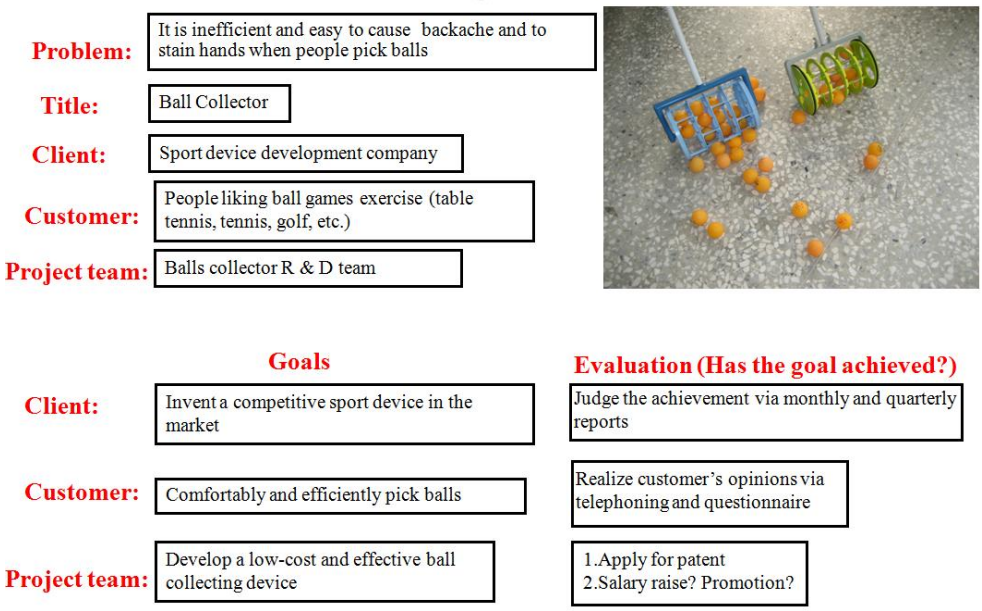

Figure 2. Stakeholders benefit analysis for developing new ball collector.

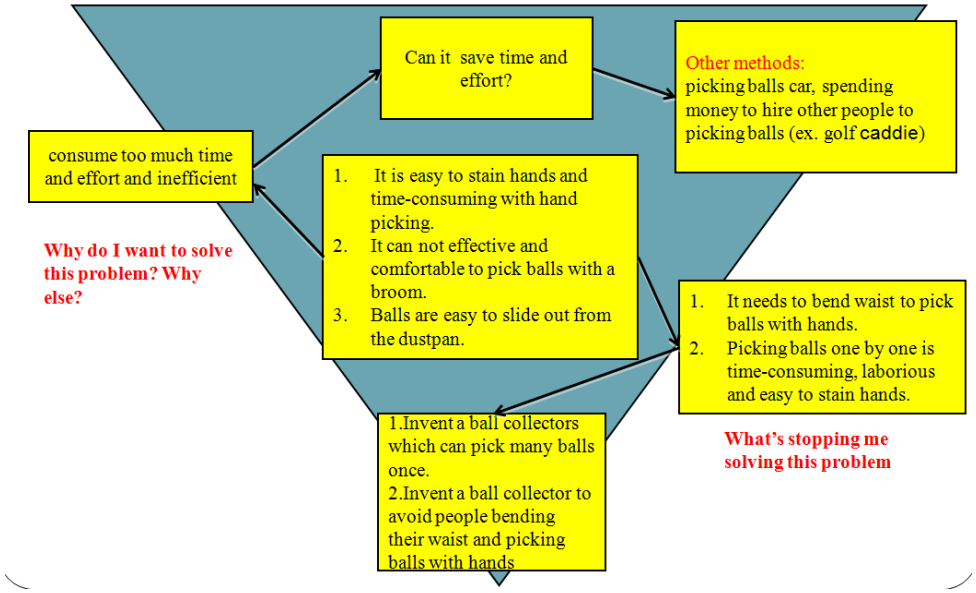

Figure 3. Problem hierarchy analysis in the ball collecting activities.

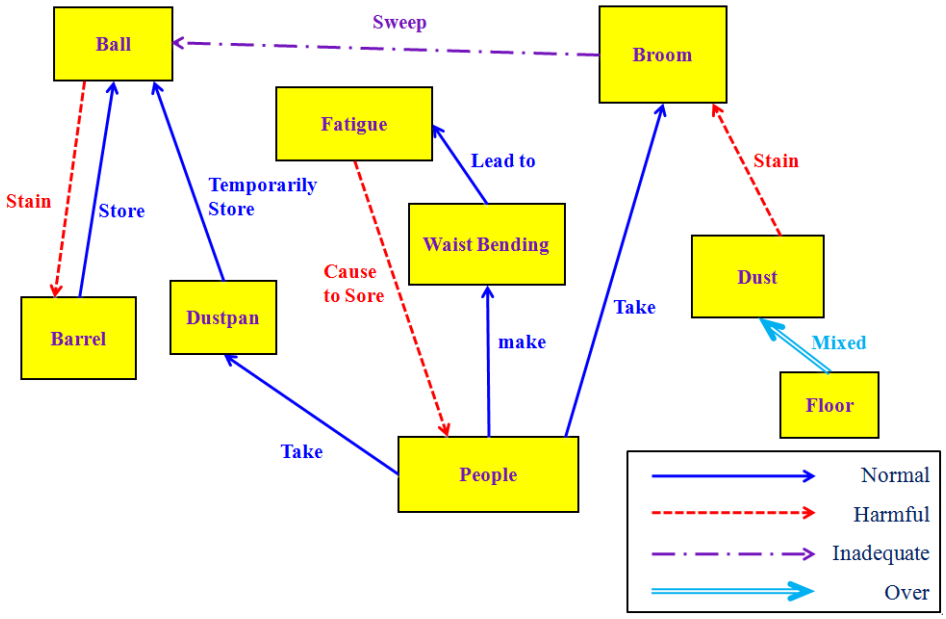

Figure 4. Functional analysis diagram in the ball collecting activities.

Besides, Table 1 shows the adopted inventive principles and the feasible implementation methods in the case study. Figure 5 shows the prototype and animation and Figure 6 shows the evaluation of this case with radar plot.

Table 1. Adopted inventive principles in the case study.

Innovative principles		Sub-item
6. Universality	Make a part or object perform multiple functions; eliminate the need for other parts.	Seize the balls and store balls simultaneously
7.Nested doll	b. Make one part pass through a cavity in the other.	Stretchable handle to fit the different height of person
13.The other way round	b. Make movable parts (or the external environment) fixed, and fixed parts movable..	Roller design can operate the balls collector forward and backward so as to increase the efficiency.
14.Spheroidality Curvature	b. Use rollers, balls, spirals, domes.	The ball tube is a cylindrical design so as to achieve continuous picking balls action.
20. Continuity of useful action	a. Carry on work continuously; make all parts of an object work at full load, all the time.	Divide the cylindrical surface into a number of grids for continuous picking.

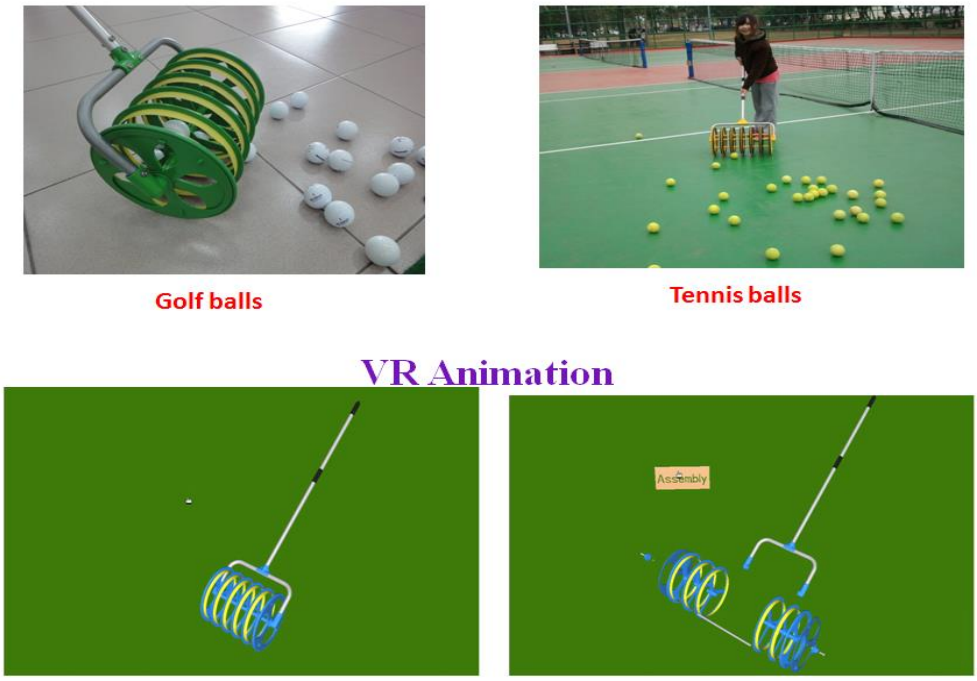

Figure 5. Prototype and animation of the designed ball collector

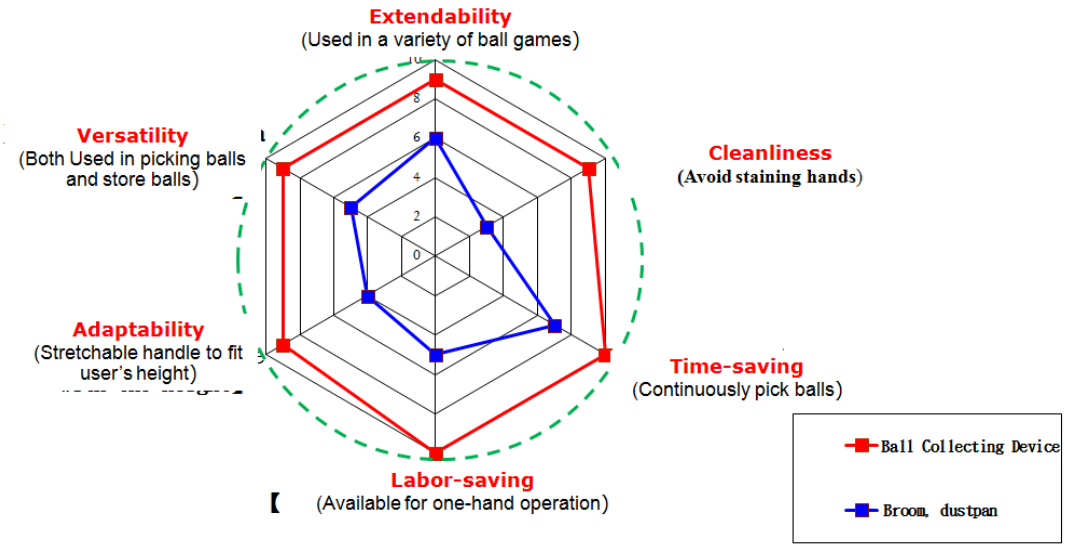

Figure 6. Evaluation of this case study with radar plot.

5. Conclusions

In this paper, we focused on design for a balls collector with TRIZ-based systematic innovation method. In the case study, an integrated approach with TRIZ tools such as problem hierarchy diagram, 9-windows, IFR, and FA was employed along with prototype fabrication and patent specification writing. This method is not only concept generation but also concept embodying so that it can provide new direction or a reference for the innovative product design education.

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Paper ID: 36

Design for a Multi-Functional Armrests of a Toilet Stool with TRIZ-based Systematic Innovation Method

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Abstract

The theory of inventive problem solving (TRIZ) has widely adopted in diverse disciplines as an effective systematic innovation method and it has revealed its promising development. In this paper, we applied the TRIZ-based systematic innovation method to analyze the problem existing in the activities of the disabled or the old using stools. The process of design method to analyze the problem includes many TRIZ tools such as problem hierarchy diagram, 9-windows, ideal final result (IFR), and function analysis (FA), etc. The process of the design method and the designed artifact were illustrated in this paper. The design method proposed in this paper might provide a reference for innovative product development.

Keywords: TRIZ, Multi-Functional Armrests, Systematic Innovation, Function Analysis

1. Introduction

TRIZ has been developed over six decades and attracted a great deal of interest in industry and education. It can provide a systematic approach to analyze problems where innovation is needed and to provide strategies and methods to solve the problem. It consists of many tools such as 40 inventive principles and the matrix of contradictions, laws of technical system evolution, substance-field analysis, ARIZ (algorithm of inventive problems solving). In this paper, we applied the TRIZ-based systematic innovation method to analyze the problem existing in the toilet stool usage activities for elder or disabled. The processes of this method include requirement analysis, confirmation of problem direction, problem definition, selection of TRIZ tools, generation of solutions, and evaluation of solutions. The authors expect this research could provide a reference for innovative product development and education and the method proposed in this paper is general in form to be applied for the other disciplines.

2. Literature Review

TRIZ has been developed over six decades and attracted a great deal of interest in industry and education. It can provide a systematic approach to analyze problems where innovation is needed and to provide strategies and methods to solve the problem. Recently, considering the specific situations

and scenario in different disciplines, many scholars have proposed some new contradiction matrices in their researches. TRIZ can be seen as a collection of tools, a complete method, or a philosophy (Mann, 2004). It consists of many tools such as 40 inventive principles and the matrix of contradictions, laws of technical system evolution, substance-field analysis, ARIZ (algorithm of inventive problems solving).

TRIZ can also be a practical auxiliary tool for product development, there have been many research papers that integrate TRIZ and others effective design or decision-making techniques such as AHP (Chang & Chen, 2004), QFD (Li et al., 2009), Kano (Chen et al., 2008). Chang & Chen (2004) developed an Eco-Design Tool which integrated TRIZ into the eco-innovation idea and evaluated the relative importance of eco-efficiency elements with AHP. Li et al. (2009) integrated QFD and TRIZ to product conceptual design based on the consideration of customer need. As TRIZ is a powerful tool, it has been applied on many disciplines to systematically solve problem. For engineering application, Pin et al. (2011) applied TRIZ principles in crowd management and found it is a very good method for solving problems which involve contradiction. Fresner et al. (2010) developed a generic approach for option identification by using elements of the so-called TRIZ method for cleaner production projects.

In addition to engineering problem-solving application, recently, instructors have paid huge attention on TRIZ. For example, Turner (2009) proposed the 'Advanced Systematic Inventive Thinking' (ASIT) method as a problem solving strategy for education. Fulbright (2004) considered that TRIZ principles are better suited for physical, chemical, and mechanical systems, so he modified the classical TRIZ into PINE-TRIZ (Permutative Information Engineering TRIZ) and extended the inventive principles from 40 to 62. Based on aforementioned literature, we know that TRIZ have attracted the attention of industry and education disciplines. However, in order to elicit student's learning interests, TRIZ's education may need more case studies in daily life and systematic innovation method for learning reference. Therefore, This research used a daily life case study – the toilet stool usage as research topics and adopted a systematic process to design related innovative product.

3. Research Method

The process in the proposed method in this paper is shown in Figure 1. The process has five stages including problem definition, tool selection, solution generation, solution evaluation, and concept embodying. The problem definition stage includes various TRIZ tools such as Ideal Final Result (IFR), 9 windows of resources and constraints, problem explorer and Function Analysis (FA), etc. After finishing the above stage, one can select the more suitable tools to generate several solutions. The fourth stage, solution evaluation can use some methods such as AHP or radar plot, etc. In order to assimilate the innovation concept, we propose the fifth stage, concept embodying, used to transform concept to real prototype with hands-on practices.

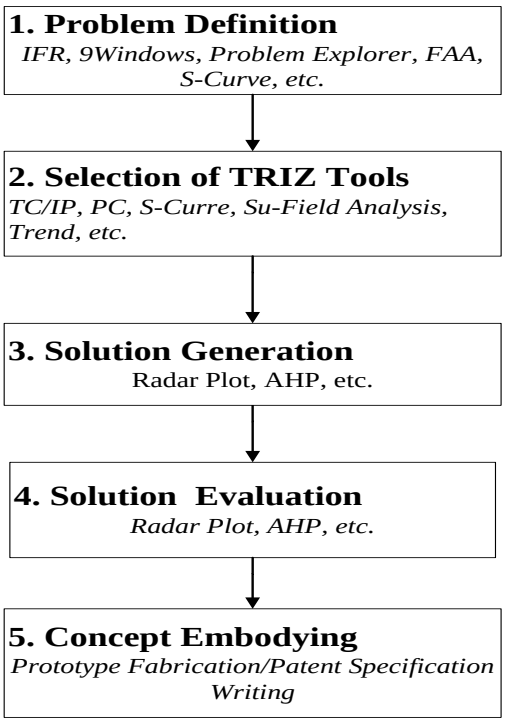

Figure 1. Process of TRIZ-based systematic innovation method in this paper.

4. Case Study

In this section, an example implemented by a topic research project was demonstrated for illustrating the proposed method in previous section. Through a series of survey and discussion, a scenario description of the problem in the toilet stool usage activities was listed as below:

Problem- Scenario description

- *The elders or the disabled persons are apt to slip and fall and get hurt while they are in the lavatory and there is no supporter to grip and support.*
- *Lifting the lid or the seat of a toilet stool by fingers might spread germs or dirty things onto the lid or the seat.*
- *The elders or the disabled persons might hurt their back while they are bending their backs and trying to lift the lid or the seat of a toilet stool.*
- *It is unsanitary to lift the lid or the seat of a toilet stool.*

Some tools used in problem analysis and definition were shown in Figure 2-4. Figure 2 shows the stakeholders benefit analysis. Figure 3 shows problem hierarchy analysis and Figure 4 shows functional analysis diagram in the toilet stool usage activities for elder or disabled. From the function analysis diagram, one will analyze harmful/insufficient/excessive/missing/effective functions between components of the product so that he/she can focus on the key-points of the problem.

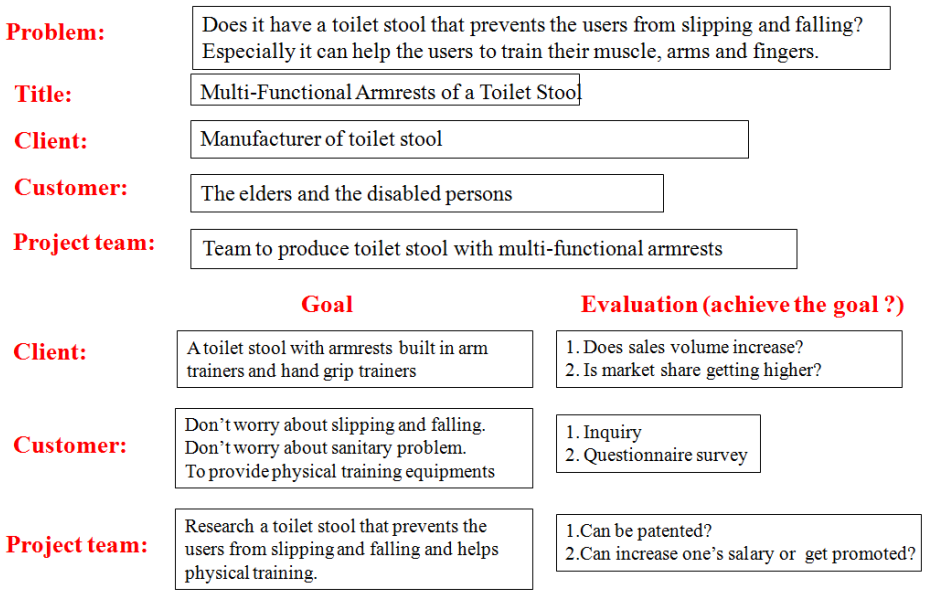

Figure 2. Stakeholders benefit analysis for developing new armrests of a toilet stool.

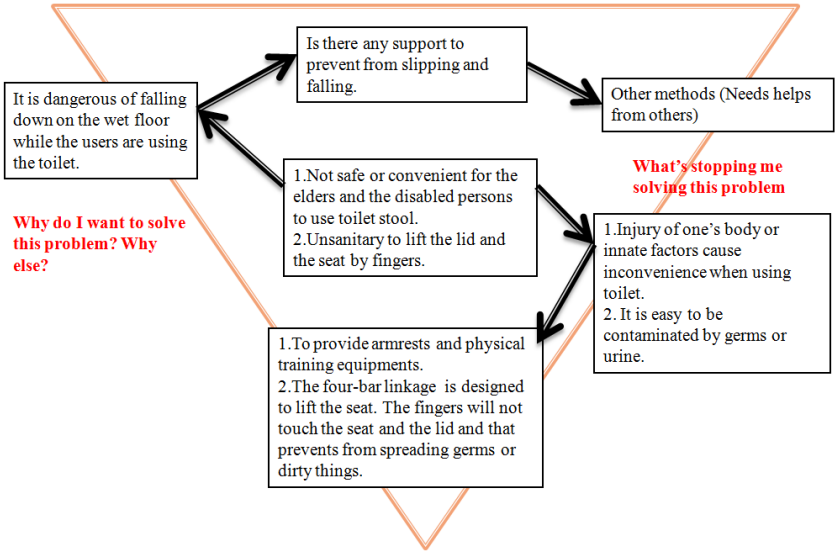

Figure 3. Problem hierarchy analysis in the toilet stool usage activities for elder or disabled.

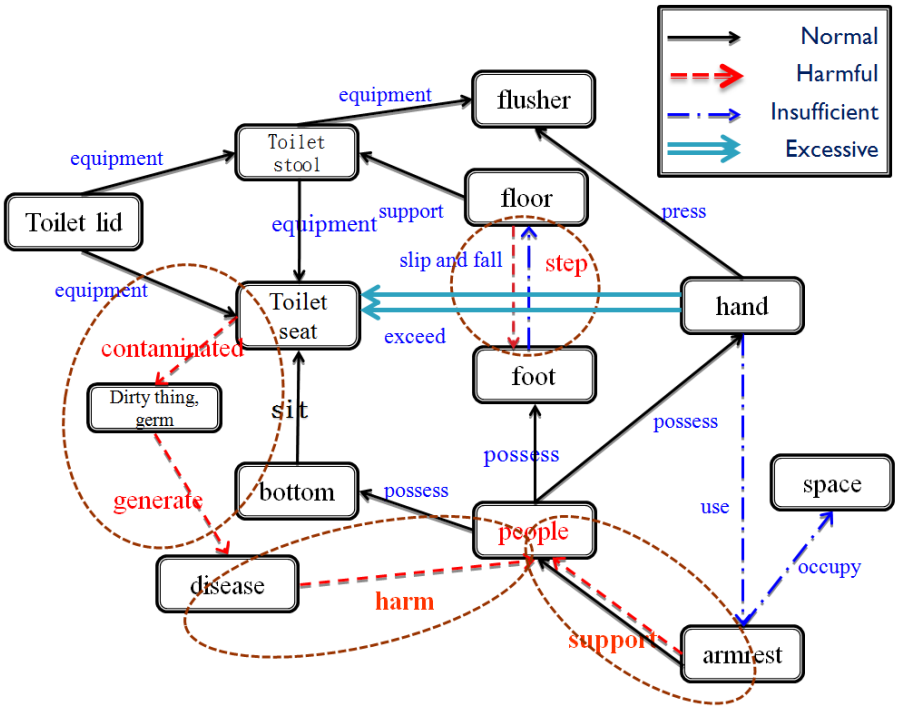

Figure 4. Functional analysis diagram in the toilet stool usage activities for elder or disabled.

Besides, Table 1 shows the adopted inventive principles and the feasible implementation methods in the case study. Figure 5 shows the prototype and animation and Figure 6 shows the evaluation of this case with radar plot.

Table 1. Adopted inventive principles in the case study.

Innovative principles	Sub-item	Application in this work
5. Merging	A. Bring closer together (or merge) identical or similar objects, assemble identical or similar parts to perform parallel operations.	Merge toilet stool, lifting mechanisms, hand grip trainers and arm trainers
6. Universality	Make a part or object perform multiple functions; eliminate the need for other parts.	Multi-function device for supporting the human body, preventing from touching the lid, and taking exercise
7. Nested doll	B. Make one part pass through a cavity in the other.	Insert arm trainers in the armrests
24.Intermediary	A. Use an intermediary carrier article or intermediary process.	Use a toilet stool with lifting mechanisms to prevent from touching the lid or the seat by fingers

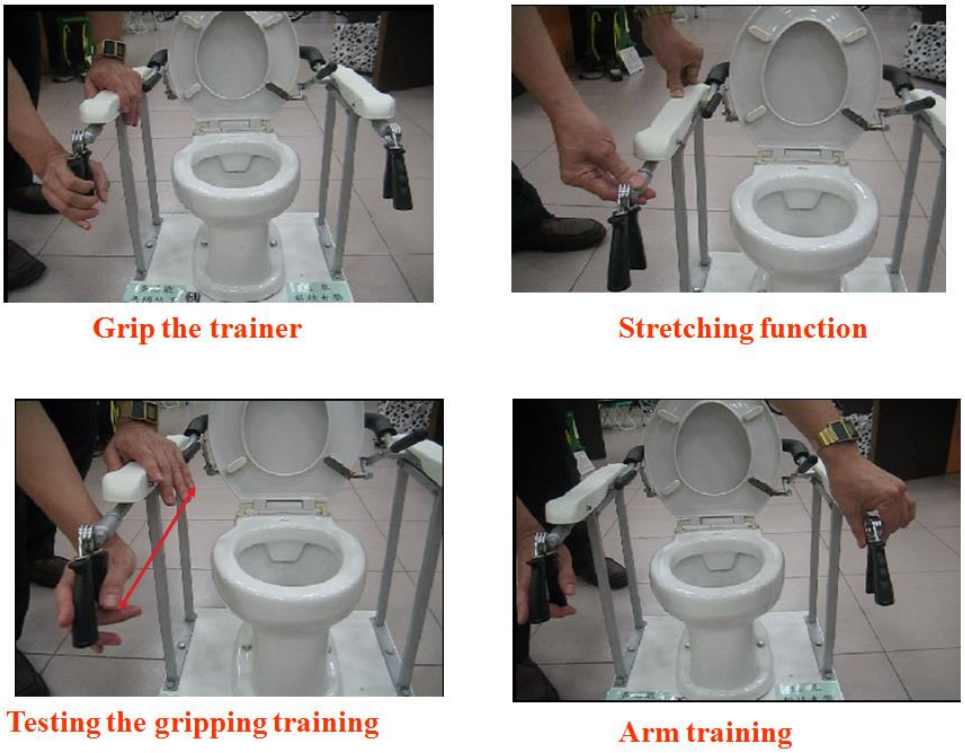

Figure 5. Prototype and animation of the designed multi-functional armrests of a toilet stool.

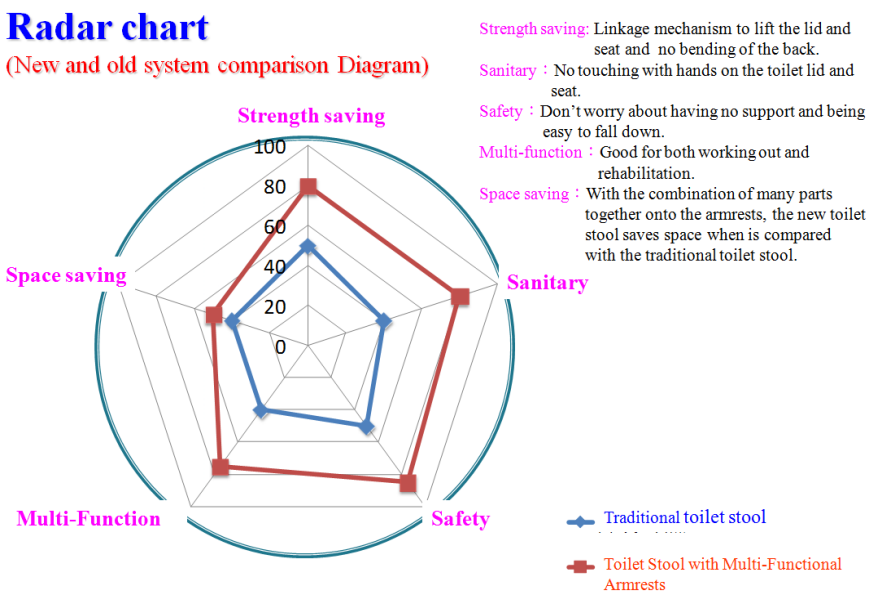

Figure 6. Evaluation of this case study with radar plot.

5. Conclusions

In this paper, we focused on design for a multi-functional armrests of a toilet stool with TRIZ-based systematic innovation method. In the case study, an integrated approach with TRIZ tools such as problem hierarchy diagram, 9-windows, IFR, and FA was employed along with prototype fabrication and patent specification writing. This method is not only concept generation but also concept embodying so that it can provide new direction or a reference for the innovative product design education.

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Paper ID: 39

The TRIZ Applications on Radical Innovations

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Abstract

Radical innovations provide the progress to the firm's competitive edge. TRIZ theory is used to product invention. From experience, the TRIZ method could help only 5% whole new radical innovation. This study surely the TRIZ is the way to help radical innovation application. Content analysis was selected to discuss some research cases and general known radical innovations by TRIZ methods. The findings suggest that ARIZ and Trends of Evolution process should combine five modes and extend to newly knowledge in TC/PC contradiction, 40 principles.

Keywords: Radical Innovations, TRIZ

1. Introduction

Radical innovations especially provide the progress to the firm's competitive edge. Previously studies concerned radical innovations achieves by knowledge and organization issues. The TRIZ theory is frequently applied to invention and invention processes. Besides the knowledge and organization issues, the TRIZ method may be the way for enterprise come within reach to radical innovations.

Radical innovations' emergences for enterprises are a hard work and concerning the organizational environment and capabilities. Sainio, Ritala and Hurmelinna-Laukkanen (2012) suggested technology orientation strategy enhances innovation radicalness and customer relationship orientation positively affects the technological and business model. The analysis also reveals that market uncertainty negatively moderates the effect of a technology orientation on technological and market radicalness. The innovation is also related to high market and technological uncertainty, new

market creation, current product cannibalization, and the effects on the company's knowledge base (Hurmelinna-Laukkanenetal, 2008).

Ritala and Hurmelinna-Laukkanen (2013) evidenced the relationship between innovation and knowledge, when incremental developments are pursued in coopetition, firms should not only seek to exchange knowledge to create value but also remember to secure the firm-specific core knowledge within the firm's borders. On the other hand, when the firm is pursuing radical innovation with its rivals, should be on protecting its existing core knowledge and also emerging novel innovations and market opportunities.

Zhou and Li (2012) examines how existing knowledge base (i.e., knowledge breadth and depth) interacts with knowledge integration mechanisms (i.e., external market knowledge acquisition and internal knowledge sharing) to affect radical innovation. The effects of knowledge breadth and depth are contingent on market knowledge acquisition and knowledge sharing in opposite ways. The suggestions are a broad knowledge base firm is more likely to achieve radical innovation in the presence of internal knowledge sharing rather than market knowledge acquisition. In contrast, a firm with a deep knowledge base is more capable of developing radical innovation through market knowledge.

The degree of newness or novelty, of a product or service is used to evaluate the radicalness (Amaraetal, 2008). Garcia and Calantone (2002) identify two general perspectives to evaluate innovativeness, the degree of discontinuity in the market and/or technological factors, which are whether or not the innovation creates a paradigm shift in technology or market structure, and what influence it has on an individual firm. A technologically radical innovation represents a clear advance and offering better functionality and/or performance. Chandy and Tellis (2000) operationalizes technological radicalness by core technology that different from the previous product generation. For market radicalness, is the difficulty in evaluating potential customers' reactions that they require major changes in thinking and behavior on the part of main- stream customers (Benner and Tushman, 2003).

In order to be successful, Gassmann, Widenmayer and Zeschky (2012) suggested five transition modes on how interfaces between radical innovation units and operational business are managed effectively as a means to implement radical innovation on a company level: (1) external validating; (2) liaison channeling; (3) showcasing innovation; (4) network building; and (5) integrative innovation planning.

Theory of Solving Inventive Problems, (TRIZ) is developed to solve inventive problem (Theory of Inventive Problem Solving, TIPS). The TRIZ theory ways are constructed by Su-Filed analysis,76 standard solutions, Altshuller's tble of contradictions, 40 inventive principles, 39 engineering parameters, ARIZ(Algorithm for Inventive-Problem Solving, the evolution of product inventions and technological effects.

The products such as air bed、medical service quality、cake knife、Hanger、CCD、can for drink、hazard light、Guarding Stick、Shampoo pushed button、flat tissue are enhanced or modified by TRIZ method. These TRIZ innovation applications focus on utility and design patent. For more beneficial invention, this study inspects the TRIZ applications on radical innovation.

2. Literature review

Radical innovation is in contrast to incremental innovation. The products have a high impact on existing markets or create entirely new markets with totally new benefits or significant reduction in cost are regarded as radical innovation (Leifer, McDermott, O'Connor, Peters, Riceand Veryzer, 2000; Leifer et al., 2001; Hauschildt & Salomo, 2005). The reasons are various that firms suffer from a lack of persistency to convert resources invested in radical innovation into profits. High pressure of equity markets can prevent the internal diffusion of radical innovation (Gilbert, Newbery, and Reinganum, 1984; Quinn, 1985). High uncertainties involved in the implementation of radical innovation are problems that hinder the transfer of radical innovation (Morone, 1993; Leifer et al., 2001).

There are types of uncertainties are discusses. Technical uncertainties apply to the underlying scientific knowledge base including technical feasibility, manufacturing process, and maintainability. Market uncertainties comprise to what extent customer needs are understood, transformed into products, and superior customer value is generated compared to competition. Organizational uncertainties address the organizational and managerial conflict of fostering radical innovation while pursuing operational activities, mainly caused by a lack of support of senior management (Burgelman and Sayles, 1986; Kanter, North,, Richardson,, Ingols, and Zolner, 1991; Dougherty and Hardy, 1996). Resource uncertainties embrace all difficulties of internally and externally acquiring needed resources for radical innovation (Chandy and Tellis, 1998). Due to these uncertainties, radical innovation activities often get neglected in favor of day-to-day business needs

The types of innovations, which are defined by Abernathy-Clark Model and Henderson-Clark Model by knowledge aspect(Afuah,2003). These two models illustrate as below.

Abernathy-Clark Model

Focusing on the perspective of the innovating firm, the model classifies innovations according to their impact on the technical and market capabilities of organization. The revolutionary innovation is the kind of technical and market capabilities destroyed. The architectural innovation is the kind of technical and market capabilities destroyed. The revolutionary innovation is the kind of technical destroyed but market capabilities preserved.

Figure 1 Abernathy-Clark Model

Market Capabilities	Technical capabilities	
	Preserved	**Destroyed**
Preserved	**Regular**	**Revolutionary**
Destroyed	**Niche**	**Architectural**

Henderson-Clark Model suggested products are normally made by components, building the products must require 2 kinds of knowledge; knowledge of the components, and knowledge of the linkages (Architectural knowledge).This model classifies innovations according to their impact on the existing technological and market knowledge of the manufacture.

Component Knowledge	Architectual Knowledge	
	Enhanced	Destroyed
Enhanced	Incremental	Architectural
Destroyed	Modular	Radical

Figure 2 Henderson-Clark Model

Architectural knowledge is often tacit and embedded in the routines and procedures of an organization. Components knowledge has not changed but the knowledge of the linkage. Technical Innovation improved products, services or processes or completely new once (may require Administrative innovation). Radical innovations (sometime referred to as breakthrough, discontinuous or disruptive innovations) is related to Architectual and component knowledge destroyed. Incremental innovation is related to technological and market knowledge enhanced. Architectural and modular innovations are one knowledge factor destroyed, the other one enhanced.

Theory of Solving Inventive Problems, (TRIZ), TIPS (Theory of Inventive Problem Solving) was created by Altshuller and its research fellows in 1946. They have analyzed and integrated 1,500,000 patents since 60 years ago. Altshuller argued that：

1.Creation is not an unknown and unreachable function.
2.Creation followed a special and achievable principles.
3.We can do the inventions with non-inventor persons, if they learn the innovating principles and algorithms.)

The problem solving logic of TRIZ is to generalize problem and solution, then find the specific solution for corresponding problem (figure 3).

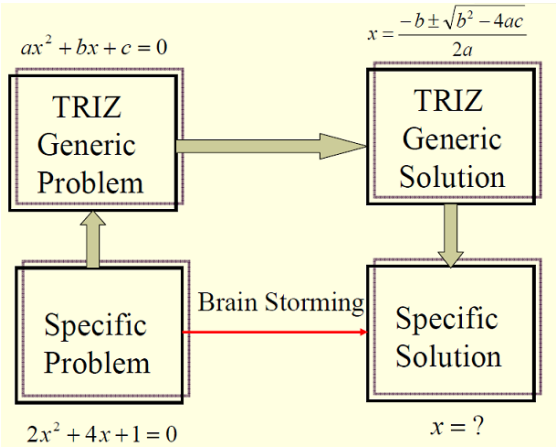

Figure 3. Problem solving logic of TRIZ

There are four steps for problem solving process; they are Problem Explorer, Function & Attribute Analysis (FAA), S-Curve Analysis and Ideal Final Result (Figure 4).

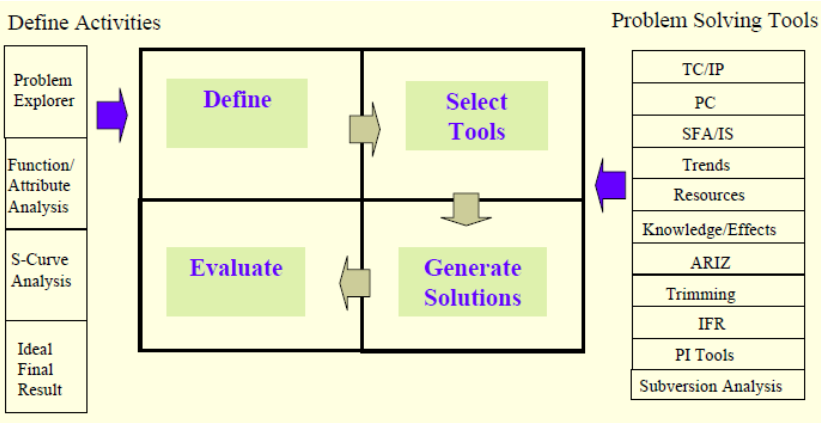

Figure 4. TRIZ problem solving process

The methods or tools of TRIZ are introduced as below:

1.TC/PC（technology/ physical contradiction）

a. Physical contradiction as,

- I want X and I want anti-X, and exaggerations of that statement.
- I want this to be cold and to be hot.

- I want my boss to be at the meeting, I don't want my boss to be at the meeting.
- I want this system to be heavy and I want it to be light, I want this system to be massive and I want it to have zero mass.
- I want all project management data always up to date, but it takes too long to enter the data. I want the data updated and I don't want the data updated.

Four basic methods of "separating" physical contradiction are in space; in time ;on condition; by transition to an alternative system

Technical contradiction as,

- When X gets better, Y gets worse.
- Strength of a structure gets better, but weight gets worse.
- Speed of a process increases, but productivity in a process gets worse (if the increasing speed causes an increase in defects.)
- The flexibility of a financial system increases, but the control of the system gets worse.
- Employee empowerment (fast decision making) improves, but standardization gets worse.

Some principle of innovation are listed as below,

- Each innovation is begun from recognizing harmful conflicts.
- Solving the recognized conflicts without destroying the conflicts structure culminates in an innovative solution.
- The conflicts in technological problems are finites, and consequents of fighting between some identities of things and functions.
- The solutions for solving conflicts from technological history are limited and categorical.）

Following Trade-off of technology/ physical contradiction, Altshuller develop 39×39 matrix arrays so that for solving each junction between two conflicts, 40 Principles are suggested. The processes are:

- Extraction of 39 parameters that are conflicted with each other in technological problems and suggesting a 39×39 matrix that consist of conflicted parameters (Table 1).
- Bringing out 40 innovation principles that solve the conflicts between the 39 Parameters and replace these 40 principles in the 39×39 matrix arrays so that for solving each junction between two conflicts, some principles of 40 Principles are suggested.
- Presenting ways for problem formulation that provide a high currency view of problem and the conflicts places for inventors.)

Table 1 39 engineering parameters of TRIZ

number	parameter	number	parameter

1	Weight of moving object	21	Power
2	Weight of stationary object	22	Loss of energy
3	Length of moving object	23	Loss of substance
4	Length of stationary object	24	Loss of information
5	Area of moving object	25	Loss of time
6	Area of stationary object	26	Amount of substance
7	Volume of moving object	27	Reliability
8	Volume of stationary object	28	Measurement accuracy
9	Speed	29	Manufacturing precision
10	Force	30	Object affected harmful factors
11	Stress or Pressure	31	Object generated harmful factors
12	Shape	32	Ease of manufacture
13	Stability of the object's composition	33	Ease of operation
14	Strength	34	Ease of repair
15	Duration of action by a moving object	35	Adaptability / Versatility
16	Duration of action by a stationary object	36	Device complexity
17	Temperature	37	Difficulty of detecting and measuring
18	Illumination intensity / Brightness	38	Extent of automation
19	Use of energy by moving object	39	Productivity
20	Use of energy by stationary object		

Use the contradiction matrix if the parameters are a direct fit for the situation, use all 40 principles if the parameters are not a direct fit (Table 2).

Table 2 TRIZ 40 inventive principles

number	principle	number	principle
1	Seg mentation	21	Skipping
2	Taking out	22	Blessing in Disguise or Turn Lemons into Lemonade
3	Local quality	23	Feedback
4	Asymmetry	24	Intermediary
5	Merging	25	Self-service
6	Universality	26	Copying

7	Nested Doll	27	Cheap Short-Living Objects
8	Anti-Weight	28	Mechanics Substitution
9	Preliminary Anti-Action	29	Pneumatics and Hydraulics
10	Preliminary Action	30	Flexible Shells and Thin Films
11	Beforehand Cushioning	31	Porous Materials
12	Equipotentiality	32	Color Changes
13	The Other Way Round	33	Homogeneity
14	Spheroidality – Curvature	34	Discarding and Recovering
15	Dynamic	35	Parameter Changes
16	Partial or Excessive Action	36	Phase Transition
17	Another Dimension	37	Thermal Expansion
18	Mechanical vibration	38	Strong Oxidants
19	Periodic Action	39	Inert Atmosphere
20	Continuity of Useful Action	40	Composite Structures

2. Substance- Field Analysis

The inventor demands a lot from technical objects , in order to meet increasing demand, technical systems (TS) should constantly increase in efficiency or decrease in harmful, or redundant, properties. This means that one group of inventive problems focuses on improving the existing technical systems. Once involved in the technological evolution process, they start facing contradictions. The increasing demand cannot always be met by improving the existing TS. But there are problems with no contradiction. Substance-field analysis allows the creation of a model that is representative of the system under discussion. The application of these principles is extremely powerful in defeating psychological inertia and increasing the innovative level of the solution (increasing the level of ideality as well).

3. Trends of Evolution

This unique TRIZ approach shows how to predict future technologies, new products and improvement of current systems using the 8 TRIZ Trends of Evolution. The 8 Trends (each with their own subsets - lines of evolution) are powerful problem solving triggers. The Trends also have great strategic power when used in planning and research. For many users, learning the Trends gives more problem solving directions than other tools.

4.ARIZ (Algorithm for Inventive Problem Solving)

ARIZ is list of (about 85) step-by-step procedures that incrementally evolves a complex problem to a point where it is simple to solve. For those problems which are so complex, that they cannot be solved with any other tools.

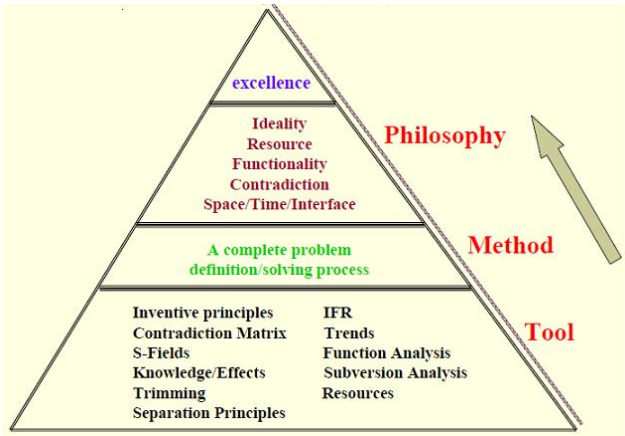

Figure 5. TRIZ concept constitution

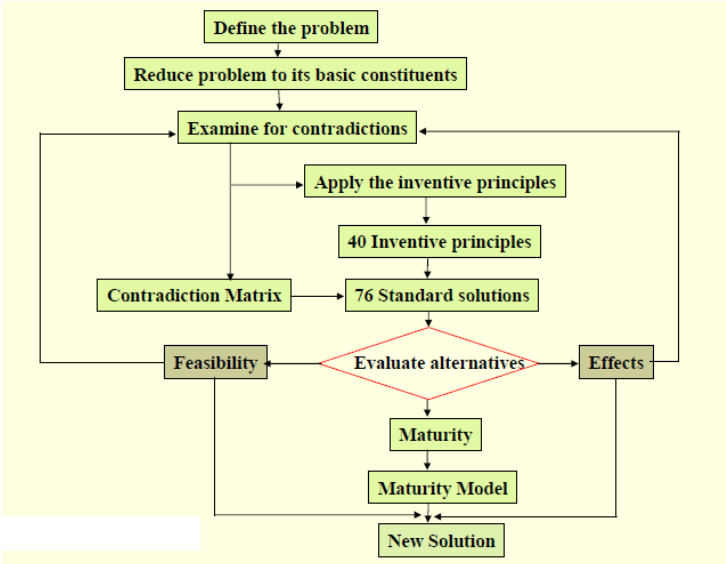

Figure 6. TRIZ application stages

TRIZ method is not only a tool but philosophy thinking (Figure 4).The concept levels are from tool, method to philosophy for invention. The philosophy level is stare at problem defined (Figure 5), follow simplification, TC/PC contradiction, 40 principles and so on. TRIZ method is complete and mature way to help invention.

3. Methodology

A multiple case study approach is chosen due to the novelty and complexity of the research object (Yin, 2003). All cases displayed in Table 1 were identified based on conducted research projects. During the research project, all selected cases addressed the implementation of TRIZ on products improved. This study concerns the frequently TRIZ applications case and try to find the important factors for approach radical innovations.

Table 3 case list

case	product	source
Case 1	air bed	Huang &Huang (2009)
Case 2	medical service quality	Chen & Chen (2011)
Case 3	cake knife	Liu (2010)
Case 4	Hanger	Deng &Huang (2011)
Case 5	CCD/ can for drink/ hazard light	Liu(2003)
Case 6	● Patents ● Guarding Stick	Liu & Chuang (1999)
Case 7	● Shampoo pushed button ● flat tissue	Liu, Wang, , Young, & Hung(1997)

Beside the TRIZ studies case in table, some radical innovations general known are;

- AOL's instant messenger (AIM) service – AOL was the first to launch a modern, Internet wide, GUI based messenger service in May 1997. This service system was built for the majority of internet users; this provided a revolutionary way to communicate in real time between two or more computers / electronic devices.
- Amazon.com's – Internet based approach to selling books enabled it to offer many more books than a traditional book store, this ultimately led to a number of the traditional book stores going out of business. As of 2010 Amazon was that largest online retailer in the US.
- Transistor technology – transistors developed by Bell Labs uprooted the major players in the electronics industry who were all at the time focusing on vacuum tube technology.
- Virgin Ones mortgage account - that reduces interest charges by combining debt with savings and income.
- Digital photography - It is rare these days that you see anyone with a camera that takes film and many retail outlets now offer self-serve digital photo outlets where you can download your images, select, crop and resize them and then print them onto photographic paper. Gone are all the "post your film in an envelope for processing" type services.

The comparisons of TRIZ research cases and common radical innovation cases could find the key factors for apply TRIZ theory on radical innovations.

4. Discussion and conclusion

This study discusses the radical innovations by five transition modes and factors of Abernathy-Clark Model and Henderson-Clark Model. The five transition modes on how interfaces between radical innovation units and operational business are (1) external validating; (2) liaison channeling; (3) showcasing innovation; (4) network building; and (5) integrative innovation planning. The factors of

Abernathy-Clark Model and Henderson-Clark Model are technical capabilities、market capabilities、architectural knowledge and components knowledge.

Altshuller also noted that the source of the solution required broader knowledge and more solutions to consider before an ideal one could be found. His findings are summarized in Table 4. Altshuller could help engineers face had been solved somewhere before over 90% of the problems.

Table 4. Levels of Inventiveness.

Level	Degree of inventiveness	% of solutions	Source of knowledge	Approximate # of solutions to consider
1	Apparent solution	32%	Personal knowledge	10
2	Minor improvement	45%	Knowledge within company	100
3	Major improvement	18%	Knowledge within the industry	1000
4	New concept	4%	Knowledge outside the industry	100,000
5	Discovery	1%	All that is knowable	1,000,000

Source: Mazur (1995)

TRIZ is the methods to complete radical innovations. For example, the level 4 and 5 inventiveness are much close to radical innovations. The solutions percentage is only 5%, but approximate number of solutions to consider is 1,100,000 (Table 4). These two level of inventiveness provide novel solutions with new technical capabilities、market capabilities、architectural knowledge and components knowledge. Most problems solvating are incremental innovations, level 1~level 3 and Table 5.

Case	product	worsen engineering parameters	improved engineering parameters	inventive principles	method
Case 1	air bed	25	11	37、36、4	contradiction matrix
Case 2	medical service quality	(09) (12) (14) (25) (27) (28) (29) (33)(35) (39)	(09) (19) (25) (26) (28) (29) (34) (36)	01、02、04、10、13、14、18、22、24、25、26、28、	contradiction matrix

				30、32、34、35、36	
Case 3	cake knife	8	33	4、18、39 。31	contradiction matrix
Case 4	Hanger	7	5	7、14、4、17	contradiction matrix
Case 5	CCD/ can for drink/ hazard light	frequently used parameters	frequently used parameters	corresponding principles	concept / intend(fewer contradiction)
Case 6	● Patents ● Guarding Stick	need	need	frequently used principles	ARIZ(algorithm of TRIZ)
Case 7	● Shampoo pushed button ● flat tissue	need (28)(33)	need (23)(25)	frequently used principles	ARIZ(algorithm of TRIZ)

Table 5. The TRIZ methods of research cases applications

The problem of TRIZ application on radical innovations is not the tools or methods. This study suggested the TRIZ problem solving process should concern the five modes (external validating; liaison channeling; showcasing innovation; network building; integrative innovation planning) and extend to newly knowledge ;capability.

The TRIZ application stages of radical innovation stress the new knowledge or capability in TC/PC contradiction, 40 principles and so on. Moreover, consider the connection to outside as five modes of external validating; liaison channeling; showcasing innovation; network building; integrative innovation planning (Figure 7).

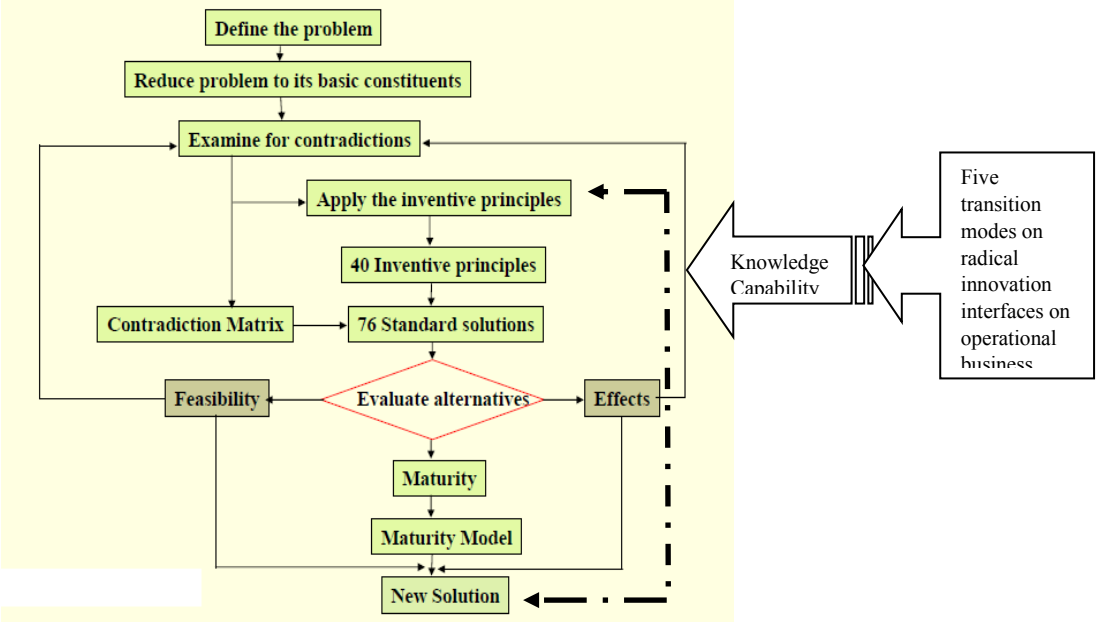

Figure 7. TRIZ application stages of radical innovation

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Systematic Innovation for the Retention and Development of Human Talent

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Abstract

In order to build and sustain competitive advantage, the knowledge that workforces possess have become an important tactical resource, this perspective places staffs into the organizations main objectives. Numerous studies have defined management of Human Talent and their organizational performance. The Motivation of this study is to create an inventive solution through systematic innovation for the human talent in the beverage industry in El Salvador. In this study, we use systematic innovation to solve retention and development of human talent problems, the guide which is introduced in this thesis may provide a useful methodology for solving intangible problems in human talent issues. Our findings show that even though Systematic innovation just has been started to being used to solve business management problems it can still be used to generate ideas or specific solutions on how to solve problems related to retention and development of Human Talent. The specific solution given by the inventive principles is to create an incentive system that can be flexible, by covering not only one product but by adapting to different situations and to many different products.

Keywords: Human talent, Incentive System, TRIZ, Systematic Innovation

1. Introduction

Having a system or program to develop and retain human talent is considered to be a competitive advantage in national and international companies [Schon Beechler, Ian C.Woodwardc, 2009]. Management of Human Talent involves planning, organizing and developing the capacities of personnel in the company, in order to make them more efficient and achieve both their individual goals and those of the company. To maintain a steady development of human talent, it is extremely important to consider programs of induction, re-induction and guidance. This will allow the continued development of staff and generate identification with the organization as well as a constant understanding of organizational changes. Furthermore, to properly develop human talent it is not enough to apply trainings and inductions, but also provide the necessary resources to employees. As a result, the material and technical resources play an important role in human talent development leading to success at the organizational level [Idalberto Chiavenato, 2009]. These resources are necessary for the successful development of human talent. However, having personnel that have this resource does not mean that is sufficient to obtain an ideal development. Therefore, it is necessary to create a philosophy that supports this.

Systematic innovation, its well known for solving problems, but systematic innovation has some limitations; they lack earlier studies to implement TRIZ (theory of inventive problem solving) in

management incentive systems[Darrel mann,2007]. In other words when you try to optimize a system, systematic innovation contains virtually no mathematics and so if we are trying to answer questions like "what is the optimum batch size" or "what is the best interest rate?" Or "what bonuses should everyone get this year?" and in this case "what could be the amount of economic incentive for the workforce?" then systematic innovation will not help because each person has a different way of thinking, an incentive that is good to one person could be bad to another one, and this makes it hard to apply a correct incentive system. We contribute to solve this problem with the use of systematic innovation and if necessary modify it so it adapts to problems like so.

Currently in El Salvador there is a very competitive beverage industry. This market is currently changing, and you cannot really predict what will happen in the future due to the constant changes that occur. All organizations have to be prepared for these changes and prevail. The best way for a company to be prepared for these events is with a staff that is trained with the appropriate skills that enables them to operate in the diverse events that occur in this market. The sales force in this industry always has a hard time with the distribution in the market, they need to have a direct contact with the retailers, by visiting their shops either by scooter or car, and this sometimes can be very dangerous. Consequently the problem is that the sales forces (from company "P") in this market cannot seem to be retained and motivated to stay for a long time and work as expected[Abrego Diego, 2011].

In this research we establish and create an incentive system for the developing and retention of human talent in organizations dedicated to the distribution of beverages. First the problem is defined and data is collected from interviews. The interviews were made to ex employees (ex-Salesman) of company "P", of the beverage Industry in El Salvador. The interviews had the objective of finding out what problems they had during their time in company 'P', and to find more information about the current incentive system in company 'P'. After gathering this information we used systematic innovation to solve the problem. The conceptual framework comprises of 9 steps which essentially follow the systematic innovation problem solving process, by the end of this study we evaluate the results and finish with a conclusion and possible future works.

2. Methodology and Results

In this part of the study we go into the procedures in use to resolve the problem in hand. We follow the procedures and most of the tools given by systematic innovation in the "Pro-Forma Tools" [Darrel Mann, 2007]. First we start with the "*problem definition*", with the use of information gathered from interviews done to ex-employees of company 'P'. Secondly the *"preliminary problem analysis",* which consists in analyzing in a broad way the problem in hand by using tools like the problem hierarchy and the 9 windows. Then we continue with the *"Problem modeling and formulation"*, in this step we create a function attribute analysis (FAA) so we can further more understand the system and to get to know what every single component is doing correctly and what they are doing wrong. The next step is the *"Contradiction Analysis"*, with the use of the information gathered before; we use the Root Contradiction Analysis (RCA) to understand the problem in a more specific matter, finding out the roots of the problem. After the RCA we carry out the "*Parameter Analysis"*, with the use of the contradiction matrix we analyze each of the contradictions given by the contradiction analysis and we select which of the parameters best relates to the contradictions. Then we create the "*Generic solution"*, with the help of the contradiction matrix and the 40

inventive principles generic solutions are created. Afterwards the "*Generation of Specific solutions"* step, which is with the ideas created with the 40 inventive principles and with the knowledge we have gathered from the researches and studies, we create a specific solution to solve the problem in hand.

2.1 Problem Definition and Interviews

The main problem is that because of the uniqueness and the needs of the market (where company 'P' is), the sales force always has a hard time with the distribution in the market, they need to have a direct contact with the retailers, by visiting their shops either by scooter or car, and this sometimes can be very dangerous. Consequently the problem is that the sales force in the beverage markets (such as company "P"), cannot seem to retain and motivate their sales force to stay for a long time and work as expected. Based on interviews done to company 'P's' ex-employees, the problem is that, there is not enough support towards the sales force, they do not receive any support material (like pop-material which are advertisement pamphlets, posters, or gas money for their transportation which they use their own source of transportation to go and contact their customers, and don't also get a depreciation expense for their vehicles). This is a really discourages the salesman, another factor is that they do not get any incentive to sell new products or products that are not the company's main product, therefore reaching the sales target for their main product but not for the other products offered by the company.

2.2 Preliminary Problem analysis

The preliminary problem analysis is to analyze in a broad way the problem in hand by using tools like the problem hierarchy Explorer and the 9 windows. The Problem Hierarchy Explorer is a way of clarifying the space around the originally stated problem definition. The Original problem is that Sales Department cannot retain and motivate their Human Talent (sales man) and because they are not motivated they do not work as expected. The reason why we can't solve this problem is because the budget of incentives given to the sales department is simply not enough to motivate and push the sales man to be better, and therefore the sales man are always with low motivation because they do not have support material (Pop material, transportation, depreciation expenses, etc…) so they can improve their sales. This leads to a bigger problem which is that the company is not really a long-term sustainable business, because their sales drop and also their human talent is in a constant change because they quit the company because of low motivation or low performance in the company. As it can be seen bellow in Figure 1 Problem Hierarchy Explorer for the "retention of sales force".

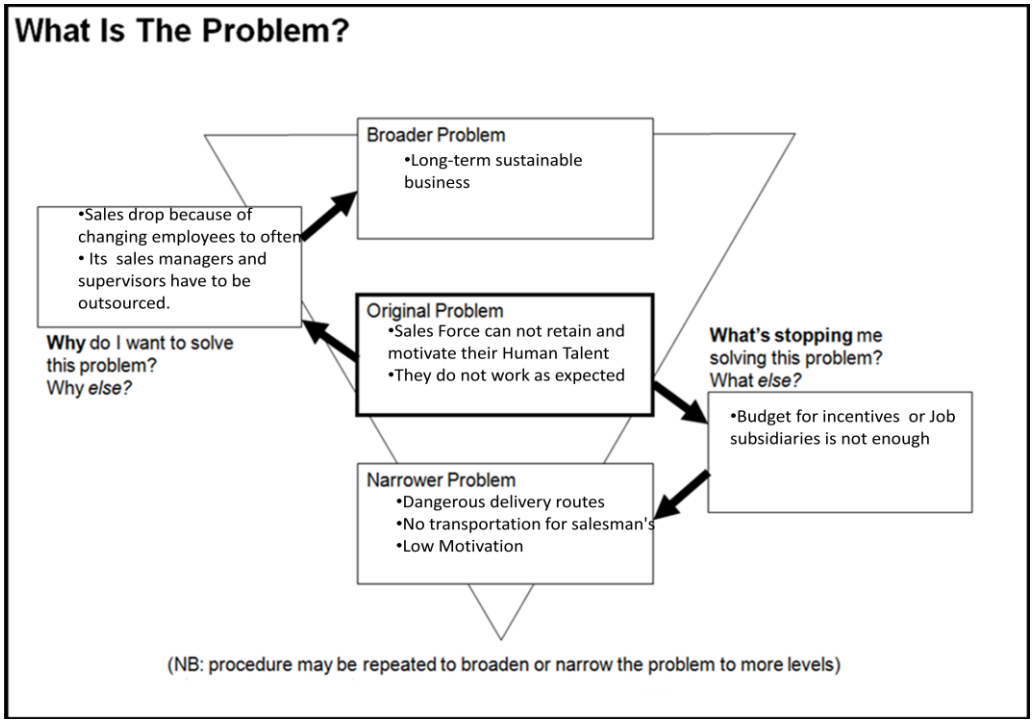

Figure 1: Problem Hierarchy Explorer for the "retention of sales force"

The 9 Window tool is used for the identification of resources in and around the system. The general identification of a resource is anything in or around the system that is not being used to its maximum potential. The main point of this tool is to adopt a systematic approach to help look for resources. With this tool we analyze in a general view of the system and at the same time the tangible (the things) and intangible (the knowledge, the people) resources. There are no rules concerning what order to fill the boxes in, or that all boxes have to have something written inside them.

The analysis of around the system, the system and finally the subsystem are done by looking into the past present and future aspects of the entire system, and also by taking into consideration the general aspects as well as the tangible and intangible resources of the system, so we can have not only a broad understanding of the system but also a more specific image of it.

First the past of the surroundings of the system were information like historical data of cycle profiles, lost costumers and exited competitors, are useful for the prediction of future demand or trends. In the present of the surroundings of the system are the customers like vendors or small shops that purchase the beverages for sales for the final consumers, non-customers or possible customers, the different channels of distribution, and the different competitors in the beverage industry. We take into consideration the tangible resources that are missing in the system which is the support material given to the sale force. Also we consider the knowledge resources which are the competitor's strategies that are unknown for the sale force. As for the future of the surrounding system are the new market trends and channels, new competitors and new customers, which in this case of study it has to be searched by the salesman instead of the company providing a list of new or possible customers; and possible transportation collaboration by the company or depreciation cost for the sales man owned vehicles used during the job.

In the system (sales model or incentive system) in the past are previous incentive systems, customer history, databases lessons learned; this type of information is useful to learn about problems that the company had before and that could be useful to solve problems in the present or future. In the present system are the current sales team and the current sales model, which in this case are lacking of sales force because of the unmotivated sales mans, that can't reach sales target because they do not get enough support from the sales department. In the future constraints of the in the system are new technologies or new products that might come to the company, long term sales workforce that comes with experience and employees loyalty.

Within the system or the sub-system, in the past constraints are the past staffs which have quit the company along with their lost experiences, also past processes and lost deals. In the present of the subsystem, there are the sales representatives, procedures, the lack of technology which in this case it forces them to use a paper base type of order and this leads to having a direct contact with the customer. In the future constraints sales could be change to home-work if new technology is applied to the company, that means that instead of having a paper base order system there will be an electronic base system which will make things faster and easier, and therefore having a chance of becoming a long sustainable business with sustainable customer relationships. Below in Figure 2 the 9 windows analysis, where all the parts of the system and all the different constraints can be seen in a more organized approach.

		Past	Present (sales workforce employees/ current customers)	Future
Around System	1	Historical Data, Cycle Profiles, Lost Customers, Exited Competitors	Customers , Non-customers, Channels, Suppliers, Competitors	Market Trends , New Channels , New Customers, New Competitors
	2		No transportation provided to sales force, No support material(Pop Material)	Transportation Provided by the Company
	3		Competitors/ Competitors strategies	Sales projections, Competitor Scenario, planning
System (Sales model or Incentive System)	1	Previous Incentive Systems, Customer History,Databases Lessons Learned ,Trials	Current Sales Team/ Current Sales Model	New Technology, New Products,Experience
	2		Lack Sales workforce	Long term sales workforce, Company Loyalty, Good salesman- customer relationship
	3	Previous business model	Business/sales model(channel)	Market trends, E-commerce
Sub-System	1	Past Staff, Experience, Past Processes, Lost Leads	Sales Representative, Procedures , Structure, Forms/Media, Communications	Home-working, Flexible Models, Autonomy, New Media, Paperless
	2		Lack of technology, Use of paper base orders, Need to have direct contact with the customer	Electronic based orders
	3	Knowledge of customers from the Sales man that left the company	New sales force knowledge of Customers	Sustainable relationships with customer

1= General Analysis
2= Tangible/ Resources Analysis
3= Intangible/Knowledge Analysis

Figure 2: 9 Window Analyses

2.3 Problem Modeling and formulation

In this step we created a function attribute analysis so we can further understand the system and to get to know what every single component is doing correctly and what they are doing wrong. The basic function analysis process is conducted in three main stages. In the first one we begun with the definition of the components (or elements) of the system. After defining the components we continue with the identification of the useful and negative relationships that exist between the various different components defined in the first stage.

2.3.1 Definition of components in the System.

+**Sales manager**: He is in charge of the sales area and he informs the Chief of sales what actions to take, by coaching and mentoring the sales team, developing sales strategies, goals and plans with and for your team, reviewing sales and marketing information both historical and current look at competitors and evaluate, develop strategies to compete, communicate the corporate message to sales team, forecast sales for senior management, work with marketing, head sales meetings and go on sales calls with team members, meet the needs of the team and be there for them when they need you, and most important to lead the team and help the individual members succeed.

+**Sales Chief**: He is responsible for a sales territory. A territory can be by a state, city, division of the country, among others. The sales chief controls, supervises, advises the actions to take, solves problems, and inform the market needs to the sales manager, among others. Also he is responsible for informing the people under their charge of how the territory will be handled correctly.

+**Supervisor:** responsible for supervising a specific area within the sales territory. These report and control the salesmen that are under his charge. These salesmen's are assigned to the area that the supervisor is in control of.

+**Salesman:** They are responsible for taking orders from customers. These are important, as they perform a direct communication with the customer and can detect market movement**.**

+**Customer:** He is the one that makes orders for the sales man to request for the product. They are retailers that sell the products to the final consumer and sometimes they are the final consumers.

+ **Product**: is simply the plain product that is sold to the customer, in this case they are beverages offered by company 'P'

2.3.2 Identification of the positive and negative relationships between components.

+Sales Manager- Sales Chief: The sales manager and the Sales chief have a positive relationship between one another, when it comes to the Manager informing the chief what actions to take, and the goals of the company, in the same way the Chief informs the Manager what the markets needs are as well as the sales reports. On the other hand they have a negative relationship because the budget which is managed by the sales manager (which is given by higher management departments) is insufficient to cover for the incentives or support material that is needed for the sales team.

+Sales Chief – Supervisor: The sales chief and the Supervisor have a positive relationship when the Chief overlooks or supervises the work that the Supervisor is doing, they also have a good communication between both of them when the Chief informs the supervisor how to handle each part of the territory. On the negative relationship the Sales Chief is not solving the problems that the Supervisor goes through, the main problem of keeping the sales man motivated, and because of this they are losing a lot of the sales force.

+Supervisor – Salesman: The Supervisor-Salesman relationship is slightly positive when it comes to informing the salesman what part of the sub-territory they should handle but, they do have a negative relationship regarding the information flowing from the salesman to the supervisor, since there are no service surveys given to customers the salesman neither the supervisor don't know if their job is being done as expected by the customers. Another negative relationship is the support material given to the salesman is missing; there is pop material or transportation given to the salesman, this resulting in an unmotivated sales force. This negative relationship results on not enough Know how, or the unwillingness to work from the sales force because of lack of support.

+Salesman – Customer: In the Salesman Customer relationship there is a positive relationship when it comes to communication, like the response from the salesman to the customer when the customer places an order, but there is a negative relationship at the same time, because of the fact that the Salesman does not have support material or does not have enough knowledge about the products he does not know how sale his product or all of the product to the fullest, making the orders insufficient because the Salesman is pushed to sell mostly their main products, since the incentive system the company has is focused only on the sales of this main product and not on new products or other products, this has a result of insufficient orders and there for not reaching all of the sales targets. Another negative relationship is that there is no recommendation what so ever from the customer to the salesmen, since there is no customer service surveys to see how the service could improve so there are no recommendations, so there is no improvement for the sales team.

+Customer – Product: The Customer-Product relationship is positive for some products of the company, mainly for the main product, but for other products or new products is negative because the salesman does not have the knowledge or support material of how to sell it to the customer therefore the image of the product gets discredited and is not sold as expected.

Below in Figure 3 FAA (Function and Attribute Analysis) where you can see all of the negative and positive relationships between the components of the system.

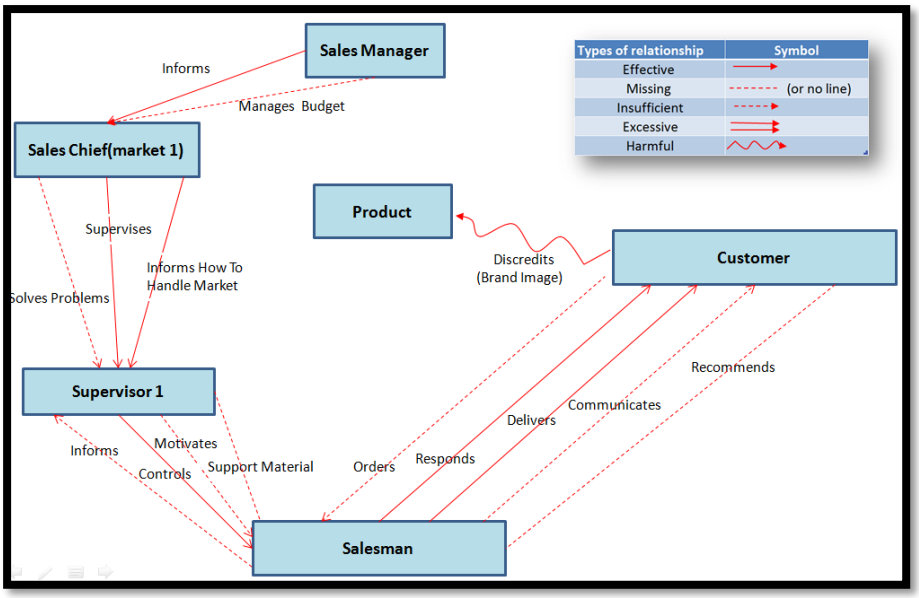

Figure 3: FAA (Function and Attribute Analysis)

2.4 The contradiction Analysis

With the help of the Root Contradiction Analysis the problem is determined in a more specific matter, finding out the roots of the problem and why things went wrong so that we can both correct them and, more importantly, prevent them from happening again. Based on the information gathered from the steps before of the process we have come up with a RCA (Root contradiction Analysis). We start at the bottom of the RCA with the roots of the problem and move up to the main problem by describing every part of the RCA showed in Figure 4.

There are two main roots in this RCA the first one is that the upper management departments give the sales department a really *(8) low budget* to work with, this resulting in having a positive and a negative effect, or in other words a contradiction (contradiction # 1). The positive effect is that since they do provide a low budget that means that there is more profit for the company since they do not have to spend that much sales revenues on budget for the next year, in other words there is less cost for the company. The negative side of this contradiction is that since there is not enough budget for the sales department the sales management cannot afford or supply *(5)support material* to their sales team. Support material is really important to the salesman because it facilitates their jobs, by making it faster (providing transportation) and easier (by providing pop-materials allowing them to sale their products in a more efficient way). The shortage of support material results on another negative impact in the system, *(3) no motivation.* When a sales force is unmotivated it does not sell or perform as expected by the company, this resulting on a drop on the sales, or lost of the sales force *((2) Sales force not retained)*.

The second root of the RCA is that management *(9) focuses only in one main product;* because of this another contradiction comes as a result (contradiction # 2). On the positive side of the contradiction, because the management focuses on only one main product the salesman are able to reach the sales target of that specific product. On the other hand (negative side of the contradiction) because management focuses on only one product they create *(6)(7) an inadequate incentive system*

or an incentive system without proper objectives. The inappropriate incentive system creates contradiction # 3, because the sales system is program to reward salesman only if they reach the sales target of their main product, they are able to reach this sales target for that product. On the negative side because of this the salesman are *(4) not able to reach the sales target of all products*, this resulting in a loss of opportunity for the company to earn more profit.

All of this conflicts or contradictions result in the company being *(2)unable to retain their sales force*, because their job is so un-motivated or hard to do and do not have that much support they are not whiling to continue working, this becoming a big problem for the company because it is not *(1)a long term sustainable business*. If they keep on losing their salesman every 6 to 8 months the experience that the salesman have gathered and the money that the company have invested in training this salesman goes to waste; also the customer relationship gets harmed because there is no steady salesman-customer relationship. Below is Figure 4 RCA, where it can be seen how the problem moves from the roots all the way up to the main problem.

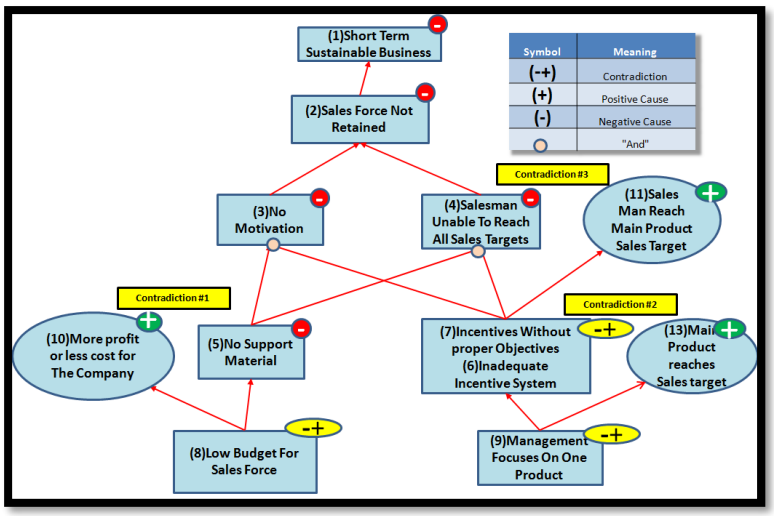

Figure 4: RCA

2.5 Parameter Analysis

In this part of the process with the use of the Contradiction Matrix we analyze each of the contradictions given by the Root Contradiction Analysis and we select which of the parameters best relates to the contradictions. Below in Table 1 Contradictions are the 3 contradictions gathered from the RCA, emphasizing what you would like to improve and what is stopping you from doing it.

	Things you would like to Improve	→	What's stopping you from doing it
#1	No Support Material	→	High Cost for the Company
#2	Incentives Without Proper Objectives	→	Drop of Sales Profit from Main Product
#3	Sales man Unable to reach All sales target	→	Drop of Sales Profit from Main Product

Table 1 Contradictions

2.5.1 Contradiction # 1 & its Parameters

Contradiction # 1 is composed by what we would like to improve that is 'No support material' and what is stopping you from improving this is 'The high cost for the company'. Based on the Contradiction Matrix we have selected the parameters that to our understanding relate the most to the conflicts in this contradiction, in the table 2 below, it is showed the parameters selected for each conflict as well as the possible inventive principles to solve or reduce the problem.

Table 2: Contradiction #1 Parameters

No support material	*Parameters*	(1)R&D-Spec /Capability/ Means	(7)Production Cost	(12)Supply Cost	(15)Supply Interfaces	(17)Support Cost	(19)Support Risk
High cost for the Co.	(7)Production Cost	3,10,35,37		2,5,31,35	3,5,12,35	2,3,10,35	3,10,25,27
	(12)Supply Cost	1,5,6,15	2,5,31,35		1,6,28,38	5,25,27,35	2,10,12,27
	(17)Support Cost	15,25,28,35	2,3,10,35	5,25,27,35	1,5,10,26		14,25,27,35
	(21)Customer Revenue/Demand/ Feedback	7,13,14,22	1,7,13,24	2,13,25,35	13,24,25,39	3,24,25,37	4,7,13,20

2.5.2 Contradiction #2 & its Parameters

Contradiction # 2 is composed by what we would like to improve that is 'Incentives without proper objectives or an inadequate incentive system' and what is stopping you from improving this is 'The sales profit of the main product'. Based on the Contradiction Matrix we have selected the parameters that to our understanding relate the most to the conflicts in this contradiction, in the Table 3 below, it is showed the parameters selected for each conflict as well as the possible inventive principles to solve or reduce the problem.

Table 3: Contradiction #2 Parameters

7)Incentives Without Proper Objectives(6)Inadequate Incentive System	*Parameters*	(26)Convenience	(28)System Complexity	(29)Control Complexity
Sales Profit from Main Product	(7)Production Cost	1,2,25,27	1,2,5,35	3,6,10,25
	(17)Support Cost	1,12,25,26	1,2,25,35	15,19,25,28
	(21)Customer Revenue/Demand/ Feedback	27,28,35,40	1,2,19,25	2,7,25,37

2.5.3Contradiction #3 & its Parameters

Contradiction # 3 is composed by what we would like to improve that is 'Sales man unable to reach sales target' and what is stopping you from improving this is 'The sales profit of the main product'. Based on the Contradiction Matrix we selected the parameters that to our understanding relate the most to the conflicts in this contradiction, in the Table 4 below, it is showed the parameters selected for each conflict as well as the possible inventive principles to solve or reduce the problem.

Table 4: Contradiction #3 Parameters

(4)Sales man unable to reach All sales target	*Parameters*	(7)Production Cost	(12)Supply Cost	(21)Customer Revenue/Demand/ Feedback
Sales Profit from Main Product	(7)Production Cost		2,5,31,35	1,7,13,24
	(17)Support Cost	2,3,10,35	5,25,27,35	3,24,25,37
	(21)Customer Revenue/Demand/Feedback	1,7,13,24	2,13,25,35	

2.6 Generic Solution

In this section, with the help of the contradiction matrix and the 40 inventive principles, generic solutions are created. Each contradiction is analyzed by looking at every row in each of the contradiction tables and taking the most frequent inventive principle as the number one option to solve the problem, because the most frequent inventive principle would be the most likely to create the best generic solution. If the most frequent principle does not create a solution, then the second most frequent principle is examined and so on. If the most frequent principle does not find a solution then we analyze the ones that are not repeated. After analyzing and finding the generic solution of each contradiction, the generic solutions will be analyzed in section 2.7 of this paper.

In contradiction # 1 after analyzing the parameters and the inventive principles related to the contradictions the most frequent inventive principles are: Principles: # 3 Local Quality, #5 Merging, #35 Parameter Changes, and # 13 'the other way around'. In contradiction # 2 after analyzing the parameters and the inventive principles related to the contradictions the most frequent inventive principles are: Principles: # 1Segmentation, # 25 Self-service, #2 Taking/Separation. In contradiction # 3 after analyzing the parameters and the inventive principles related to the contradictions the most frequent inventive principles are: Principles: # 3 Local Quality and #13 'the other way around'[Darrel, Mann, 2007].

2.7 Generation of Specific Solution

In this part of the process, after the generation of generic solutions, the ideas given by the 40 inventive principles and the use of the knowledge we have gathered from the researches and studies, we create a specific solution to solve the problem in hand. Based on the analysis of the contradictions parameters/generic solution, the answer to solving this issue is by creating a flexible incentive system, one or different incentives for each part of the sales force system, one which is not only applied to the results of the sales of the main product, but one that can also be applied fairly or for each product in a different way adapting to every different situation, that is no matter what product it is (main-new-old product) there would be some compensation for the sales done if of course the sales target is reached. From each compensation resulting from the sales, part of it would be as an economic incentive for the salesman, and the other part would go for expenses done for support material or transportation expenses, in other words the more they sell the more economic incentives they will receive and the less expenses they will have, and therefore solving the problem of not having any support material for the salesman. The main idea is that instead of the company giving the sales man money for support material, it can be solve by compensating them with support expenses if they reach the sales target of every product, instead of giving them money at the start for

support material, the company will provide support material only if they have a big percentage of sales or if they reach the sales target, and therefore motivating the salesman to do better.

Another option can be once the new incentive system is completed, ex-employees that have been quitting could be rehired with an offering of a better contract, the experience that they had can be recovered and with a new or extra incentive they would perform better. The incentive system can self motivate the salesman, by offering them that the more they sell the less support material expense they would have. If ex-employees get rehired they can be introduced with a new incentive system that will cover all of the products and therefore raising the sales of every product covered by the incentive system not only the main product. Below is Figure 5 Problem conflict and corresponding solution, where it can be seen how each principle creates an idea for a specific solution.

Contradiction #	Problem/conflict	Generic Solution	Specific Solution	
1	(+)No Support Material (-)High Cost for the Company	[3]Local Quality [13]'the other way around [35]Parameter changes	• Principle 3: From uniform incentive system to, flexible incentive system. • Principle 13: instead of company providing support material let the salesman earn their support material by selling. • Principle 35: Giving ownership to salesman, make them invest in their own company.	Flexible Incentive System
2	(+)Incentives Without Proper Objectives (-)Drop of Sales Profit from Main Product	[1]Segmentation 25]Self-service	• Principle 1: divide the incentive system in an way that it covers all of the prodcuts the salesman are incharge of. • Principle 25: rehire employees that quit, regaining their experience and making them better with a new incentive system.	
3	(+)Sales man unable to reach Sales target (-)Drop of Sales Profit from Main Product	[3]Local Quality [13]'the other way around	• Principle 3: From uniform incentive system to, flexible incentive system. • Principle 13: instead of company providing support material let the salesman earn their support material by selling.rm incentive system to, flexible incentive system.	

Figure 5: Problem conflict and corresponding solution

2.8 Specific Solution for incentive system

The incentive system is a vital part of the sales force and of any company. Besides helping increase sales volume, coverage, customer service, among others, it also helps with the developing of human talent through the direct contact they have with customers. It is necessary to have a system of incentives that is effective and not only benefits the company but also helps with the developing and retention of human talent. The system of incentives that will be offered will be directed to the sales force of companies engaged in the distribution of beverages.

The Incentive system that will be proposed consists of different tasks that will help to develop and retain human talent. This system will be to the benefit of company 'P', to develop and retain their sales workforce. Every task proposed is essential because it has a specific objective in the incentive system. Below in Figure 6 it's the Tasks that the proposed incentive system will have.

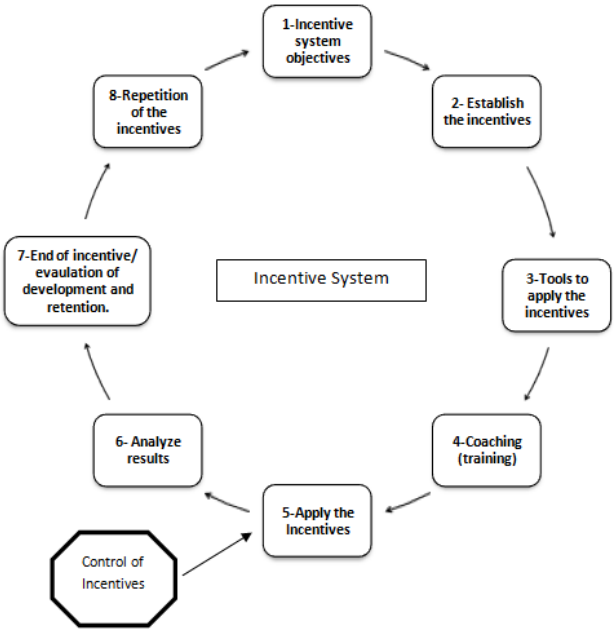

Figure 6: Incentive system.

The incentive system must always be found in constant feedback. The feedback will allow the system to remain in maintenance of the incentives. This means learning to improve every activity avoiding mistakes that have happened in the past by keeping it in constant improvement. That is, to improve every aspect of the activities and to benefit and achieve the development of talent within the sales force. The development of human talent gives the company a competitive advantage over the competition. This is because the staff knows his way in and does its work efficiently and effectively. By having different types of incentives in the incentive system, it adapts to every single aspect that company 'P', incentives like sales incentive, customer Service incentive, Customers resources incentives, coverage Incentive, and clients Served Incentive help to overcome the problems of the company.

3. Conclusion & Future works

A good incentive plan is straightforward and predictable. It is easy to comprehend; so that people can link their performance with their pay. It is predictable, so that people can plan their hard work to their objectives. A good plan is fair and flexible to accommodate new product launches and changeable markets. It is economical, yet competitive. Finally, it meets the needs of its customer's sales force and the company. Researches indicate that broad-based incentive plans can be utilized as a means to encourage both employee performance and productivity (Gordon, A. A. & Kaswin, J. L., 2010). When implementing an incentive plan, several considerations are needed to ensure the plan is successful. However, it is important to note that incentive plans cannot guarantee employee productivity by themselves. They must be tied with effective human resources practices in order to ensure a successful work environment. These include determining the appropriate incentive prizes, instituting a broad

In the last few years, TRIZ methodology was used in several subjects, it started to be studied in several non-technical areas like business, finance etc. (Souchkov, V., 2007). This study is inspiring because Human Talent has not been inspected to the fullest before by Systematic innovation, and Systematic Innovation can be used as a creative tool to design a guide for managers. The major contribution of this paper is to show that Human Talent is an appropriate area to use Systematic Innovation methodology as originally, Systematic Innovation was only applied to engineering problems.

Regarding future research, it is recommended that researchers, who are interested, should focus on analyzing this study with different kinds of culture or ambiance, the fact is that this study is applied to a company in El Salvador; it does not mean that it could be adapted to a different industry in a different country. Every company has its own "personality" or culture. For an organization to be successful over the long term, its management style needs to be designed depending on its culture. To take this fact into consideration, the incentive system created can be designed or adapted depending on companies or the countries characteristics.

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Applying TRIZ to Graphic Design using Genetic Algorithms

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Abstract

A CAI (Computer Aided Innovation) tool called AEGIS (Accelerated Evolutionary Graphic Interface System) is being developed and applied to graphic design. The tool, which uses TRIZ 'guided' algorithms, is being tested with graphic design experts. The AEGIS processes initial inputs (initial design ideas) and apply TRIZ based algorithms to them and outputs 'innovative designs'. These designs may further be processed using manual techniques to achieve the final outputs desired by the designers.

This paper discusses two versions of 6.6 of AEGIS (A/B). In these versions, Genetic Algorithms (GA's) are being utilized. Genetic algorithms are one of the best ways to solve a problem for which little is known. They are a very general algorithm and so will work well in any search space. Genetic algorithms use the principles of selection and evolution to produce several solutions to a given problem.

In AEGIS, Genetic Algorithms are implemented through which TRIZ guided effects and mutations are applied here to graphic design elements. It attempts to code TRIZ Principles based transformations (function/method parameters) into genes. The present version of AEGIS has 15 chromosomes. This paper discusses the detailed implementation of Genetic Algorithms and hence the translation and implementation of TRIZ Principles to Genetic Algorithm structure to obtain generations of phenotypes (Images).

The outputs from the software i.e., designs, are promising, and have to some extent motivated professional graphic designers to accept that this tool has benefits in aiding them to produce more innovative designs or at least speed up this process. Some 'design' examples using GA's are shown in this paper.

Keywords: CAI, GA's, TRIZ Principles, Graphic Design.

1. Introduction

The paper identifies two main types of step change which are called here "incremental steps", and "innovation steps" which we later characterize as associated with a 'wow' feeing. This paper discussed the structure, implementation and analysis of a CAI tool (León-Rovira 2006). Whether the step change is perceived successful in the user context or not is the main question which identifies and classifies the steps into the two categories. This paper highlights research in which innovation design through computer based tools can be performed. The results of this research besides providing automated innovation for specific Automating Innovation Using Computer Aided Innovation industries also provides copious data and experience to develop further, computer based innovation.

TRIZ is an integral part of this research (Ilevbare, Probert et al. 2013). This paper presents the structure and implementation of a CAI tool (software) and analysis of the outputs for validating the value of TRIZ implemented in an automated tool (an attempt to automate innovation). The software is called AEGIS has been developed through six versions until now and the latest version (6.6) has been coded using Genetic Algorithms, where TRIZ Principles have been transformed in to graphic design effects or transformations. Genetic Algorithms have been previously implemented to artificially evolve the graphic populations (Sims 1991), but this research takes a slightly different approach and is based on TRIZ guided transformations. This paper discusses the detailed implementation of Genetic Algorithms and hence the translation and implementation of TRIZ Principles to Genetic Algorithm structure to obtain generations of phenotypes (Images). Various versions of AEGIS have been developed previously (Filmore 2010); the current two versions are specially implemented with Genetic Algorithms.

2. Structure of AEGIS

2.1. Inputs/ Outputs of AEGIS.

The AEGIS takes following inputs at the start of a designing session from the designer:

a. Background Image (See Figure 4 for samples).
b. Logo (See Figure 2 for samples).
c. Extra Image (See Figure 3 for samples).
d. Font Specifications for Font Images/ Layers (See Figure 1 below).

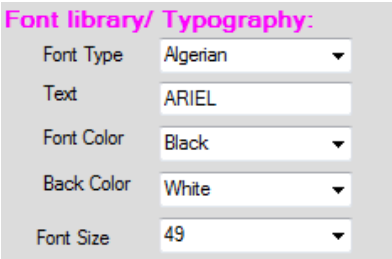

Figure 1: The configuration of **Font Element** as input by user.

Figure 2: Sample **Logo Images** as input by user.

Figure 3: Sample **Extra Images** as input by user.

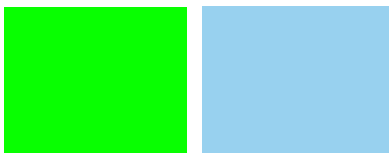

Figure 4: Sample **Background Images** as input by user.

2.2. Layered approach in AEGIS (AEGIS image components).

The AEGIS maintains designs as images/ layers and manipulates/ transforms them as separate layers which are presented and combined together as a combined output during each iteration. Eight layers are maintained for each design during the each iteration (Each iteration produces nine outputs during execution.

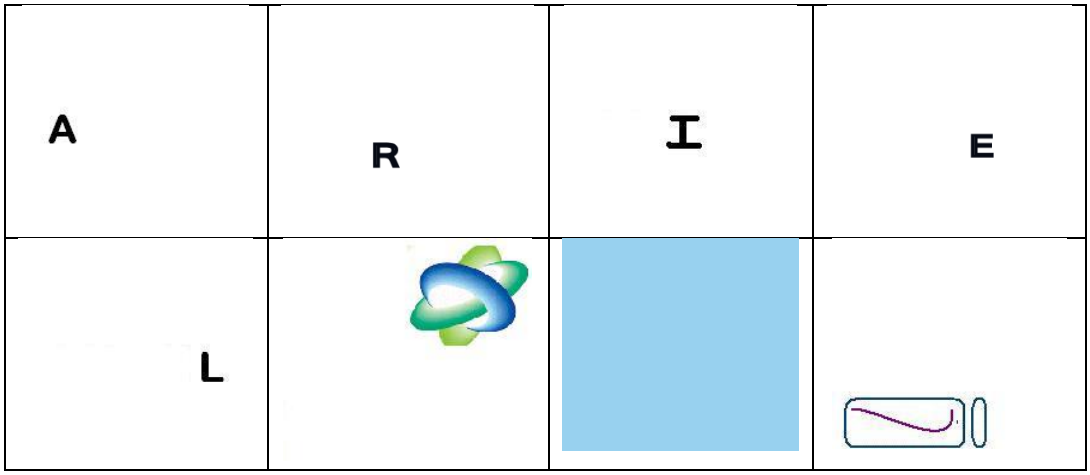

Table 1: Different (eight) layers maintained during iterations in AEGIS.

2.3. Levels of transformations in AEGIS.

There are mainly two levels of transformations in which TRIZ effects are applied to the image components: atomic level and molecular level. The atomic level mutations are applied to individual font images (the font layers are generated using the input specification as given by designer – see Figure 1). These are then subject to genetic algorithm based TRIZ guided transformations.

These layers along with the other layers input by the user as images (logo, background and extra) are mutated in molecular level of mutation and the user is presented with nine sets of combined layers of these images undergoing different transformations (see Figure 5 and 6).

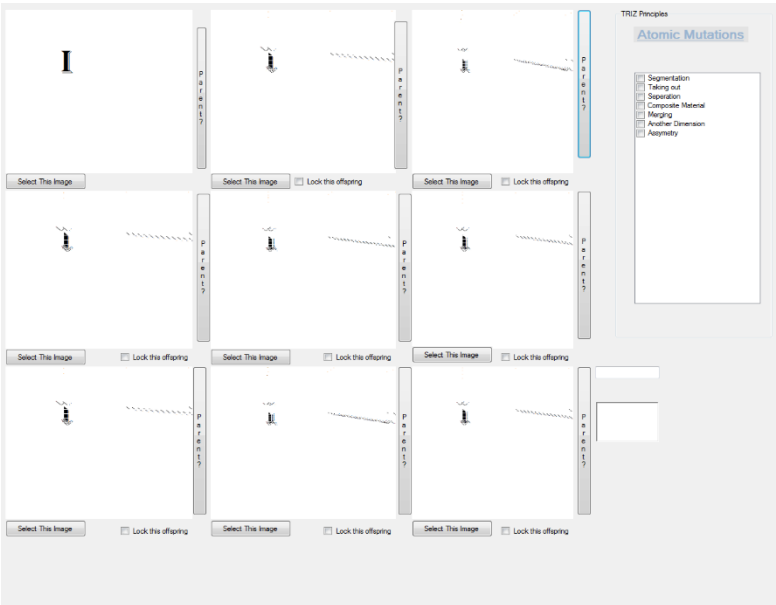

Figure 5: Atomic Level Mutations (individual font layer level).

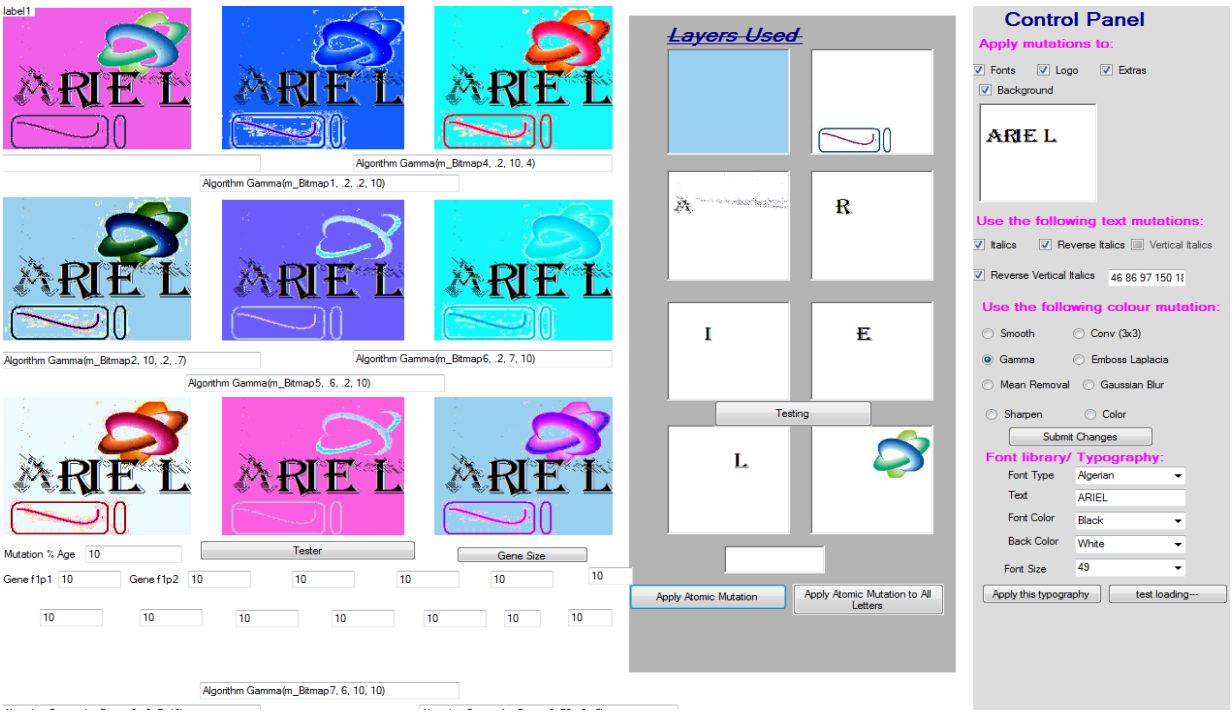

Figure 6: Molecular Level Mutations (all layers).

3. Genetic Algorithms

In GA approach, each organism is considered to be made of cells which in turn consist of chromosomes; chromosomes are made of genes (which are functional blocks of DNA). Each gene controls a particular property of an aspect or behavior or part of the organism. The different possibilities, which a property can have, are called 'Alleles'. Genes have a particular place in a chromosome that is called 'locus'.

3.1. Genetic Algorithms Structure and Implementation

Table2 below shows the general structure of Genetics for AEGIS (version 6.6_GA-A and B):

Name of process/ element type	Equivalent in AEGIS_6.6_GA	Example
Gene	Function/Method Parameters in c#.net	In the method alterIlalics (001111,001111,000011) 001111,001111 and 000011 are the genes.
Chromosome	Function/ Method	The method alterIlalics (001111,001111,000011) altogether is called a chromosome.

Gene controlled property	The size, shape and degree of different mutations in AEGIS	Curvature of an alphabet.
Allelle	Different colours, sizes, shapes of the gene controlled property	The gradient colour of base
Locus	The point where the parameters of a function end.	In the method above, the ',' represents a locus separation point as it marks the end of one gene and start of another.
Phenotype/Individual	The image	One of the images in generated generation.
Population	Group of all individuals (images) generated.	Images generated in each iteration (9).
Genome	Collection of all chromosomes for an individual (image).	Summation of all methods and their parameters for an image generated at point 3 of the 3x3 grid of AEGIS.

Table2: General structure of Genetics for AEGIS (version 6.6_GA-A and B).

3.1. Chromosomes and Genes in AEGIS first GA version

The first GA enabled version of AEGIS has three chromosomes namely (AEGIS_XML_GA_6.6 (A)):

- 'alterItalics' (4 genes)
- 'spheroidality_curve_v' (4 genes)
- 'Segmentation_pieces_hor' (5 genes).

These have in total 13 genes. The software is capable of producing infinite number of generations, but the computing resources such as disk space, processing speed, determine a realistic time limit/ generation limit).

3.2. Chromosomes and Genes in AEGIS current version

In the version AEGIS_XML_GA_6.6(B), the font letters are subjected to TRIZ based transformations. There is a set of 15 transformations defined (transformed from TRIZ Principles to Graphic Design effects specifically for fonts). Each set of transformation in coded in the form of a chromosome. Each chromosome is coded in the form of a function (method) in C#. Each function is considered as a chromosome and the parameter of each function is considered a gene which controls the specific alleles of the image

The chromosomes coded in **AEGIS_6.6_XML_GA (B)** version applied to the fonts are listed in Table-3, along with the main TRIZ Principle behind these transformations:

Chromosome	*TRIZ Principles Pool* (Sub-Principle)- Main Principles Discussed
Spheroidality Trait	Principle 35 Parameter Changes (B) Principle 26 Copying (B) Principle 32 Color changes(A) Principle 7. Nested Doll (A) Principle 8. Anti-Weight (A).
Outlining	Principle2 Taking Out(A) Principle 7 (A)
Segmentations	Principle1 Segmentation (A,B) Principle21 Skipping (A) Principle19 Periodic Action(A,C)
Extensions And Shortenings	Principle 35 Parameter Changes(B)
Fragmentations	Principle 1 Segmentation (A) Principle 2 Taking Out(A)
Shapes Introduction	Principle 40 Composite Materials (A)
Symbols Introduction	Principle 40 Composite Materials (A)
Repetition(s)/ Copy	Principle 26 Copying (B)
Cases and Sizes	Principle 35 Parameter Changes (B) Principle 16 Partial or Excessive Actions (A)
Slanting	Principle 14 Spheriodality Curvature (A)
Scaling	
Rotation	Principle 14 Spheriodality Curvature (A)
Colour/Toning	Principle 32 Color Changes (A)
Distortion Colouring	Principle 22 Blessing in Disguise (A)
Distortion Mutilating	Principle 22 Blessing in Disguise (A)

Table 3: The chromosomes coded in **AEGIS_6.6_XML_GA (B)** version applied to fonts, together with the main TRIZ Principle behind these transformations:

4. Technology Used

Different versions of the AEGIS have been developed in different technologies: C#.NET, forge.NET and Mathematica. A brief description of one of these technologies (C# as employed in GA enabled versions of AEGIS) follows.

C# is one of the main languages being used in AEGIS project. C# (pronounced "see sharp") is a multi-paradigm programming language encompassing imperative, functional, generic, object-oriented (class-based), and component-oriented programming disciplines. It was developed by Microsoft

within the .NET initiative and later approved as a standard by Ecma and ISO. C# is one of the programming languages designed for the Common Language Infrastructure.

5. Outputs and Analysis

This section discusses the outputs and a brief analysis at two levels of AEGIS: Atomic and Molecular level transformations.

5.1. Atomic Transformation Outputs

Table 4 below shows the atomic transformations as obtained by applying TRIZ to font layers individually.

	Snapshot of Live Output	**Chromosome Applied** (With Gene Values- converted to decimal values).
 Parent Image		Chromosome Applied: Spheroidality Trait *Parameter Values (Decimal): (5,30,15,20)*
		Chromosome Applied: Outlining *Parameter Values (Decimal): (Blue,Line,0,5,0,1,0,1,0)*
		Chromosome Applied: Segmentations *Parameter Values (Decimal): (H,3,2,10,L,0)*
		Chromosome Applied: Extensions And Shortenings *Parameter Values (Decimal): (Extention,10,0,1)*
		Chromosome Applied: Fragmentations *Parameter Values (Decimal): (10,1,5,2,H)*
		Chromosome Applied: Shapes Introduction *Parameter Values (Decimal): (Oval,1,20,5,30,Brown)*

		Chromosome Applied: Symbols Introduction *Parameter Values (Decimal): (Star,Brown,1,5)*
		Chromosome Applied: Repetition(s)/ Copy *Parameter Values (Decimal): (1,1,1,0,1)*
		Chromosome Applied: Rotation *Parameter Values (Decimal): (30,Right)*
		Chromosome Applied: Distortion Colouring *Parameter Values (Decimal): (Blur,29,-,100)*
		Chromosome Applied: Distortion Mutilating *Parameter Values (Decimal): (15,15,30,18)*

Table 4: Atomic transformations obtained by applying TRIZ to font layers individually (AEGIS_XML_6.6_GA(B)).

5.2. Molecular Transformation Outputs

A few of the image transformations of all image layers (molecular mutations) are discussed in this section.

Table 5 below shows the outputs from different iterations in AEGIS on the molecular level. The different combinations of atomic mutations as depicted in the molecular level mutations result a wide range of varieties of designs available for selection by the designer. Currently the designs are being validated and rated by the designers. A special module of the software called 'self-learning' is in the final stages of development so that the software will be made capable of recording all the useful and non-useful outputs and hence can use this intelligently to guide future designers to reach their designs quickly and more innovatively.

Image Output	Brief Configuration	Comments
	Algorithms Applied: • 'alterItalics' • 'spheroidality_curve_v' • 'Segmentation_pieces_hor' . Gene Size Limit :10	• The texture of this image has been considerably changed. • The text leaves a trailing effect due to extreme value of one of the parameter value of gene.

Table 5: Molecular mutation obtained from AEGIS.

6.0. Conclusion

The outputs from the software: designs, are promising, and have to some extent motivated professional graphic designers to accept that this tool has benefits in aiding them to produce more innovative designs or at least speed up the design process.

Many questionnaire sessions have been carried out with graphic designers. The graphic designers have expressed interested in using the software in the near future. They have highlighted few of the advantages of AEGIS as compared to other commonly used software packages for graphic design (Adobe Photoshop, etc.). A few of the advantages include fast delivery of many outputs (with considerable variations) in a short span of time and each iteration representing many (nine) outputs each

Further development of this software along with constant feedback could result in design processes more or less being automated with the help of TRIZ triggered transformations which could potentially help graphic designers in their initial design phase. This will also highlight the potential of TRIZ application in graphic design field and also could establish the hypothesis that there is a possibility to automate innovation.

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Computer Aided Innovation from the Perspective of Bibliometrics Analysis: A Literature Review

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Abstract

In recent decades, technological innovation has become a key factor for companies that want to defend their competitive position, increase profits and obtain competitive advantages in their markets. From a little orderly process, innovation has come to be systematized, with the establishment of tools, methodologies and theories. A variety of computer programs have been created to support innovation, giving rise to a new category of tools that has been called Computer-Aided Innovation (CAI). Under this term a scientific community concerned to contribute to the foundations of the theoretical framework and practical implementation of innovation supported by computers was born. This area is still relatively new, since the first conference on CAI occurred only in 2005. In this scenario, we are conducting a bibliometric study. Our intention is to understand the present and foreseeable future of CAI. This paper is a report of our literature review.

Keywords: Bibliometrics, Computer-Aided Innovation, New Product Development.

1. Introduction

Companies are being increasingly influenced by global competition. The speed of technology development has increased, while the life cycle of products is getting shorter. This means that innovative products come to the market in less time and with greater quality. Thus, in recent decades, innovation has been seen as a crucial factor for the competitiveness of organizations. From a little orderly process, innovation has come to be systematized, with the establishment of tools, such as CAD, CAM and CAE, methodologies such as TRIZ, QFD and FMEA, and process models, such as the Stage-Gate^{TM} process, Concurrent Engineering, and other organizational and technological innovations (HÜSIG and KOHN, 2009). A variety of computer programs have been created to support innovation, giving rise to a new category of tools that has been called Computer Aided Innovation (CAI). The first developments of CAI began in the early nineties in the U.S., when a wave of methodologies and computational tools

to support invention were created. Basically, CAI emerged from computational tools that support the use of TRIZ, which is recognized as a systematic methodology to aid technological innovation. However, the first international conference, under the name of Computer Aided Innovation, occurred only in 2005, in Germany. Since then, there have been three conferences, the second in 2007, third in 2009 and last in 2011. Due to the few years of the keyword CAI, it is still difficult to have a clear definition of this emerging technology. There are many researchers around the world, both in the academic and corporate arenas, working on developing tools and methodologies related to Computer Aided Innovation, and their collective work needs to be better understood.

In this context, it is fundamental to find out where, when, what and who is contributing to the consolidation and growth of CAI. Bibliometrics is a statistical tool and its empirical approach allows precise analysis of the scientific production in a specific area of knowledge. The accelerated expansion of science and technology has created the need to assess and monitor the development and progress made in various areas (SILVA, 2004). Thus, it is our view that bibliometrics should be used in the area of CAI, to analyze how the publications are developing, to find out who and where they are contributing to its growth, to determine which means of scientific communication are used, and to understand the impacts of this area in the scientific community. Current and new researchers could benefit from such view of CAI developments.

Previous studies have assessed CAI. Cavallucci (2011) made an analysis of 121 articles related to CAI, correlating them to the Stage-Gate™ process, which is considered one of the most used in innovative companies. This study made it possible to know which areas of the whole product development processes are covered by CAI researchers and which are not. The result showed that the generation of ideas, preliminary research and development are relatively well developed. However, the stages of marketing, testing and validation are still very underdeveloped. Thus, more CAI related research is required in these areas.

Hüsig and Khon (2009) also made a contribution to the assessment of CAI. Their work presented the state of the art of CAI from the perspective of New Product Development, and established a categorization scheme for CAI software available on the market. This scheme was divided into three main areas, namely: idea management, strategy management and patent management. The authors also performed a survey of over 150 CAI tools. After their analysis, 115 programs were categorized into different areas. The result of this research showed that most of CAI software is in the sub-category idea collection (15%) and only 4% of the software provide a holistic solution. Hüsig and Khon (2009) also contribute to a clearer view of the available solutions in the field of CAI.

Another important evaluation of CAI was provided by Leon (2009), who showed in his work a future perspective of CAI. He addressed the new information technologies and methods,

such as semantic web, data mining, text mining, chaos theory and evolutionary algorithms. He also presented an overview of the integration of Product Lifecycle Management (PLM) with CAI systems to reduce development time while increasing product functionality, quality and reducing environmental impact.

2. Computer-Aided Innovation: an overview of the publications

In 2004, the first special topic in CAI, still under its first name of Computer-Aided Inventing, was organized at the 18th World Computer Congress in Toulouse, France. This initiative was promoted by Professor Noel Leon (JACQUART, 2004). On this occasion, there was already a strong concern about the lack of integration of CAI systems with other computer systems, such as CAD and CAE, both widely used in engineering design. This integration could best meet the demand of a systematic process innovation from start to finish. Also, an integration of CAI with PLM (Product Lifecycle Management) was proposed (CASCINI, 2004).

The first CAI conference was held in Ulm, Germany in 2005. On this occasion, 22 works were presented.

In 2006, there was another special topic on CAI at the IFIP International Conference under the title "Knowledge Enterprise: Intelligent Strategies in Product Design, Manufacturing, and Management" held in Shanghai, China. On this occasion, 10 papers were presented (WANG et al, 2006).

2007 was a very productive year for CAI. The 2nd Conference on CAI, organized by IFIP, happened in Michigan, USA. A total of 22 papers were presented and published in the proceedings book "Trends in Computer Aided Innovation" (LEON, 2007). Also this year, two special editions on CAI were published, with 12 papers in the International Journal of Product Development, and 13 other papers in the International Journal of Computer Application in Technology. Thus, the year ended with a total of 47 CAI publications.

In 2008, there was another special edition on CAI, organized by the IFIP World Computer Congress in Milan, Italy. The results proceedings book was titled Computer-Aided Innovation, and contained 21 papers (CASCINI, 2008).

The year 2009 was also very productive for CAI. The 3rd Conference on CAI, organized by IFIP was held in Harbin, China. The proceedings book named Growth and Development of Computer-Aided Innovation was published with 35 papers (TAN, CAO and LEON, 2009). In this same year, a special issue was published in the journal Computers in Industry, with 10 papers. Thus, 2009 closed with a total of 45 published CAI studies.

In 2011, there were 24 CAI publications: 14 at the 4 th Conference on CAI, organized by IFIP and based in Strasbourg, France, and 10 in another special issue of the journal Computers in Industry. The IFIP conference proceedings book was titled Building Innovation Pipelines Through Computer-Aided Innovation (CAVALLUCCI, DE GUIO, and CASCINI, 2011).

Over the years, some studies had major highlights and relevance to the community of CAI as Cascini and Russo (2007). They report that TRIZ is a systematic methodology for innovation and a powerful tool for forecasting technology, but also that the patent analysis needed for its effective use is still too complicated. According to these authors, text mining has a great capability for extracting relevant information from large data sets, but lacks specific means for supporting patent analysis in order to identify the underlying contradictions in a given technical system. The authors proposed an algorithm for solving this problem.

Cavallucci and Khomenko (2007) described in their work that the methods and tools developed in the era of quality and optimization have reached their limits and became inappropriate in the context of the needs of the current era of innovation. They also declare the incapacity of classical TRIZ to face complex situations. These authors propose an OTSM TRIZ-based computer program for managing complex issues and a practical study on the development of a ground-based radar that has been done to validate their proposal.

Hüsig and Khon (2011) discuss in their work CAI in the era of open innovation and Web 2.0, and propose the "Open CAI 2.0". According to them, CAI was originally developed in Employee-Driven Innovation (EDI) and closed innovation. However, in the recent past, new technologies such as Web 2.0 and open innovation have gained popularity and are breaking paradigms in the area of new product development. They discuss the benefits and challenges to software providers and users that arise from this new evolutionary step of CAI.

In summary, there was a significant amount of publications in the period from 2004 to 2011, opening a large field for study, both by quantitative and qualitative methods.

3. The importance of bibliometrics in a new knowledge field

Bibliometrics is defined as the application of mathematical and statistical methods to books and other media. Its use is suggested in all studies that seek to quantify the process of written communication (BUFREM and PRATES, 2005). The word bibliometrics was first used by Otlet in 1934, but it was only in 1969 that Alan Pritchard suggested replacing "statistical bibliography" with bibliometrics.

According to Vanti (2002), bibliometrics is a set of research methods in constant evolution, and developed within the context of information science, which uses quantitative analysis, statistics and data visualization, primarily to map the structure of knowledge of a scientific field,

and also as a tool for analyzing the behavior of researchers in their decisions concerning the construction of this knowledge.

Finally, one of the definitions used in Bibliometrics, according to Pritchard (1969), is that it encompasses "all studies that attempt to quantify the processes of written communication."

Many researchers have tried to use some means of bibliometric analysis to assess the development condition of a scientific field. They studied the distribution of publications, the distribution of authors, countries, and the number of citations based on the online literature database, in order to achieve the target of discovering the current research condition (ZHU and GUAN, 2013).

Literature review is a critical process to ensure that the financial investments in research produce the desired economic, social and political results. The more productive the scientific area, the more rigorous and frequent its bibliometric assessments should be. Evaluation procedures are based on two methodologies: the qualitative assessment made by peers, strongly connected to the reputation gained by the participant, and the quantitative assessment, based on bibliometric and scientometric methods (VANZ and STUMPF, 2010).

3.1 Main bibliometrics laws

The main laws governing bibliometrics are: Bradford's law, which studies the productivity of journals; Lotka´s law, which concerns the authors' productivity and, ultimately, Zipf's law, which verifies the frequency with which words appear in scientific texts.

According to Vanti (2002), Bradford's law allows, by measuring the productivity of journals, to establish the core areas and the dispersion areas on a given subject in a same set of journals. Thus, it is possible to estimate the degree of relevance of journals in a given field of knowledge, because journals that publish more on a particular subject can be regarded as having a higher quality and/or relevance in that area. Bradford's law can identify which are the most prestigious journals and the ones that contribute the most to the development of a particular area of knowledge.

Lotka's law is based on the premise that some scholars publish a lot and a lot of scholars publish a little. More specifically, this law states that the relation between the number of authors and the number of articles published by those, in any scientific area, follows the Inverse Square Law $1/n^2$. For example, in a given period of time, the number of scientists writing two articles on a subject would be equal to ¼ of the number of scientists who wrote one. In the management of information, knowledge and scientific and technological planning, Lotka’s law applicability is verified in the evaluation of productivity of researchers able to identify the research centers that most contribute to the development of a certain area (VOOS, 2002).

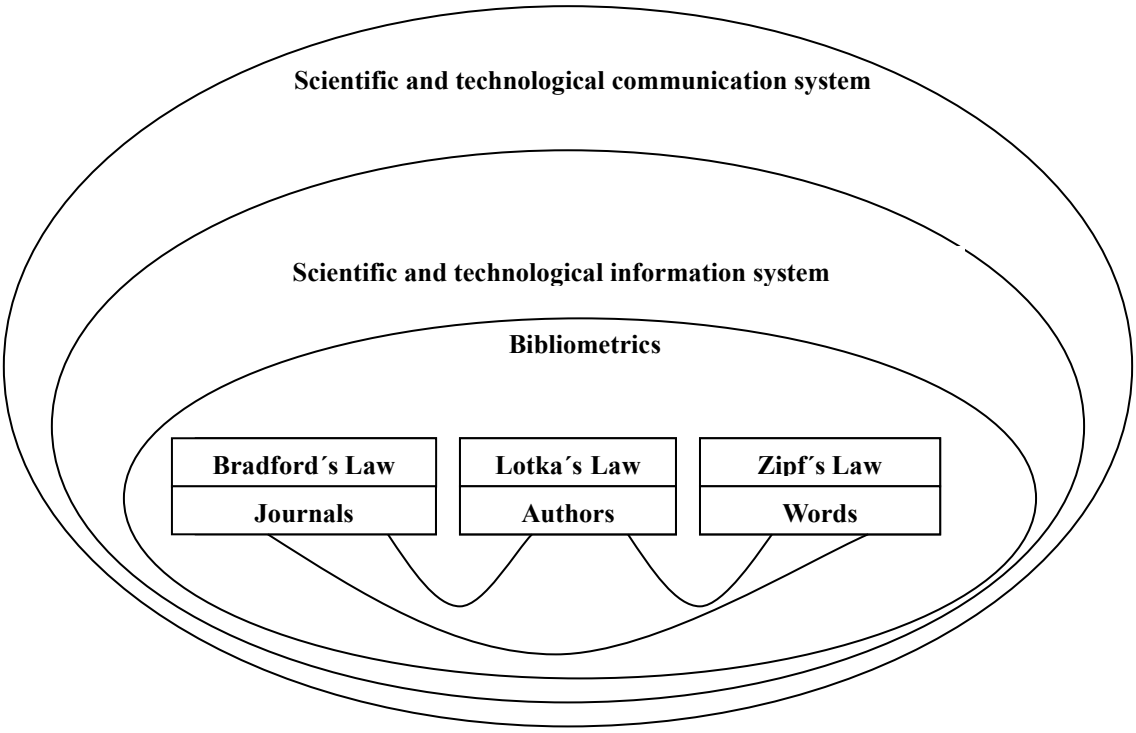

Figure 1. Main laws of bibliometrics and their relations with communication and information systems

Zipf's law, formulated in 1949 is known as the fundamental quantitative law of human activity. It is subdivided the first Zipf's law, which corresponds to high frequency of words appearing in a text (number of occurrences of words). It is defined by the following mathematical expression:

$$K=R.F \qquad (1),$$

where K = constant, R = word order, F = frequency of words.

This law states that by listing the words that occur in a text, in decreasing order of frequency, the position of a word in the list multiplied by its frequency is roughly equal to a constant. Zipf's law is used to measure the frequency of occurrence of words in various texts, generating an ordered list of important terms for a particular discipline or subject.

Bibliometrics is a quantitative tool that allows researchers to minimize the subjectivity inherent in indexing and retrieving information. Ultimately it contributes to decision making in the management of information and knowledge, as it assists in the organization and systematization of scientific and technological information (GUEDES and BORSCHIVER, 2005).

4. Final remarks

Due to the few years of life of CAI, it is essential to identify, understand and analyze its development in order to identify who are the people who are in the research front, where these people are and what institutions they belong to, and measure the quantity of articles and their impact. Thus, efforts to develop this scientific community can be better organized. This paper provided a literature review of CAI development and the tool which we intend to apply to it in order to obtain new insights, which is bibliometrics.

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Using Zen Meditation Practices for "In the Zone" Systematic Innovation Thinking

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Abstract

The core of systematic innovation is to target the right problem to solve and solve contradictions. Therefore, discovering the right problem (or contradiction) to solve is essential. However, due to our psychological inertia, current systematic innovation tools become too overwhelming when first applying them, and in turn, finding that "right" problem (or contradiction) can become intense or an adventure. Hence, other psychological-related tools should be applied to facilitate the flow needed in systematic innovations thinking. This paper proposes using zen meditation practices of de-centralizing our thoughts to create that "in the zone" environment. Since the inner psychological journey is often disregarded in training and practice, zen meditation should be introduced into systematic innovation tools and incorporated as a significant training tool into the structure for innovative thinking practices.

Keywords: flow psychology, psychological inertia, systematic innovation, zen meditation

1. Introduction

As society advances, many corporations integrate innovation techniques to increase product production. The first step in this course of action is opportunity identification. TRIZ and other systematic innovation methodology have been utilized to provide creative solutions to do such a task. The rule of thumb of TRIZ and other systematic thinking processes is to find or define the "right" question to solve. Defining the "right" question is a crucial process and one that will directly generate the "right" solutions (Mann, 2002). The course of finding the "right" question is often a journey, externally and internally. Furthermore, TRIZ and other systematic thinking tools have the role of solving contradictions and producing creative or systematic innovations. These tools are often used for overcoming psychological inertia and preconceived notions. In order to attain a breakthrough, the mind needs to break free of psychological inertia. Hence, it is actually a straining internal journey of psychological development in becoming systematic innovation thinkers.

Although there are many tools for breaking free of psychological inertia, such as mindmaps, TRIZ, DeBono's six thinking hats, NLP, QFD, etc., training the mind takes time and practice. Zen meditation has been used for centuries to train the mind to become more aware and attentive of the present state, de-centralizing the thought process. Current meditation practices are often applied to

psychological situations, such as reducing stress, being bipolar, and other mental conditions. However, Zen meditation gives insight for training the mind to become mindful innovators. It is an extensive journey and the number of practice is immense, not the usual few hours of training to become proficient in systematic innovation. Therefore, it is critical to have mental preparation, or train to be "in-the-zone" in creative problem solving or our psychological inertia will prevent us from targeting the "right" problem to solve.

2. Hero's Inner Journey

Developing a mature capability to innovate is actually a time-consuming process. Darrell Man (2012) presented the Innovation Capability Maturity Model (ICMM). In Mann's book, The Hero's journey models Joseph Campbell's findings and Matchett's views. This journey describes the basic steps for this quest of Innovation Capability Maturity:

Act I-Separation

1. The Ordinary World

2. The Call to Adventure

3. Refusal of the Call

4. Meeting the Mentor

Act II-Descent

5. Crossing the Threshold

6. Test, Allies and Enemies

7. Approach the Inmost Cave

8. The Ordeal

9. Reward

10. Road block

11. Resurrection

12. Return With Elixir

(for more details, read Matchett, 2011, p.i-viii)

Figure 1 illustrates Darrell Mann's representation of the Hero's journey in relation to the evolutionary S-curve, jumping from one S-curve to another. However, this is the external view of the Hero's Journey. The Hero's Psychological or Inner Journey is often neglected or overlooked. Figure 2 shows Chris Vogler's view of The Hero's Inner Journey (retrieved online). Figure 3 integrates Chris Vogler's view of The Hero's Inner Journey with the S-curve scenario.

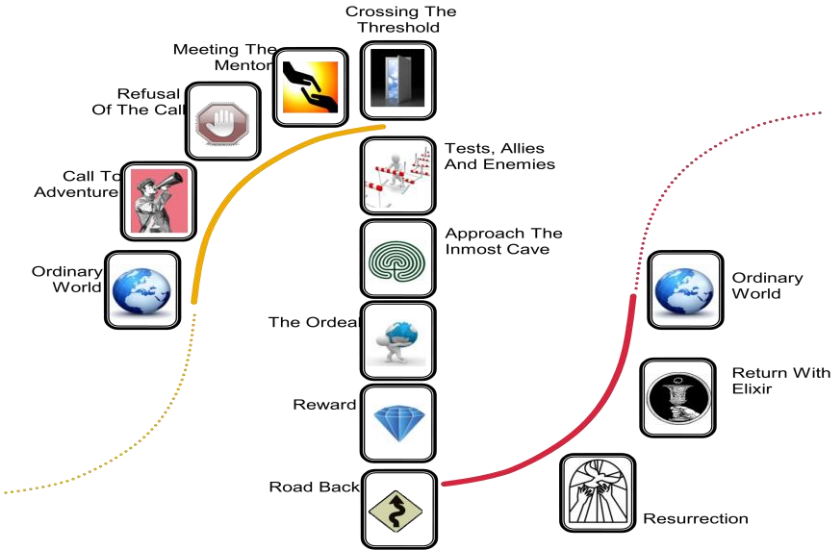

Figure 1. Hero's Journey and Discontinuous Jump From One S-curve to Another

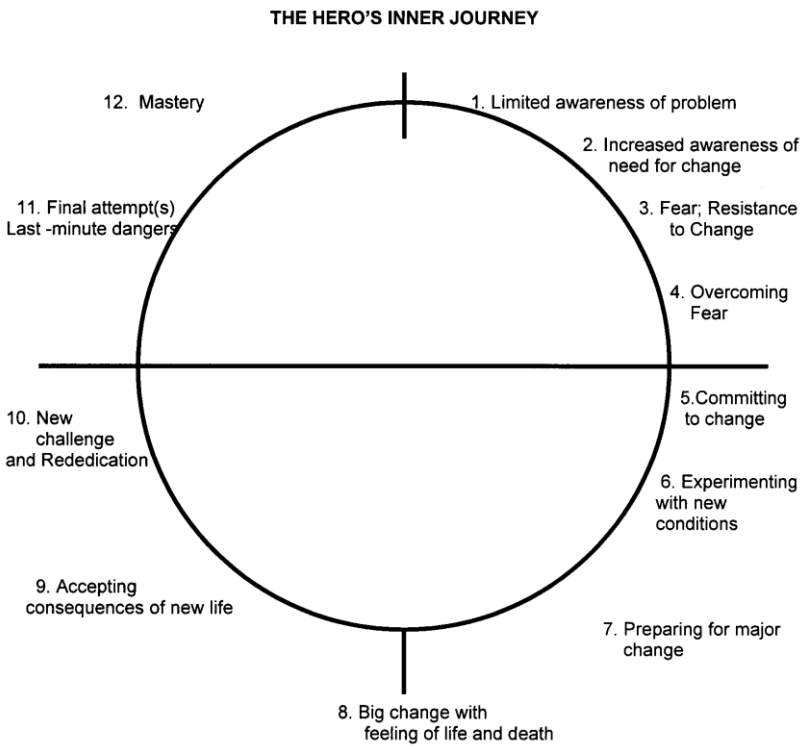

Figure 2. Chris Vogler's view of The Hero's Inner Journey

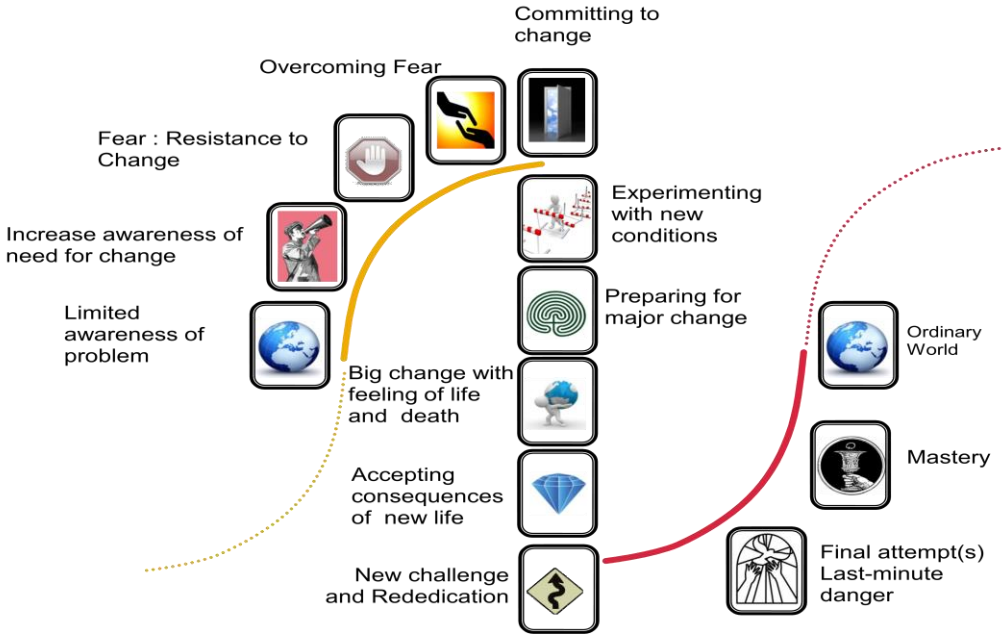

Figure 3. The Hero's Inner Psychological Journey to Mastery and Discontinuous Jump from One Psychological S-curve to the Next

Current TRIZ and other systematic innovation tools focus on achieving the external Hero's Journey, jumping from one S-curve to another. Over the years, science has focused on the development of material state as seen in the Hero's Journey. On the other hand, since the role of TRIZ and other systematic innovation tools is to break away from psychological inertia, psychological development should be integrated into the system. However, on the contrary, the inner psychological journey is often ignored. Hence, the Hero's Inner Journey, focusing on the changes of the inner psychological or conscious state, is often overseen. In the book, *A Theory of Everything* (Wilber, 2001), it states that everything is connect, both the interior states (consciousness) and exterior states (material). Thus, the internal state, or inner psychological world, and the external state, or outer material world, should both be recognized in the developmental process.

The Hero's Inner Journey is actually essential, because it is the inner psychological journey to mastery. Edward Matchett's *The Road to True Professionalism* (2011) gives insight on the psychological pathway of gaining mastery or "professionalism." Nevertheless, mastering a skill, technique, or a tool, takes time and practice. Thus, the inner psychological state matures as the skill, technique, or a tool is being mastered. Consequently, understanding the Hero's Inner Journey is as significant as the Hero's (external) Journey. Therefore, both the internal, the mind, and the external, TRIZ and systematic tools, state should synergize to increase the level of maturity in innovations thinking. On that same note, mind training and practices prior to using systematic tools are crucial in the development of a creative mind.

3. S-curve and Flow: The Psychological Stepping Stones

The Hero's Inner Journey can be seen in entrepreneurs when they take advantage of their failures or errors. Barrett (2012) indicates "prior mistakes" play a critical role in innovations in organizations. These prior experiences can aid their ability to distinguish ideas that will lead to success and projects that will create genuine innovations. This concept is similar to IDEO's slogan: "Fail often in order to succeed sooner." In addition, there is a tolerance of these mistakes or errors, calling them constructive failure. The process of learning from these failures and willing to change is the identical to the Hero's Inner Journey. Each journey begins with the awareness of the failure and each acceptance to change is the jump the next psychological S-curve. This is an ongoing development. Therefore, constructive failure is more than "trail and error," it is the cycling process of maturing innovations capabilities. It takes time, practice and effort for the psychological aspect to progress maturely.

Rerup (2005) noted that although failure is perceived as "endemic to entrepreneurial activity," researchers find that "prior entrepreneurial experience positively affects opportunity discovery and opportunity exploitation" (p.451). Rerup discusses prior entrepreneurial experience and mindfulness, by analyzing habitual entrepreneurship and how the degree of mindfulness retaining the prior experience may help or hinder the ability to discover and exploit opportunities. Additionally, there are case study examples of both mindless and mindful opportunity discovery and opportunity exploitation. Rerup agrues that mindfulness is the key capability to utilizing past experience successfully, and by understanding the aspects of mindfulness, habitual entrepreneurs can "improve their prospects" in opportunity discovery and opportunity exploitation. Therefore, mindfulness training and practice should be utilized as the tool for psychological development in the Hero's Inner Journey.

During the Hero's Inner journey, the psychological state must reach a state of maturity to jump from one psychological S-curve to another. This climax is similar to flow psychology, proposed by Mihály Csíkszentmihályi. Flow is "the mental state of operation in which a person performing an activity is fully immersed in a feeling of energized focus, full involvement, and enjoyment in the process of the activity" (Wikipedia). Although flow focuses on positive psychology and is often studied in work and leisure, the concept of flow can be seen in each psychological jump to the next S-curve. Flow is described as representing "perhaps the ultimate experience in harnessing the emotions in the service of performing and learning" (Wikipedia) according to Csíkszentmihályi. This mental state is the "in the zone" psychological state needed in constructing innovative ideas. When the experience is fine-tuned, the mind works positively and will be willing to change and explore new territories; in doing so, the mind matures. Therefore, creating an "in the zone" psychological environment is essential in innovations thinking. Hence, TRIZ and other systematic innovation tools ought to integrate techniques and methods training mental flow.

Once the mental flow is established and the psychological state is matured, the mind enters the next level of consciousness, jumping from one psychological S-curve to the next. Figure 4 demonstrates the levels of consciousness, presented by Darrell Mann (2009). Therefore, with each Hero's Inner Journey, the jump is a psychological stepping stone to the next level of consciousness.

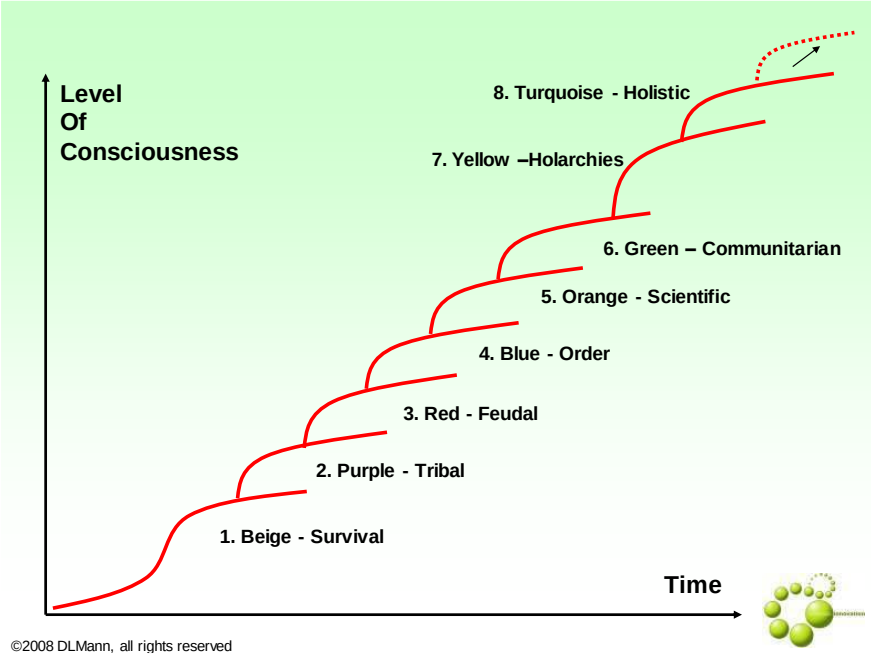

Figure 4. Levels of Consciousness

4. Zen meditation and Mindfulness Training

TRIZ and other systematic thinking tools are created to solve contradictions and produce creative or systematic innovations. The role of these tools is often used to overcome psychological inertia and preconceived notions. However, they focus on solving physical contradictions of matter (material) and not inner psychological contradictions. What happens when a person encounters mental contradictions? Mindfulness research and the long-time practice of meditation apprehends understanding of encountering mental contradictions/conflicts.

Zen meditation has been used for centuries to train the mind to become more aware and attentive of the present state, de-centralizing the thought process. Thus, understanding zen meditation can facilitate training the mind of innovators to become more mindful. Mental training can exercise the mind to let go of psychological inertia. Therefore, inner psychological preparation is essential prior to systematic innovation training. Matchett (2009) listed some preparatory strategies (p.14-15):

- Become quietly centered.
- Take conscious control of your mind and body.
- Let your mind surrender all desire and pretence to take command.
- Let go of everything that is stress inducing, all fears and anxieties.

- Let go of all pre-concepts and expectations of goal, process, resources, and structure.
- Let go of all thoughts, anticipation, knowledge, memories and habits.
- Let go of everything that inflates your ego—get yourself completely out of the way.
- Let go of everything other than a "will to meaning"
- Perfect your nothingness, but become totally alert and available.
- Permit the present moment to be your total world. Totally open to unexplored possibilities—like a newly born baby, exceedingly vulnerable, yet unconcerned.

The strategies listed above are similar to mindfulness training and meditation practices. Therefore, going to the source of long-time practice and training of mindfulness thinking and zen meditation can give insight on how mental conflicts or contradictions are eliminated and understand methods to break free of psychological inertia.

▪4.1 Training and Practice

Zen meditation is resourceful in facilitating psychological jumps from one S-curve to another. Zen is the oldest form of meditation in Buddhism. Another form is shikantaza, a Japanese term for zazen introduced by Rujing (Wikipedia). In Zen, there is vipassanā bhavanā or vipaśyanā (觀禪) and samattha bhāvanā or śamatha (止禪). Vipassanā (Pāli), or vipaśyanā, literally meaning "clear seeing" (Fronsdal, 2001). It is an ancient and central form of Buddhist meditation, introduced by Gautama Buddha and commonly referred to Westerns as "insight meditation", which means "insight into the true nature of reality" (Wikipedia). Samatha (Pāli), or shamatha, is also a form of Buddhist meditation focusing on concentration practices (Wikipedia). It is designed to cultivate "attention", stability, and being calm. In other words, it trains in calming the mind and becoming concentrated. Silent illumination Chan (mozhao chan 默照禪) is the integrated practice of Samatha and Vipassanā, called yuganaddha (union), meaning practicing with both a calm mind and insight observation (Wikipedia).

Mindfulness and meditation are two sides of the same action, letting go of attachments while becoming attentive, alert, and aware of the present state as is, without any judgment, resistant, or clinging on to anything. Hence, part of mindfulness training and practice is set at meditation. Current studies on meditation are commonly used for patients on easing their pain and unpleasantness. However, meditation can also exercise the mind to let go of self-ego, self-centered thoughts, habits, bias, etc. The mind then becomes decentralized, deautomatized, and detached (Shapiro et al, 2006). Although meditation facilitates the mind to disentangle perceptions, thoughts, feelings, judgments, and biases, letting go of attachments doesn't mean to train the mind to become mindlessness. Instead, it is the opposite; it promotes the mind to become mindfulness, "seeing clearly of the present". By not being attached to any thought, the mind can become fully aware of the whole situation at present. Therefore, during mindfulness training, in the practice of "noticing" or the practice of being aware of our thoughts, once a thought arises, learn to let it go and leave out the "self" and other attachments or "clinging".

Fronsdal (2001) listed four kinds of clinging that Buddha enumerated: (1) clinging to spiritual practice, (2) clinging or grasping to our views, including all opinions, stories, or judgments that we hold on to, (3) clinging or grasping to a sense of self, and (4) clinging or grasping to sensual pleasure. Understanding we have such clinging can facilitate our understanding in why we have psychological inertia. For example, over the years of working or studying in our own field of expertise, our knowledge and our concepts build only in a certain area. If we become successful in solving problems in a certain way, we maintain the same pattern, doing things habitually, or even thinking habitually. We do so because we cling on to the fact: "I was the one coming up with the solution; it was correct, so I will keep doing it", "I was successful", or "I am the expert in solving such a problem." We cling on to our views, our sense of self, and our pleasure of success. These are the cause of our mental conflicts, causing pain, suffering or frustration. It even causes us to think habitually in a certain way, psychological inertia. Therefore, meditation can eliminate the desire to cling on to things.

It is essential to understand how psychological inertia works (the clinging and attachments) and how to evolve on the inner psychological journey to mature innovative capabilities (the Hero's Inner Journey). Zen meditation and mindfulness training can offer psychological development methods to facilitate each stepping stone to the next psychological journey. Rerup (2005) research in being mindful sheds light on its positive effects on opportunity discovery and opportunity exploitation. In a case study analyzing habitual entrepreneur Haji-Iannou, the positive advantages of being mindful are: (1) he is open to almost any industry or service as long as it fits the brand extension model, (2) he moves to new industries such as pizza and telecommunications, and (3) he develops innovative ways to operate in distinct industries (p.465-466). On that same note, utilizing mindful training techniques can drive us to be (1) more open and become "out-of-the-box" thinkers, (2) willing to work across interdisplinary fields, and (3) become innovators.

▪4.2 The 10,000 Hours Rule

As with any type of training, there should be much practice to master a skill, even on a psychological level. Intense meditation training of the mind will enhance the thought process to be without constraints or bias. As the mind is trained, the barrier of psychological inertia will break and the mind will become attentive and aware of the present situation; thus, becoming more mindful. As the mind is trained to think without attachments, creative problem solving can be established and tools used in systematic innovation can be used more effectively and efficiently. It is critical to have mental preparation, or be "in-the-zone" in creative problem solving or our psychological inertia will prevent us from targeting the "right" problem to solve. The internal state should be as sophisticated as the external state. Hence, inner psychological preparation should be emphasize in systematic innovation.

In Gladwell's book, Outliers, it stated that although achievement counts on innate talent, putting effort and preparation plays an even bigger role (2008). It gives an example of research on elite violinists practicing more hours than others as they get older and became future top world-class

violinists in comparison with the good violinists and the future classroom teachers. It seems that innate talent begins to fade, as they have to put more effort to become true talents. It concludes that this research proposes that "once a musician has enough ability to get into a top music school, the thing that distinguishes one performer from another is how hard he or she works" (p. 39). Gladwell's words are well put. Furthermore, Gladwell believes the magic number for expertise is 10,000, since research suggests it takes this long for the brain to "achieve true mastery", and it usually takes ten years of practice to do so. "True mastery" takes time and practice, Bill Joy, the Beatles, and Bill Gates are no exception. Even the Chinese have a saying, "上台十分鐘，下台十年功。(To perform on stage for ten minutes, it takes ten years of training off stage.)" Therefore, to become the best innovative thinkers, this 10,000 rule should also be accounted for in training, putting at least 10,000 hours of time and effort to train the mind to think attentively with a clear mindset, or to become mindful.

5. Conclusion

In this society, systematic innovation techniques are incorporated to increase product production. TRIZ and other systematic thinking tools have the role of solving contradictions and producing creative or systematic innovations. Their metholodogy is to find the "right" problem to solve. The role of these tools is often used to overcome psychological inertia and preconceived notions. In order to attain a breakthrough, the mind needs to break free of psychological inertia. However, this process is often an intense journey, externally and internally. It is critical to have mental preparation, or be "in-the-zone" in creative problem solving or our psychological inertia will prevent us from targeting the "right" problem to solve. The internal state should be as sophisticated as the external state. Hence, inner psychological preparation should be emphasize in systematic innovation. Zen meditation has been used for centuries to train the mind to become more aware and attentive of the present state, de-centralizing the thought process. Thus, Zen meditation gives insight for training the mind to become mindful innovators. However, it takes time and practice. It is an extensive inner psychological journey and the number of practice should be immense, not the usual few hours of training to become proficient in systematic innovation. Thus, it takes more than a few hours of training to be able to use systematic innovation tools, and overcoming the internal journey is as crucial as the external journey. Therefore, vast meditation training in becoming mindful is essential.

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Creativity through the eyes of innovation experts and novices: similarity and differences

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Abstract

The attention of the scientific community toward design creativity is witnessed by the growing number of conferences and journals entirely dedicated to topics directly related to its theoretical aspects and to methods and tools for creativity enhancement. Besides, creativity itself is interpreted in different ways by different actors, thus revealing a critical weakness of any theoretical study on this topic: the assessment of creativity is often intrinsically subjective. Some recent experiences show a certain degree of convergence between assessments employing more objective metrics and evaluations of creativity made by experts in design and innovation. With the overall goal of determining whether such judgments are reliable and repeatable, a critical analysis is here proposed to highlight the differences between the assessment of creativity by skilled and novice designers. The investigation is carried out by means of a questionnaire asking to evaluate the creativity of several market successes and commercial flops. The experiment tests also whether commercial results influence the perception of creativity. The outcomes confirm that experience play a not negligible role in evaluating creativity.

Keywords: Design Creativity; Creativity Assessment; Product Design; Product Innovation.

1. Introduction

It is acknowledged in the literature that the capability to generate novel and original ideas is not influenced just by individual talent, but also by systematic procedures and thinking methods (Chulvi et al., 2012; Gero et al., 2012). Shared and repeatable criteria employed to measure creativity of products would strongly contribute to provide greater understanding about the mechanisms that allow designing innovative and successful products. Additionally, reliable assessments of the degree of ideas creativity could be welcomed at the end of design tasks, with the aim of selecting the most proper design alternative. In this sense, objective metrics of creativity would also contribute to better support decisions in the initial stages of design.

The assessment of creativity for the recalled purpose is a largely debated theme within engineering design community, whose discussion is mainly focused on the following aspects: the dimensions to be considered for the estimation of creativity, or in other terms, the factors that participate to determine the extent of creativity (as better explained in Section 2); the procedures to be followed (e.g. Verhagen et al., 2011) and the metrics to be employed (e.g. Oman et al., 2013) for the measurement; the reliability and repeatability of people's evaluation of creativity, which is often deemed to be a very subjective perception (Caroff and Besançon, 2008).

With reference to the last issue, the literature provides sufficient evidence about the differences among designers in facing design tasks, hence leading to very diversified outputs. Innovativeness is considerably affected also by education curricula, which do not necessarily enforce design creativity (Genco et al., 2012). On the other hand, insightful studies reveal that experience plays a key role in shaping individuals' aptitudes to design processes, resulting in a major attention paid to the consideration of initial requirements (Cross, 2004; Atman et al., 2007). It might be inferred that a different emphasis on problem scoping vs. ideas generation should lead to varying criteria to select alternative design results in terms of effectiveness of the solution, originality, suitability to the field of use and so on. In other terms, the perception of creativity could be extensively affected by the supposed priorities (at the individual level) in performing design tasks and, in the last instance, by the degree of experience in design of the subjects requested to express creativity evaluations. In this sense, Casakin and Kreitler (2008) provide preliminary indications by observing discrepancies among creativity assessments expressed by teachers and students of design courses in the field of architecture.

It follows that the remarked differences inherent to the various players of the design community suggest to cautiously interpret the results of individual assessments of creativity, as well as their use as a litmus test for verifying any hypothesis about measurement procedures or metrics. Furthermore, it has to be highlighted that the literature documents experiments aimed at measuring creativity of both ideas emerged during the design process (e.g. Shah et al., 2000) and products or services, whose commercial destiny is known (e.g. Borgianni et al., 2012). Little or no information is available about the potential influence of the awareness of designers about the success of design outputs in evaluating creativity.

In such framework the paper illustrates an experiment aimed at bridging various problematic aspects concerning the assessment of creativity and its exploitation within innovation initiatives. The performed test attempts to answer the following research questions: do expert and novice designers disagree also about the creativity of well-known innovative products? Does the situation differ considering separately acknowledged successful innovations and market failures?

The answers to the above queries provide preliminary indications about the convergence of designers on the degree of products creativity and, consequently, on the reliability of individual assessments. The state of the art, presented in Section 2, better elucidates the importance of undertaking research programs devoted to a major understanding of the treated subjects. Section 3 presents an experiment designed to extract evaluations of experts and freshmen with regards to the creativity of commercial products. The emerging outcomes are analyzed, as presented in Section 4, and discussed in Section 5, that includes planned future activities to overcome the current limitations of the experiment.

2. Related Art

The evaluation of several aspects of creativity within engineering design is a relatively recent branch of research, influenced by seminal works carried out mainly in the field of cognitive psychology (Thompson and Lordan, 1999; Howard et al., 2008). It follows that initial studies have been addressed to evaluate the creativity of designers, with or without the employment of tools and methodologies.

The work documented by Shah et al. (2000) first underlined the importance of assessing the creativity of the ideas generated during a design task. Since then, many hypotheses have been formulated to reveal the factors that mainly contribute to the evaluation or assessment of products creativity. Chiu and Salustri (2010) reviewed previous experiences in academics addressed at measuring the creativity of design projects, revealing that novelty and usefulness (sometimes referred as utility or value) are the most agreed assets of creativity. A not marginal amount of contributions include however additional components of creativity, more diffusedly appropriateness and surprise. The former concerns the property of products to fit practical purposes (Runco and Charles, 1993), in terms of being correctly designed for the conventional domain they belong to. The latter refers to exceeding the boundary of expectedness (Macedo and Cardoso, 2001), by proposing objects that get people's attention by deviating from the line of products evolution dictated by seeded knowledge.

However the two dimensions suggested by Chiu and Salustri (2010) undoubtedly represent a shared starting point for any model or criterion to assess creativity. This thought is somehow supported by the discussion reported in (Goldschmidt and Tatsa, 2005), which remarks how the precondition of effective design ideas is their goodness (thus their utility or capability to fulfill design requirements) and that they can be considered creative, when they additionally show elements of originality or newness.

Still focusing on novelty and usefulness, Sarkar and Chakrabarti (2011) report a proposal to quantitatively assess creativity of products. Its main strength stands in the employment of objective metrics, which do not require evaluations of individuals. The suggested model exploits a previously developed causal functional model to characterize the degree of novelty, i.e. SAPPhIRE (Srinivasan and Chakrabarti, 2009) and multiple criteria to estimate usefulness including the urgency of the need to be satisfied, the potential quantity of people interested in the product, the duration of the employment of the system or of the provided benefits. The main limitation of the proposal stands in a verification of the illustrated metrics by comparing creativity measures of known products with evaluations performed by experts in design, hence resorting to subjective judgments.

On the other hand, creativity assessments entrusted to individuals are the most diffused in the literature (Oman et al., 2013). Despite the noticeable amount of contributions treating experiments of creativity estimations carried out by design experts, no standard methodology for performing the task and evaluating the results has been established. However, Horn and Salvendy (2006) remark how the Consensual Assessment Technique (CAT) and the Creative Product Semantic Scale (CPSS) are the most common references for measuring product creativity. The former (Amabile, 1982) assumes that creativity exists only if a sample of experts agrees on its presence, which is tested through a 5-point Likert scale. The latter (Besemer and O'Quin, 1986) explores a plurality of creativity components by asking individuals their perception with respect to several semantic pairs (e.g. unknown vs. familiar within the judgment of novelty).

2.1 Open issues investigated in the research

As an evidence, also when employing objective metrics, there are no references to compare creativity assessments with, but individual estimations. If subjective evaluations represent a starting point for identifying criteria to measure design creativity, convergence of judgments, at least among experts, should be ensured to guarantee sufficient reliability of any study in the field. Whereas satisfying agreement among individuals owning expertise in design and innovation would be met, as in some experiences documented by Horn and Salvendy (2006), a further issue of investigation regards the tendency of less skilled subjects in expressing similar creativity evaluations.

Moreover, if both usefulness (in terms of goodness of the design task) and novelty represent fundamental ingredients for creativity, it might be inferred that original but unsuccessful products cannot be regarded of being creative. However, according to authors' vision, such statement has been not sufficiently proven.

The scope of the research is to provide a major comprehension of the phenomena that lead experts and novice designers to evaluate products as creative. The understanding of such mechanisms can motivate or reject the employment of subjective evaluations (provided by narrow or large arenas of designers) as a reference for assessments extracted by more objective criteria. According to the above general goal, the methodological objective of the paper is the fine-tuning of an experiment devoted to highlight the differences in creativity evaluations within separate groups of experts in design and engineering students, as well between the two samples. Particular attention will be dedicated to underline potential dissimilarities when successful products and acknowledged market failures are evaluated apart.

3. Design of the test

The performed experiment is based on the administration of a specific questionnaire to a sample constituted by individuals belonging to different domains of product design and innovation and having different skills. Hereinafter, a detailed description of the performed test, as well as of the criteria used to assess the results, is presented in order to clarify the followed approach and to provide other scholars, interested in deepening the treated subject, a framework to replicate such a kind of experiment.

3.1 Structure of the questionnaires

The administered questionnaire is anonymous, so as to allow respondents to answer freely and to avoid biases in the evaluation of the results; it is constituted of two main sections.

The first section requires to provide some personal details such as age, gender and profession/job. These data allow classifying the collected answers according to experience and competencies of the participants about product design and innovation.

The second part of the questionnaire asks to perform an assessment of the creativity level referred to a set of 20 products, which are summarized in Table 1. The set deliberately includes 10 products that have observed a widespread diffusion in the market, while the residual of the sample is constituted by goods unsuccessfully commercialized. Nevertheless, the questionnaire does not report information about which items resulted successful (those identified by the numbers 2, 6, 7, 9, 10, 13, 14, 15, 18, 19 in Table 1) or failing; indeed, the products are listed according to alphabetical order. The individuation of artifacts has been performed by

extensively exploiting sources devoted to provide major understanding about the reasons behind thriving (such as Kim and Mauborgne, 2005) or failing (e.g. Haig, 2010) in the market. The success or, conversely, the commercial flop of the listed products is however witnessed by a plurality of literature sources. The authors decided to differentiate the considered goods in terms of technical domains and delivered functionalities, in order to avoid any potential distortion of the creativity assessment process ascribable to an excessive focusing of the set on specific industries or technologies. Moreover, besides the commercial name, each product reports the year of launch in the market, a picture and a brief description (maximum 15 words) providing essential information about its main features in a neutral form, without the use of expressions potentially influencing the judgment of assessors. Such a way of presentation is supposed to facilitate the contextualization of the products within the historical period of their launch. The objective is making the task more independent from the age of the participants and evaluating the extent of creativity by comparing the treated products with older artifacts. To the purpose, the respondents were free to gather any information about the products and technologies available in the reference periods indicated in the questionnaires, previously administered by email.

Table 1. Products submitted to the creativity assessment through the questionnaire.

#	Product	Picture	Year	Description
1	Amphicar		1961	The first car-ship for civil use. It may be driven as car or ship in the same way
2	Apple iPod		2001	MP3 reader capable to host a great volume of data, easy to use and with unmistakable aesthetic features
3	Apple Lisa		1983	First personal computer with a graphic interface and a mouse.
4	Apple Newton		1993	Personal Digital Assistant and Tablet with specific software, fax and email applications
5	BMW C1		2000	Scooter with anti-crash chassis and safety belts
6	Canon Copiers		1973	Small copiers for desk
7	Croc's shoes		2002	Slipper and plastic shoes, cheaper, with an unmistakable design
8	Dodge La Femme		1955	Car with accessories and colors dedicated to women
9	Geox		1995	Shoes with perspiration sole
10	Nintendo Wii		2006	Console for videogame that allow to play with a joy-pad, owning improved interaction

11	Nokia N-Gage		2003	Mobile phone and portable console that allows playing with other people through Bluetooth
12	Pepsi Crystal		1992	Transparent Cola aimed at transmitting a sense of purity of the drink
13	Pfizer Viagra		1998	Drug for erectile dysfunction
14	Polo Ralph Lauren		1967	Elegant and classical T-shirt made of high quality material.
15	Red Bull		≈ 1995	Energy drink
16	Reynolds' Smokeless		1988	Smokeless cigarettes, employing cartridges made of tobacco that are heated but not burnt
17	Sony Betamax		1975	Video recorder with magnetic tape for domestic use
18	Sony Walkman		1979	Portable stereo with earphones for playback through magnetic tape
19	Swatch		1983	Cheaper watch with interchangeable band.
20	Telecom Italia Fido		1998	Mobile phone that can be used within the city, that has an improved range with respect to a domestic

3.1.1 Building of a tailored creativity assessment tool

After the illustration of the case studies, it is requested to evaluate the degree of creativity for each product. The most diffused techniques were considered unsuitable for the specific purpose of the work. On the one hand, the CAT, besides poorly exploited within the design field (Jeffries, 2012) and noticeably time-consuming, cannot be used because of the required involvement of unskilled subjects for creativity evaluation purposes. On the other hand, the experiences witnessing the use of CPSS are restricted to the judgment of few products (Horn and Salvendy, 2006) and show limited convergence among assessors. Nevertheless, the authors decided to employ a Likert-type scale, which represents a reference instrument for the wide majority of activities aiming at measuring creativity in the design context (Oman et al., 2013).

In order to avoid the so called "neutral point" in scales with an uneven quantity of possible answers, the participants were asked to choose among four options, which follow: "Definitely Not", "More Not than Yes", "More Yes than Not", "Definitely Yes". The respondents were explicitly invited to make the assessment by following an intuitive, free and personal process, thus without using specific criteria, but considering the degree of creativity according to the context in which the products appeared for the first time.

3.2 Sample of participants

The set of participants, constituted by a sample of convenience, has been built by joining two different groups of individuals. The former comprises experts in the field of design and innovation, while the latter is constituted by novice designers.

More in detail, the group of experts is constituted by 43 participants belonging to the following categories: professors of machine design coming from different Italian Universities, senior designers having a marked sensitivity towards product and process innovation, professionals dealing with innovation processes in industry and technology transfer. The group of unskilled subjects comprises 21 volunteers coming from the course of Product Design and Development that is held during the first year of the MS program in Mechanical Engineering of Florence University.

Notwithstanding the marked difference in the size of the two groups, the samples present a supposed sufficient number of individuals, besides being homogeneous and clearly defined.

3.3 Criteria to assess the results of the pool of respondents

The judgments expressed by the participants about the degree of creativity of each assessed product are converted into scores to allow their handling for statistical analyses. Such operation is required to elaborate representative values of creativity for both the sub-samples of the whole set of respondents to be compared against. The conversion is performed by applying the metrics shown in Table 2, which have been proposed in a detailed report for evaluation purposes of the teaching in Italian Universities (Chiandotto and Gola, 2000), representing a reference point for this task (Rampichini et al., 2004).

Table 2. Metrics for the conversion into scores of the judgments about the creativity of the products collected through the questionnaire.

Judgment	Score
Definitely Not	2
More Not than Yes	5
More Yes than Not	7
Definitely Yes	10

3.4 Analysis of the outcomes

The emerging data are thus analyzed in order to fulfill the research questions. In a first instance the objective was to investigate the differences in the creativity judgments between the two samples of participants. The authors propose to perform such examination by:

1. calculating for each product the mean and the standard deviation of creativity evaluation in charge of experts and freshmen;
2. comparing the means of both the subsets with a suitable test: two-tailed t-test is proposed to the purpose, because the variances of the distributions are not known a priori and it is not known whether the two

sub-samples effectively belong to two different populations; the test swivels on the following hypotheses:

a. H0 (null hypothesis): the means of the populations are identical, i.e. skilled and novice designers provide the same creativity evaluations, hence experience provide no influence in judging products creativity;
b. H1(alternative hypothesis): the means of the populations differ, i.e. skilled and novice designers provide different creativity evaluations, hence experience plays a role in judging products creativity

3. evaluating for each product, the significance level of the test through p-values, then establishing for each case study whether experience has affected the estimation of creativity.
4. In a second instance, the goal was to investigate the potential influence of the commercial success/failure of artifacts in creativity evaluation. It is proposed to achieve the objective by:
5. building the contingency table putting into relationship the success of the product and the agreement between experts and freshmen with respect to judgments of creativity;
6. computing the probability of the independence between the samples by a $\chi 2$ test, hence estimating to which extent experience determines differences in creativity assessments.

4. Results of the experiment

For the sake of brevity, the whole set of answers to the questionnaires is not included in the paper. The assessments of creativity are indeed replaced by statistical descriptors (mean and standard deviation, as illustrated in Table 3), which are obtained through the metrics shown in Table 2. According to the above description of the experiment, distinct values are reported for the groups of expert and novice designers; the actual sample size of the respondents is added in the Table, since some designer did not provide creativity evaluations for all the investigated products. In the last column of the Table, the p-values are reported for the hypothesis test described in Section 3.4. Tests leading to the acceptance of the test (p-value <=0,05, as a common rule of thumb), i.e. such that experience has not affected the estimation of creativity, are marked with an asterisk in Table 3.

Table 3. Assessments of creativity performed by experienced designers and engineering students. Descriptive statistics except for the last column, collecting the p-value of the Hypothesis test mentioned in Section 3.4.

	Experts in design and innovation			Freshmen in design and innovation			**p-value**
Product	**Mean**	**Std. deviation**	**Sample size**	**Mean**	**Std. deviation**	**Sample size**	
Amphicar	6,64	2,61	42	6,67	2,42	21	0,044*
Apple iPod	8,19	1,91	43	7,62	1,88	21	0,872
Apple Lisa	9,26	1,48	42	9,19	1,54	21	0,172
Apple Newton	7,81	1,93	43	7,43	2,04	21	0,694
BMW C1	6,70	1,74	43	6,86	2,01	21	0,341

Canon Copiers	7,21	2,21	43	7,19	2,36	21	0,037*
Croc's shoes	5,79	2,72	43	4,23	2,30	21	0,999
Dodge La Femme	3,79	2,14	43	4,05	2,46	21	0,478
Geox	7,16	2,67	43	6,38	2,16	21	0,931
Nintendo Wii	8,53	1,93	43	8,00	1,90	21	0,847
Nokia N-Gage	5,37	1,86	43	5,38	1,91	21	0,019*
Pepsi Crystal	3,98	1,99	43	4,24	1,95	21	0,512
Pfizer Viagra	6,05	2,79	43	7,48	2,18	21	0,998
Polo Ralph Lauren	3,74	2,26	43	4,71	2,31	21	0,981
Red Bull	5,95	2,53	43	6,05	2,36	21	0,177
Reynolds' Smokeless Cigarettes	6,26	2,13	43	6,19	2,50	21	0,129
Sony Betamax	8,47	1,93	43	8,00	1,90	21	0,788
Sony Walkman	9,18	1,44	43	8,62	1,69	21	0,911
Swatch	7,95	2,31	43	6,71	2,55	21	0,966
Telecom Italia Fido	5,53	2,33	43	6,57	2,99	21	0,982

As clear from the Table, the null hypothesis is rejected in the great majority of the cases: Amphicar, Canon Copiers and Nokia N-Gage represent the only exceptions. The emerging outcomes guide to infer that experience in design influences the assessment of creativity for many marketed products. It is interesting to notice that not necessarily freshmen assigned a higher creativity score to the proposed products: indeed experts ranked ten products as more creative, while seven received a higher score by the engineering students.

As clarified before, the second research question invites to verify whether the situation differs by separately considering market successes and failures. It is straightforward to observe that in both samples of case studies a marginal part of examples does not lead to the rejection of the hypothesis supposing the missing influence of experience in judging design creativity. Indeed, the formulated H0 is accepted for 1 success (out of 10) and 2 market flops (still out of 10, thanks to the way the experiment has been planned). The next task of the investigation requires thus to verify whether the above different behaviors result statistically significant. By considering a global number of 3 cases for which a convergence in evaluating design creativity is met, an equal distribution of these examples between successes and failures is represented in Table 4, while Table 5 reports the real observed outcomes.

Table 4. Expected outcomes of the test, by imposing a global number of 3 cases meeting the null hypothesis

	Successful products	Unsuccessful products	*Total*
Products having a significant difference in creativity evaluation	1,5	1,5	3
Products not having a significant difference in creativity evaluation	8,5	8,5	17
Total	10	10	20

Table 5. Observed outcomes of the test

	Successful products	Unsuccessful products	*Total*
Products having a significant difference in creativity evaluation	1	2	3
Products not having a significant difference in creativity evaluation	9	8	17
Total	10	10	20

Under the hypothesis that the two above distributions are non-correlated, the resulting probability of such supposition assumes the value of 0,531 according to the $\chi 2$ test. Hence, it might be inferred that it is quite probable that the incongruence in creativity evaluations between experts and freshmen is not influenced by the market success of the products. Undoubtedly, such claim cannot be anyway assessed with great confidence.

5. Discussions and conclusions

The paper illustrates an experiment about creativity assessment through questionnaires (to which 64 people participated), revealing how experience in the field of design and innovation plays a not negligible role in performing such kind of evaluations. Therefore, the outcomes of the test support, within product design, what has been already remarked by Casakin and Kreitler (2008) in the field of architecture. Just in 3 cases out of 20 it is possible to state with sufficient statistical evidence that creativity judgments of expert and less skilled designers converge. Hence, if evaluations provided by skilled designers could be considered as a reference for measuring creativity, the results of the experiment discourage the employment of inexperienced subjects for the same purposes.

Given the proven discrepancy between samples of skilled innovators and students, it should be better researched if evaluations provided by experts can represent a reliable benchmark for creativity assessment. Data about standard deviations reported in Table 3 can represent a starting point for stimulating a discussion in this sense. The extension of the sample of respondents is however required to this aim in order to determine the effective variability of experts' measures of creativity.

Also due to the very narrow quantity of akin creativity evaluations between samples of expert and novice designers, the $\chi 2$ test carried out to verify the twisting effect of market success vs. failure provided poor

information. Thus, in order to answer the second research question defined in the Introduction, the experiment should be reorganized. The redesign of the test could favorably include considerations about the knowledge of the designer with respect to the investigated products, as well as the awareness of their commercial results. Such measure would allow considering whether information about market success could represent a bias in creativity evaluations and correctly evaluating the effect played by the age of the respondents and markedly the supposed greater awareness of experts with respect to old products. At the current state of the research, it seems that this phenomenon does not take place, by observing that an unsuccessful case (i.e. Apple Lisa) is the product attributed of the maximum extent of creativity by both experts and students.

Among the planned future activities, beyond the administration of the test to a major quantity of designers and the intention to include questions about the knowledge of the surveyed products, the authors intend to evaluate the extent of a certain amount of factors in determining creativity judgments. The demographic information already provided through the experiment and a further segmentation of experts' sample (already distinguished among professors, senior designers and professionals in the field of innovation) can represent the basis for a set of explanatory factors to be analyzed. The authors commit to achieve information about the impact played by any parameter pertaining both respondents and the investigated product (e.g. its market success or failure) through statistical regressions. Such techniques are expected to determine whether the investigated factors concur to increase or diminish creativity evaluations and to which extent the same parameters result statistically significant. By employing ordinal regressions, the problem could be avoided of transforming qualitative assessments into quantitative measures, which relentlessly introduces a bias into the analysis of the results.

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The objective laws of theory innovation and method support ---- and the simplification of technology innovation principle

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Abstract

Innovation activities have a certain objective regularity. Understanding the regularity, be helpful for people to support method in innovation activities. This article in view of the current popularization and application of TRIZ theory involves the innovation process and its confusion, in-depth look at, to explore the objective regularity of innovation activities, and discusses the simplification principle of technological innovation, and to solve some of the current application of TRIZ theory, provides a reference model.

Keywords: TRIZ, Innovation activities, Objective laws, Methods support, Innovation tree

Introduction

Innovations exist in every field of human life, work such as technology, economy, culture and philosophy. The implementation of the innovation activities, including individuals, businesses, organizations at different levels, region, country. Academic research on innovative activity regularity and revealed that involves Chuang ZaoXue, psychology, logic, behavioral science, economics, system theory, holistic, scientific methodology, philosophy, and modern information theory, cybernetics and so on thought and the guidance of the scientific method。

Enterprise, organization, region, country by different levels of innovation activities, is activities at all levels, mainly involved in strategic decision-making, system construction, and innovative methods are just a small part of the of the. Individuals on the implementation of innovation activities, is the basis and pioneer of human innovation activities. In this paper, only focusing on the individual in the implementation of innovation behavior (mainly is the engineering and science and technology) process, the existing objective regularity. Associated with organizational behavior innovation is different, we avoided the strategic decision in the sense of innovation, system construction.

What is the innovation activities？ Innovation activity in different areas if there is a same regularity？ Can you find a simple, general creative problem solving steps？ To know and answer these questions, to cultivate innovative talents, to build an innovation-oriented country, guiding people to carry out technical innovation activities, has the positive reference significance.

1 The main academia ideas about the innovation process

Innovation process has certain objective regularity. At present, the academia has a variety of discourse on innovation process。 Major such as：

In the book "how we think", Dewey analyzes the problems of psychological activity process, puts forward five steps: 1) encounter difficulties; 2) defining the difficulties; 3) suggested answer, make assumptions; 4) deductive reasoning conclusion out solutions; 5) verify the hypothesis.[1]

British psychologist Wallace put forward the "four stages": the first stage, the creation of preparation. It includes found problems, collect data, and the experience of people acquire knowledge and get enlightenment;

The second stage, the incubation period. This stage mainly meditation, including using existing knowledge and methods, to make various exploratory problem solving; The third stage, the illumination. Which is based on the last stage of brewing mature stand out, be suddenly enlightened, that sudden inspiration or producing period of enlightenment. The fourth phase, the validation. Means to get inspired by the preliminary outline of the new ideas to test and prove。[1]

Guilford suggested to combine creativity and problem solving directly, the creative process includes the following four stages: 1) aware of the existence of the problem; 2) there is a lot of related ideas; 3) make evaluation on possibility; 4) can describe the suitable method to solve the problem。[1]

higher and Chiappetta think: because of curiosity, beliefs and values, prompted by imagination and reasoning to "thinking" and "problem solving", this activity is a kind of creative problem solving activities。[1]

Palmer, in 1966, the United States scholars (Parnes) according to Osborn "brainstorming" strategy, Gordon organization theory, Guilford intelligence structure theory and omar spindle (Marceau) demand and perceptual training strategy theory, put forward the Creative Problem Solving, Creative Problem Solving, referred to as the CPS model. Palmer, the problem solving process is divided into five steps: the discovery of truth to find problems, to seek the idea - seek solutions - accept it。[2]

1985, Isaksen and Treffinger, proposed consummates the CPS model and put forward universal use of current educational model "six stages of CPS three ingredients". Three components respectively is to know the problem, generate ideas and plan action; Six stages were found challenges, collect data, found the problem, inspired ideas, seek and accept. Among them, each stage but also divergent thinking and convergent thinking two stages.[2]

In addition, there are stanish model of six phase, multidimensional total four ingredients of eight stages model.

Stanish and Fberle put forward the creative problem solving process includes six procedures: find out chaos to collect data to discover problems, to collect ideas, find countermeasures to accept ideas. 1) mess finding: with things, aware of the need to improve the situation and decided to try to improve. 2) data finding: asking questions to elicit clues; The collection of data to enhance understanding; Classifying data, organize, and repeatedly look at; Developed method. 3) problem finding : will a lot of problems to organization; To subdivide problems; Select a smaller (bite - size); Will issue to IWWMI (In What Ways took I?) In the form of a statement. 4) idea finding: the group members speak freely, brainstorm, there is a lot of problem solving ideas, but no comments; Would favour the idea to solve the problem. 5) solution finding : list of evaluation criteria; Screening of ideas; Select the best idea. 6) acceptance finding: adopt idea, decided on a plan of action of every step.[1]

Dorval el al on the finger and isaacson proposed CPS six stages of three elements model, based on the further modify it to four ingredients eight stages: 1. find problems, looking for information, to determine the problem definition, structure; 2. Generate ideas, stimulate ideas; 3. Prepare a plan of action (development solutions, seeking to accept); 4. Plan the way (the evaluation process, the design process)。[1]

Min Basadur in his book the simplification: fly to creative, said: simplicity is the complete process to solve the problem. It consists of three phases: discovery problem; Put forward the creative solution; Finally, the implementation of these measures. But each phase need to have different creative again。[3]

McKinsey 7 steps to analysis is the company according to they have done in the vast majority of cases, summarized a set of analysis method of business opportunities. It is a practice, is important for startups and mature companies are thinking and working methods.

By, on academic opinions on the innovation process, there are many different in many things。

2 Simplification principle about technological innovation process guidance

Innovation process has certain objective regularity, but revealing the regularity, has subjectivity. Academics

about the innovation process of different types, this paper precisely reflect people's subjective reflection objective awareness of the differences in personality.

Subjective reflect the objective, then gradually approach the objective, this is the basic rule of human cognitive process.

Technology innovation activities, it is the subjective behavior under the guidance of practice and cognition interaction process, it embodies human practice, cognition, practice again, reinterprets general rule.

Seek simplicity and efficiency maximization of technological innovation, this is people's subjective consciousness pursuit, the real objective is to carry out technical innovation activities, is the objective law of technology innovation. So it is with the technology innovation process, people also pursue the basic principles of simplification。 So we to guide people's technological innovation activities, and to reveal its intrinsic objective regularity, should also follow the principle of simplification.

So, what is simplification principle？ In this view, Ma Hengzeng about " how to found the problem, how to analyze and how to solve problems" [4], can give us some beneficial inspiration。

Discovering problems, analyzing and solving problems is a simplified description of the process of technology innovation, we can briefly describes as the "discovery, analysis, solve"。 Then, how to found the problem, how to analysis problem and how to solve the problem, this should be in the process of innovation especially need to pay attention to solve the problem of good.

2.1 How to discover the problem

Discovering the problem is the first step in the process of technological innovation, is also the first question。 Einstein said: "(find) a question often is more important than solving a problem, because the solution is probably just a math or experimental skills. And put forward new questions, new possibilities, from a new Angle to see the old problem, but need to have a creative imagination, and marks the real progress of science ". Thus, found the problem in the important role in the process of innovation。

How to find problems in science and technology? I think the following points for reference:

- innovation desire
- think much
- dare to question
- seeing much
- sensitivity
- catch a contradiction (hold controversial issues)
- idealized technological problems (evolutionary method)
- See the essence through the phenomena

All these points, innovation is based on the consciousness of innovation rich strong spirit of innovation, the pursue is the significant common characteristics of innovative talents. It has consciousness, initiative, and also is the continuation and innovation of the important spiritual pillar of success. Without innovation, it will be difficult to base on the starting point of innovation activities. No innovation, innovation is difficult to sustain。

Sensitivity is one of the fine quality characteristics of innovative talents, innovative activities is source of life. If lack of Sensitivity of innovation issues, innovation will be confused, they're lost. Therefore, innovation is difficult to establish。

Ideal is a kind of good way to found the problem. Ideal is one of the basic methods of creative thinking in scientific research, is also an powerful thinking TRIZ tools, plays an important role in the innovation process. With idealized dimensions to measure things, will be able to constantly found defects of things, and constantly put forward technical progress of system development direction. Therefore, ideal and self education improve the

sharpness of the problems of innovation.

2.2 How to analysis the problem

Analysis of the problem is "continuity" of key steps in the process of innovation activities. If won't analyze problems, or can't correctly analysis reflect the problem, innovation process will "die", will fall by the wayside. This section, we continue to solve the problem of technological innovation as an example, discusses the concrete technological tools to analyze link。

All aspects of innovation issue involves different disciplines. Due to the differences of the subjects and the different characteristics, analyze the problem of the method is also different. The problem about how to analysis, according to the discipline characteristic, and accumulated many useful methods have been proposed. Some combination of professional analysis methods and analysis steps, build up the guidance professionals to carry out the process of problem analysis. This kind of problem analysis process associated with discipline characteristic, is suitable for basic professional and technical personnel. But it lacks universality, therefore increasing the general public to learn to master the difficulty of innovation problem analysis method. We put forward, in the problem analysis phase, widely introduced the basic analysis method of innovation problems and applicable scope, provide people to combine their professional background, choose appropriate tools for analysis, which is beneficial to the initiative of analysis to the scientific research and technical personnel, to cast off the yoke of the rules, play to their subjective initiative。

Generally speaking, the analysis method of technology innovation questions as follow:

- brainstorming
- system analysis
- function analysis method
- reason analysis
- TRIZ analysis
- analogy analysis method

Brainstorming is created by American scientist A·F, for the first time in 1939, put forward a method of stimulating creative thinking can be divided into direct brainstorming method (often referred to as "brainstorming) and questioned the brainstorming method (also known as the brainstorming method). Is expert in group decision as creative as possible, produce as much as you can imagine, the method of the latter is the former ideas, plan one by one put forward by the question, analyzing the practical feasibility of the method.

Organize group decision by brainstorming method, want to focus experts held special meeting, presided over by the clear way to all participants to clarify problems, explain the rules of the meeting, try our best to create the harmonious relaxed atmosphere of the meeting. Generally does not comment, so as not to affect the free atmosphere of the meeting. Put forward by experts "freedom" as much as possible.

System analysis method is derived from the system science. Refers to the problem to be solved as a system, comprehensive analysis of system elements, find out the feasible scheme to solve the problem of consulting method.

Functional analysis: analyzing the phenomenon from the form the internal structure of the relationship, can make clear phenomenon within each element in the form of arrangement and proportion; Through analyzing the phenomenon from the content and effect on the mutual influence between various elements within functions (internal), can be clear between groups with and without interaction and influence between factors, how to interact and influence. Through the phenomenon of the overall analysis of its effect on society and the function (external) function, you can tell it what aspects of the influence and function to the society.

Cause analysis refers to the analysis method analysis to find the cause things, called for analysis. The

analysis of the causes of common method mainly：

- five "why" to pursue
- the fault tree analysis method
- fishbone diagram analysis method
- causal matrix analysis
- failure mode and effects analysis
- analytical method

Fishbone diagram analysis is an important reason analysis, also called features in figure. Using diagram analysis causes of the problem, easy to brainstorm. Because this figure reflects causation intuitively and clearly marked, regulations, more convenient to use, the effect is good, so many enterprise attaches great importance to.

Analytical analysis method is also called the "5W1H " method, it analysis the object as a whole, then according to constitute the overall factors of decomposition, based on the analysis of these factors to define the nature of the problem, so as to deeply grasp the causes of existing problems, to take corresponding measures to provide a basis.

TRIZ theory provides a number of systems, scientific and operability of the creative thinking method and the invention problem analysis methods, such as screen method, resource - time - cost more, goldfish and SIMS (RTC) operator method, etc. In addition, TRIZ theory system put forward a variety of analysis tools, such as conflict matrix, material - field analysis and 76 standard solutions, such as eight laws of evolution, commonly used have contradiction matrix method based on macroscopic and microscopic based field transformation method.

Substance field analysis by building material field model is established, clearly expresses the product structure, the interaction and function of nature, help us to quickly and accurately find and identify the problem to be solved, the foundation for effective to solve the problem behind.

TRIZ technology system of eight laws of evolution can be used to solve problems, predict technology system, and strengthen creative problem solving tools. These eight principles are respectively：

- technology system of S curve evolution
- improve the ideal of law
- subsystem of uneven evolution
- dynamics and controllable evolution
- increase integration and then to simplify the law
- subsystem coordination evolution
- to the microscopic level and field applications of evolutionary laws
- Reduce artificial into the evolution of the law.

Ideal is a kind of good way to found the problem. Idealize the object of study, is one of the basic methods of creative thinking in scientific research, is also an powerful thinking TRIZ tools, is the soul of thinking in TRIZ theory, plays an important role in the innovation process. At the beginning of the TRIZ theory in solving the problem, first of all, despite all kinds of objective conditions, through the ultimate ideal solution is to define the ideal thought, in order to make clear the orientation and position of ideal solution where, ensure that in the process of problem solving along the goal and ideal solution in the end, to avoid the disadvantages of the traditional innovation involves methods lack of goals, improve the efficiency of innovation design. Based on idealized "improve degree of ideal law" is the backbone of TRIZ technology system evolution laws and master plan.

Analogy analysis method is also called the comparison analytic method, it is the objective things to compare, to recognize the essence and law of things and make a correct evaluation. It is the commonly used methods for engineering analysis and quantitative results are more accurate.

Analogy analysis method is usually to compare two related index data, quantitatively shows and describes

the size of the object of study, the level of high and low, the speed of the speed, as well as a variety of relationship coordination. In comparison and analysis, the choice of suitable contrast standard is very critical step, choose appropriate, to make objective evaluation and choice not appropriate, evaluation could draw wrong conclusions.

2.3 How to solve the problem

Problem solving is the fundamental aim of innovation process and the end-result. After analyzing problems, how to solve the problem, become the final fortress facing innovation process. Because the innovation problem areas and major differences, especially innovation engineering technical personnel's habit difference, solve the problem also appear different difference.

TRIZ theory is that: most of the invention or innovation is not new, but some of the existing principle or the structure in the field of new applications. People just follow the objective laws of development of products and technology, you can move to product design and predict the future trend of the product. This is reflected in three conclusion of TRIZ theory：

1. different areas used in the invention and innovation of the principle of the method is not much; The invention of the different times, different areas of the invention, the principle and method of application is used repeatedly.
2. with the problems and solve the problem by using the principle of repeated in different field.
3. and system evolution model (regular) in different engineering and scientific field appeared again and again

This shows, in the stage of problem solving, TRIZ theory for our different fields of technology innovation provides a powerful guide, this should cause our special attention. Whatever subject areas, we should strive to avoid industry or personality of the inertial thinking, make good use of human innovation knowledge base, must not "behind closed doors”.

3 Based on the simplified principle of technological innovation process tree

Knowledge on people's influence has duality. The main aspect, it can guide people's scientific research, life, such as a positive positive impact, to speed up the development of human society progress. On the other hand, affecte by knowledge form the inertia of thinking, produce the rules thoughts, is not conducive to creative thinking.

Tree in the process of technological innovation, on the one hand, is that it can guide the creative thinking of the people, have a positive impact on people's innovation process. But on the other hand, it also easy to make people's innovation process form the bondage of rules, a negative dependence。

Can effectively guide and break the shackles of thinking of innovation, is precisely based on the principle of simplification innovation roadmap. The basic idea is that, as far as possible close to the objective laws of human innovation activities, build simplification principle innovation roadmap. Its main links are found the problem, analyze and solve problems. At the same time, we are clear about the problem has been found, the basic method to analyze and solve problems, or innovation psychology indexes, etc. So, people in the process of innovation activities, first of all to follow by discover problems, analyze and solve problems in the composition of the "three point one line" roadmap. Next, want to apply in various stages of specific methods, tools, etc., gradually found good problem, analysis problem and solve problems.

Of course, due to the characteristics of subject areas, concrete methods to analyze and solve problems may each has its characteristics, more targeted. This is helpful for the professional and technical personnel, but they are not able to analyze in this paper.

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Using TRIZ methodology for design of large surface microfludic chip for cell culturing

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Abstract

The significant development of microfluidic cell culturing systems in recent years is a good indication for the importance of the technology. The issues faced under the large surface culturing systems being developed are similar. The foremost problem of shear stresses experienced by the cells whether during the initial injection and during culturing of the cells need a solution. The current research is to design a system to solve the shear stress problems faced. The design utilized the specific surface tension of the built in material along with specially designed gap to minimize the shear stress within the culturing system. During culturing, the shear stress generated by the medium flow is further reduced by the large gap space built for the system. In combination with the up and downstream flow channel designed to aid in the medium circulation, the shear stress damage can then be minimized. With these elements combined into one system the dilemma experienced by the current small space or large space micorfludic cell culturing systems can be solved. The effectiveness of the design proposed in this research was then tested under engineering and biological experimentations showing excellent results.

Keyword: TRIZ, microfluidic, cell culture, cell seeding, shear stress, surface tension

1. Introduction

Microfluidic cell culture systems offer several advantages for cell research (Wu, Huang et al. ; Young and Beebe ; Meyvantsson and Beebe 2008; Regehr, Domenech et al. 2009). The micro flow channel within the device is small, which allows the rapid diffusion of nutrients. This low shear stress and high mass-transfer rate environment is similar to the in vivo cellular microenvironment (Lee, Hung et al. 2006). To enhance cell functionality, the cultured cells

are transformed from a 2D to a 3D cell culture, which is sustained in all directions by cells or the extracellular matrix (ECM) (Griffith and Naughton 2002; Tsang and Bhatia 2004; Griffith and Swartz 2006; Tsang and Bhatia 2007; Xia, Ng et al. 2009). For these microfluidic cell culture devices, the cell culture well dimension is of the micrometer scale. Most of them are unable to sustain the large cell number required by bioartificial liver devices (BAL)(Allen, Hassanein et al. 2001). Therefore, BAL research on microfluidic liver-cell culture systems must increase the cell culture region and also enhance the functions of the continuous injection of the cell culture wells in the cell-seeding process. The cell-seeding method must be simple and easy to operate. In addition, the shear stress and mass-transfer balance for a large-area cell culture must be considered to achieve high cell viability.

Previous gel-free cell-seeding methods for microfluidic cell culture systems can be divided into 4 categories: (1) The gap of the microstructure is less than the diameter of the cell (Ferrell, Gallego-Perez et al. ; Di Carlo, Wu et al. 2006; Lee, Hung et al. 2007; Zhang, Kim et al. 2009); (2) The gap of the single row of the microstructure is larger than the diameter of the cell (Ong, Zhang et al. 2008; Huang, Lu et al. 2009; Toh, Lim et al. 2009); (3) The device contains an active control valve (Park, Brown et al. ; Gomez-Sjoberg, Leyrat et al. 2007; Wang, Bao et al. 2008); and (4) The gas-permeable material property is incorporated into the system design (Wang, Ni et al. 2009). Type (1) and Type (2) cell-seeding designs provide a facile operation and repeatable results. However, Type (1) has a small gap, resulting in a low mass-transfer rate and rendering it incapable of sustaining large-area cell cultures. The type (2) cell-seeding design requires a pre-mixture of condensed biomaterials that can raise the complexity of the operating procedure and reduce the mass-transfer rate. The medium cannot diffuse through a condensed ECM because the diffusion force is not strong enough (Mazzei, Guzzardi et al.). Therefore, a large cell culture area and the type (2) cell seeding design are combined under high velocity. If the proposed gel-free design can be applied to the type (2) cell seeding design in a large cell culture area, the large gap of the microstructure can raise the mass-transfer rate and reduce the operational complexity of the designed system. Although applying the gel-free design can solve a number of problems associated with the type (2) design for large cell culture areas, the functionality of the gel-free design might be limited under the requirements of reducing shear stress and maintaining a stable cell-culturing operation. This is a major conflict in engineering design.

The goal of this study is using methodology of TRIZ to resolve these issues in the cell-seeding method of large gap microstructure type and raise cell viability in the millimeter size cell culture well. We also want to achieve efficient cell seeding under low shear stress, a high mass-transfer rate, and uniform cell density, and still maintain a simple method of operation.

The TRIZ su-field model analysis showed that it is possible to effectively utilized the original system parts and even reduce the number of parts needed to solve the dilemma faced in the

system design. The solution to the large or small gap microfludic cell culturing system can be had without additional cost. The resulting engineering and biological testing on the design system using TRIZ had showed the effectiveness of the TRIZ analysis.

2. Method

EC (Engineering contradictions) and PC (physical contradictions) should be first identified before the application of TRIZ in finding a solution to the problem(Savransky 2000; Orloff 2006). By identifying the contradictions the problem can be focused and make searching for solutions easier. The engineering contradictions can be represented in a su-field model. In order to solve the problems of shear stress, increase mass transfer, lower the cell seeding steps, and the complexity of the component manufacturing; the problem is divided into three smaller problems. These small problems include: cell seeding, remove bubbles, and culture medium perfusion.

2-1 cell seeding

The contradiction of cell seeding operation is centered on the proper diffusion of the medium through optimized system design. The microstructure of the system containing small gaps can stabilize the cell and medium under flow. But this stability has a negative impact on the medium exchange with fresh medium and waste products of the system. According to the su-field model indicated on EC1 diagram, the alternative large gap design can enhance the mass-transfer but it is ineffective in stabilizing the cell and medium flow (Figure 1). According to EC2 diagram, the function analysis performed has pointed out the problem areas in the design in the following su-field model (Figure 2).

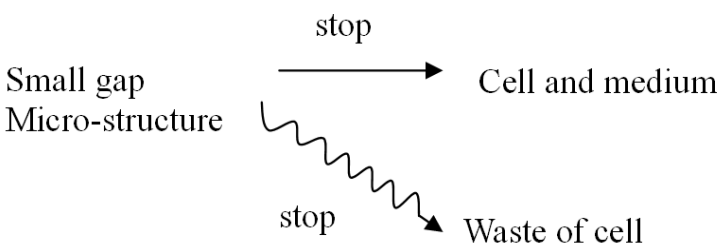


Figure 1 su-field model of small gap micro-structure in cell seeding

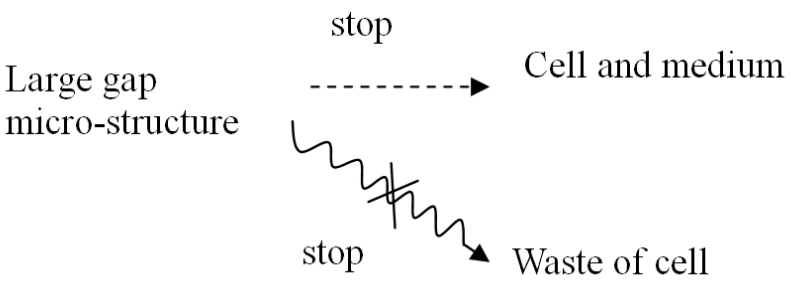


Figure 2 su-field model of large gap micro-structure in cell seeding

The large gap microstructure for cell culturing is ineffective in reducing the flow of the cells and the medium. Therefore, it is important to identify the existing factors within the system that can be harnessed to minimize the problem. This should all be done without adding to the complexity and the cost of building the system. Using the TRIZ method the system can benefit from the known scientific phenomenon of surface tension and the hydrophobic nature of the PDMS to provide the microstructure with a film barrier between the liquid and gas elements. Although the film can become a barrier for the cell and the medium but because the larger surface area of the gap of the culture system the effect can expand the volume of the culture well. Therefore, the film will not affect the fresh medium and waster product exchange. This su-field model of design concept is displayed in the Figure 3.

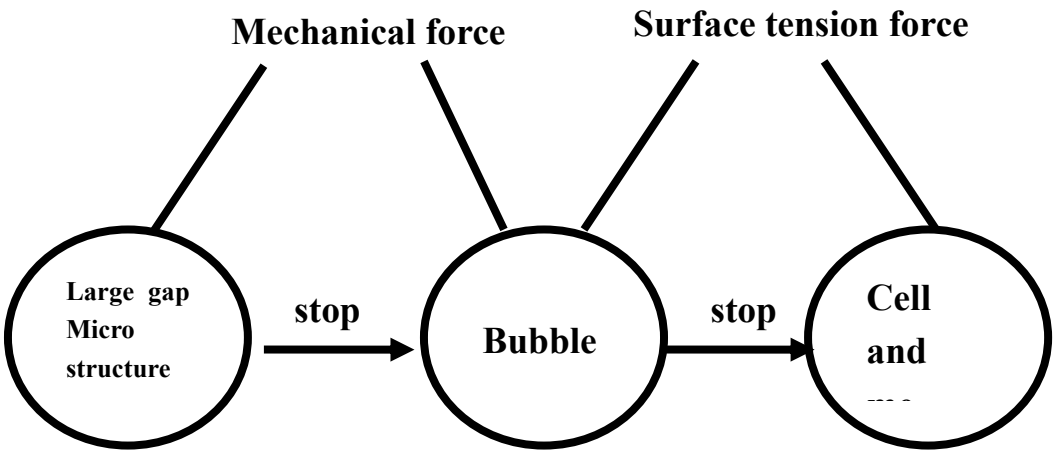


Figure 3 su-field model of design concept in cell seeding

2-2 Remove bubble

Based on the EC1 diagram (Figure 4) the small gap microstructure design can minimize the shear stress of the system and allow for uniform medium transfer through the microstructure. But

at the same time it also prevented the exchange of waste products with fresh medium. The mass-transfer is decreased as a result. The EC2 diagram (Figure 5) indicated that the use of the large gap microstructure design can solve the mass-transfer problem but cannot minimize shear stress.

During the degassing stage, the removal of bubbles from the system can cause major pressure imbalance of the medium flow within each cell culture well. If the pressure is first applied at the downstream flow channel the resulting pressure would be concentrated at the area where the pressure is initially applied. While this can supply the flow of some of the medium through the upstream flow channel but the pressure would be great enough to force the cells out of the culture wells. Therefore, the balanced flow of the medium throughout the microstructure of the system is important while keeping the cost effectiveness of the design.

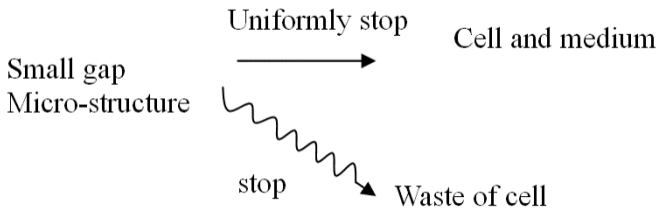


Figure 4 su-field model of small gap micro-structure in remove bubble

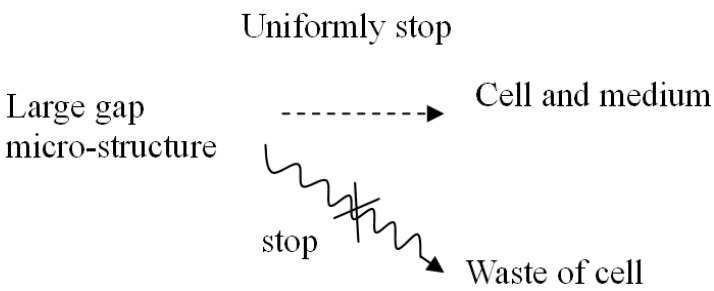


Figure 5 su-field model of large gap micro-structure in remove bubble

Through the permeable characteristics of the PDMS material the small structure will allow uniform medium flow through the microstructure. The bubbles can be moved allowing uniform medium flow. The logical solution is to go with positive pressure to avoid consuming excessive resources in solving the problem. The su-field model for this proposed solution is shown in the Figure 6.

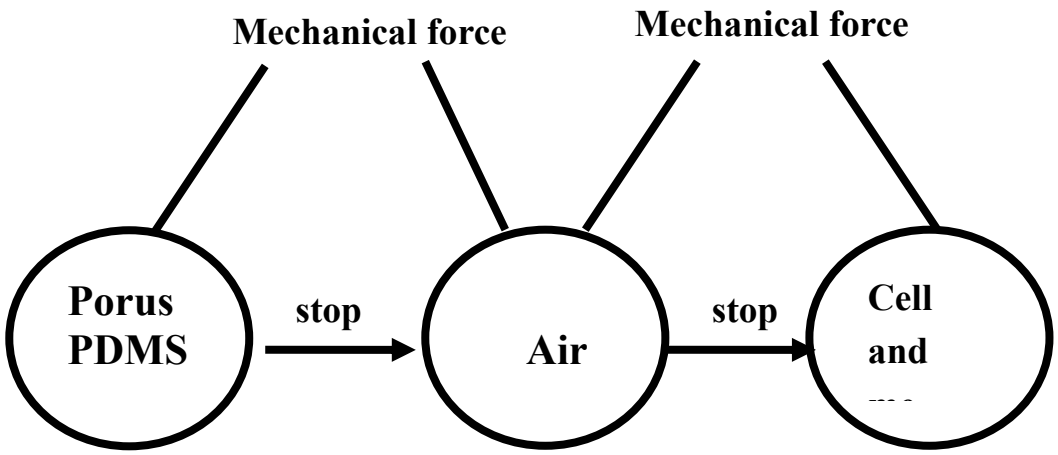


Figure 6 su-field model of design concept in remove bubble

2-3 Medium perfusion

Based on the EC1 diagram (Figure 7) the small gap microstructure design can minimize the shear stress of the system but at the same time it also prevented the exchange of waste products with fresh medium. The mass-transfer is decreased as a result. The EC2 diagram (Figure 8) indicated that the use of the large gap microstructure design can solve the mass-transfer problem but cannot minimize shear stress.

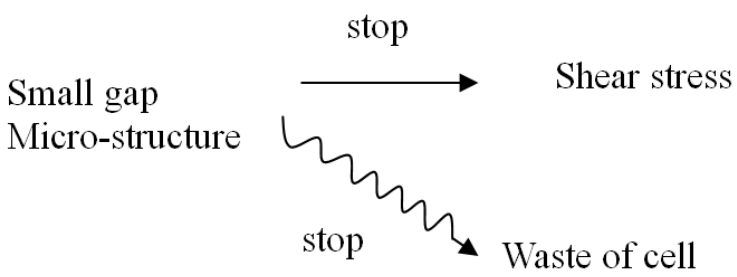


Figure 7 su-field model of small gap micro-structure in medium perfusion

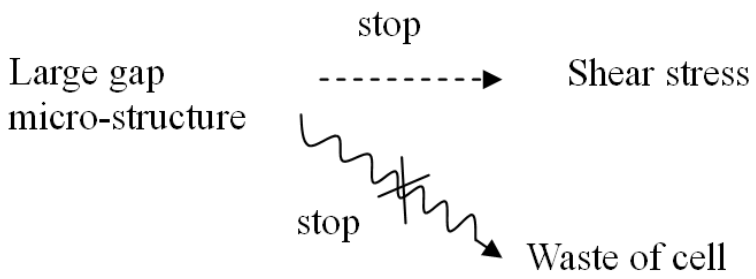


Figure 8 su-field model of large gap micro-structure in medium perfusion

The large gap microstructure for cell culturing is ineffective in reducing the flow of the cells and the medium. Therefore, it is important to identify the existing factors within the system that can be harnessed to minimize the problem. This should all be done without adding to the complexity and the cost of building the system. The components between the medium and any other component of the system can utilize the resistance from the pressure balance. The pressure from the top and bottom channels can avoid medium from flowing into the cell culture area, which forms the basis for the system design. The original large gap micro-structure can be replicated but with longer channel design to reduce shear stress. This, however, has a diffusion limit which will require a multi-row pillar type design as a solution to the limit. The su-field model is depicted in the Figure 9.

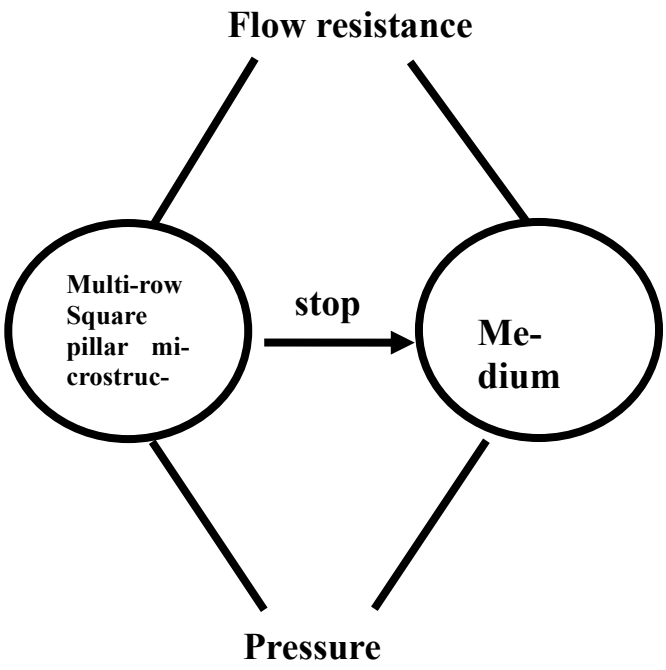
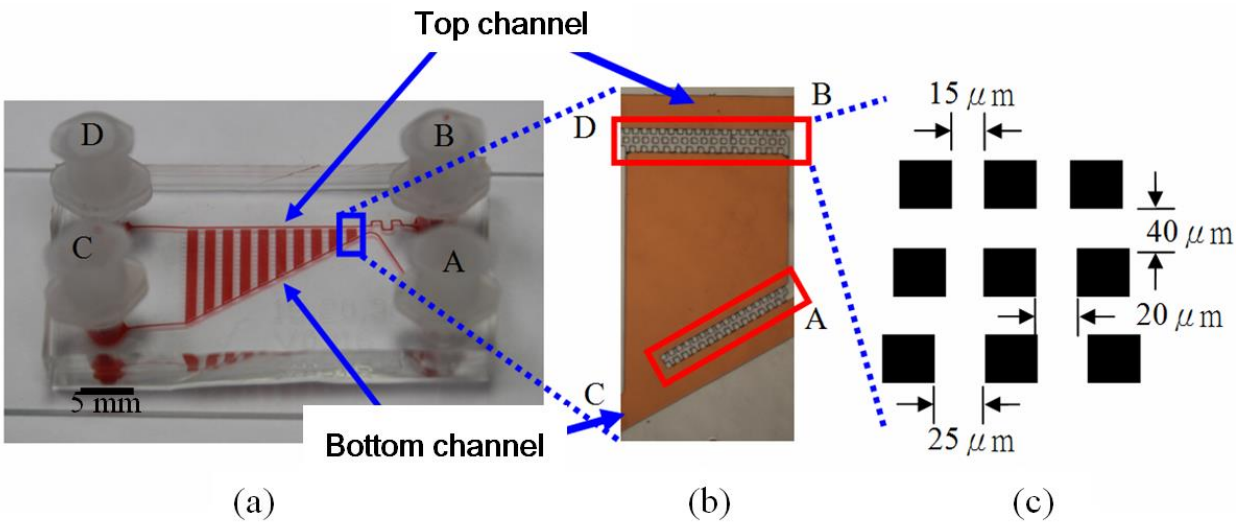


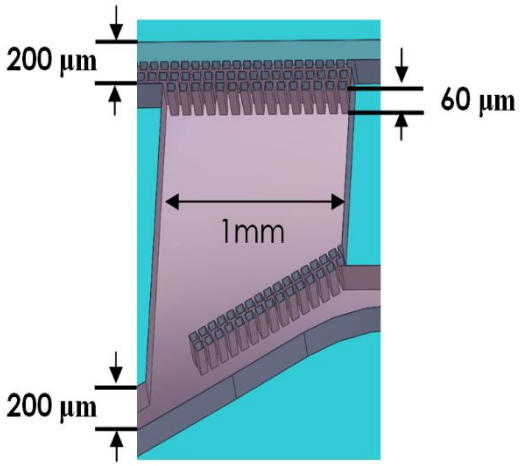
Figure 9 su-field model of design concept in medium perfusion

3. Result

3-1 Fabricated micro-device

Microfluidic devices with the multi-row microstructure were designed using AutoCAD software (Autodesk, USA) and fabricated with PDMS (Sylgard 184, Dow Corning) by using soft lithography (Quake and Scherer 2000; Unger, Chou et al. 2000). The height of the top channel and downstream channel was 60 µm. The microfluidic cell culture device contains 2 inlets and 2 outlets, as shown in Fig. 10(a). The cell culture wells, with a width of 1 mm and varying lengths from 1 to 10 mm, were located between the top and bottom channels. When red ink was simultaneously injected into the top and bottom channels, air was trapped within the multi-layer microstructure by the surface tension force, as shown in Fig. 10(b). A 40 x 40 µm2 multi-layer microstructure with a 15 to 25 µm gap was situated above the cell culture well (Figs. 10(c) and 10(d)). SU8 photoresist templates were fabricated using the standard photolithography process. The microfluidic channels were then obtained by molding PDMS onto the SU8 photoresist templates. The PDMS structures were plasma-treated in oxygen plasma for 30 s (30 W, 13.5 MHz, 100 sccm) for irreversible bonding to the glass cover slips before connecting to the fluidic components of a Luer-lock fitting (Upchurch, USA).





(d)

Figure 10. A finished microfluidic chip (Shih, Tseng et al.)(a) A finished microfluidic chip with 4 medium inlets (ABCD) and 10 cell culture wells. The width of the cell culture well is 1 mm. The length varies from 1 to 10 mm. (b) The magnified picture of the cell culture well in the microfluidic chip. The top channel (DB channel) and bottom channel (CA channel) are located above and below the cell culture well, respectively. The highlighted red box is the multi-row square-pillar microstructure situated between the cell culture area and top/bottom channel, respectively. (c) The design sketch of the 3-row microstructure for Type C. (d) The 3D diagram of the 1 mm cell culture well.

3-2 Operated process

The fabricated microfluidic devices were sterilized by using an autoclave in 2 ATM at 120 °C. Type I rat tail collagen (BD Biosciences) dissolved in 0.02N acid was injected into the cell culture chambers in the microfluidic device and placed in an incubator at 37 °C. After 1 hour, the cell culture wells in the microfluidic device were washed 3 times. Then, the cells and the medium were placed in a centrifuge tube and prepared for cell seeding.

The operational procedures for the cell-seeding method are as follows: The cells were suspended and pre-mixed by using a pipette in the cell medium. Thereafter, 20 ul of the medium with suspended cells was drawn with a pipette and rapidly injected into the inlet of the bottom channel. This step was performed with ease and did not alter the pre-mixed cell concentration. The cells in the bottom channel were washed away by the slow medium flow, which did not block the downstream channel during the process.

Once the cells were attached to the glass substrate for 4-6 h, they remained biologically active. The slow medium flow maintained cell viability, and the slow flow rate was maintained via gravity. The cells and the medium were introduced through Port A, whereas Port C was left open (Fig. 10). Because the cross-section of the cell culture region was larger than that of the connecting Channel C, the flow resistance in the cell culture region was less than the flow resistance at the connecting Channel C. The cells and the medium spontaneously flowed into the cell culture area because of differential flow resistance. The air, because of its smaller molecular size, was expelled to either Port B or Port D through the hydrophobic microchannels, where almost no resistance was encountered for the gas molecules (Fig. 11(a)). The gaps between microchannels were 15 m wide, which is similar to or slightly larger than the diameter of most cells types. When the cells and the medium filled the culture area, surface tension in the hydrophobic microstructure stopped the flow toward Port B and Port C (Fig. 11(b)). Therefore, if the cells and the medium continued to perfuse into the chip, the cells and the medium that flowed into the next cell chamber would repeat the cycle until the cell array was filled with the cells and the medium (Figs. 11(a) and 11(b)). At this point, discarded cells remaining in the bottom channel must be removed. The medium was then slowly injected from Port A (Fig. 11(c)) to Port C to wash out the non-viable cells and to provide the cells with a sufficient amount of fresh medium through mass transfer. The process was carried out with the help of gravity until cells attached onto the substrate (Figure 11(d))

The proposed cell-seeding method utilized the hydrophobic and gas permeability characteristics of PDMS material (Eddings and Gale 2006; Johnson, Liddiard et al. 2009). As mentioned in the previous section, the cells were trapped in the cell culture area because of surface tension from the hydrophobic microstructure. In the degassing process, the cell culture medium was first delivered into Channel BD (Fig. 11(e)). The air pressure was raised to 4.2 psi in this device to diffuse micro-bubbles within the microstructure through the PDMS membrane. Closing the 3 valves connected to the 3 inlets (A, C, D) and joining the 4.2 psi air pressure to the other top-channel inlet (B) enable the air bubbles trapped within the microstructure to be thoroughly degassed (Fig. 11(f)).

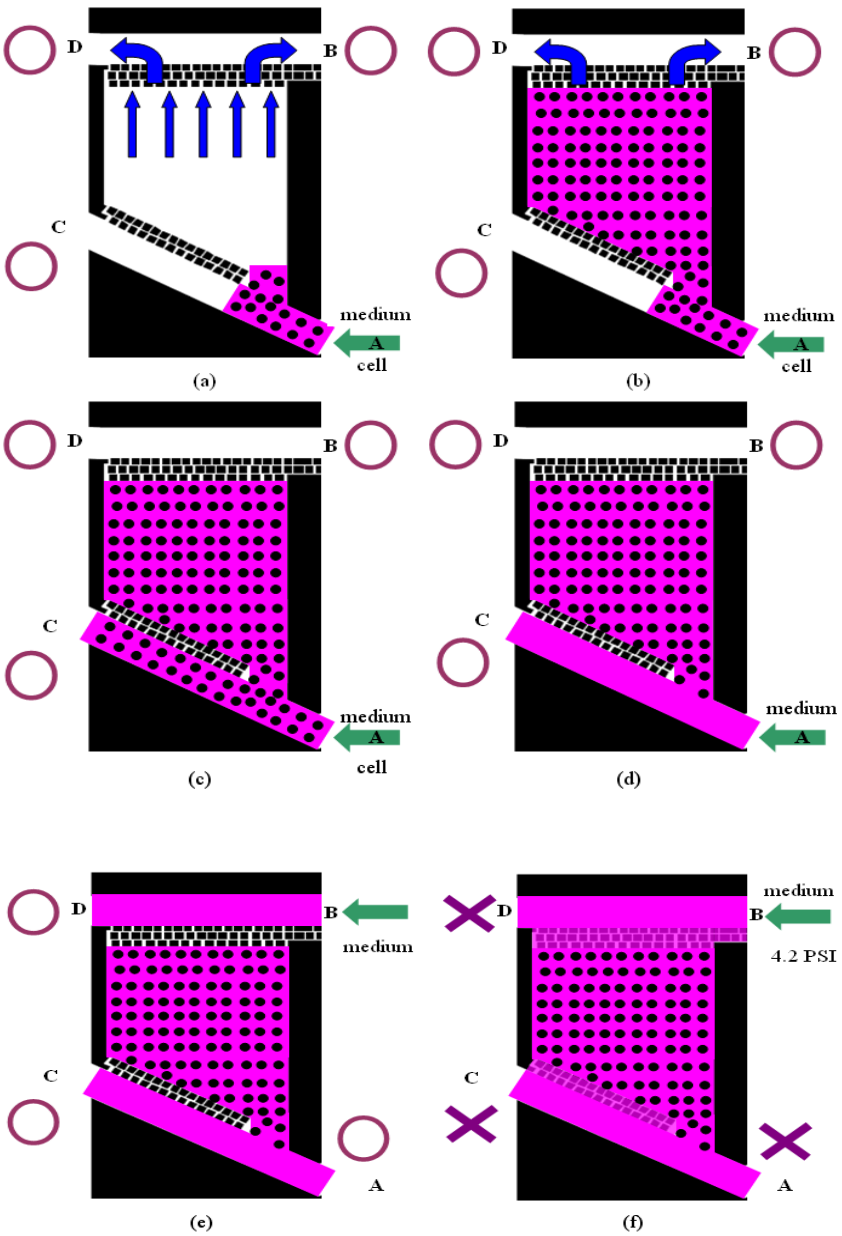


Figure 11. The cell-seeding operation(Shih, Tseng et al.). Medium and suspended cells were injected into the cell culture well (a)-(d). The degassing process after the cells attached onto the substrate (e)-(f). Pink represents the medium. The black spots represent the cells. The blue arrow shows the flow direction of the air. The green arrow shows the flow direction of the injected fluid. The circle indicates that the flow channel is open. The cross indicates that the flow channel is closed.

To verify whether the proposed chip design can be injected continuously into multi-wells and distributed uniformly by cells, the red dyes rather than the cells and the medium were first injected into the chip. Figure 12 shows that the fluid with the red dyes was injected sequentially into separate cell-culture wells in time lapse.

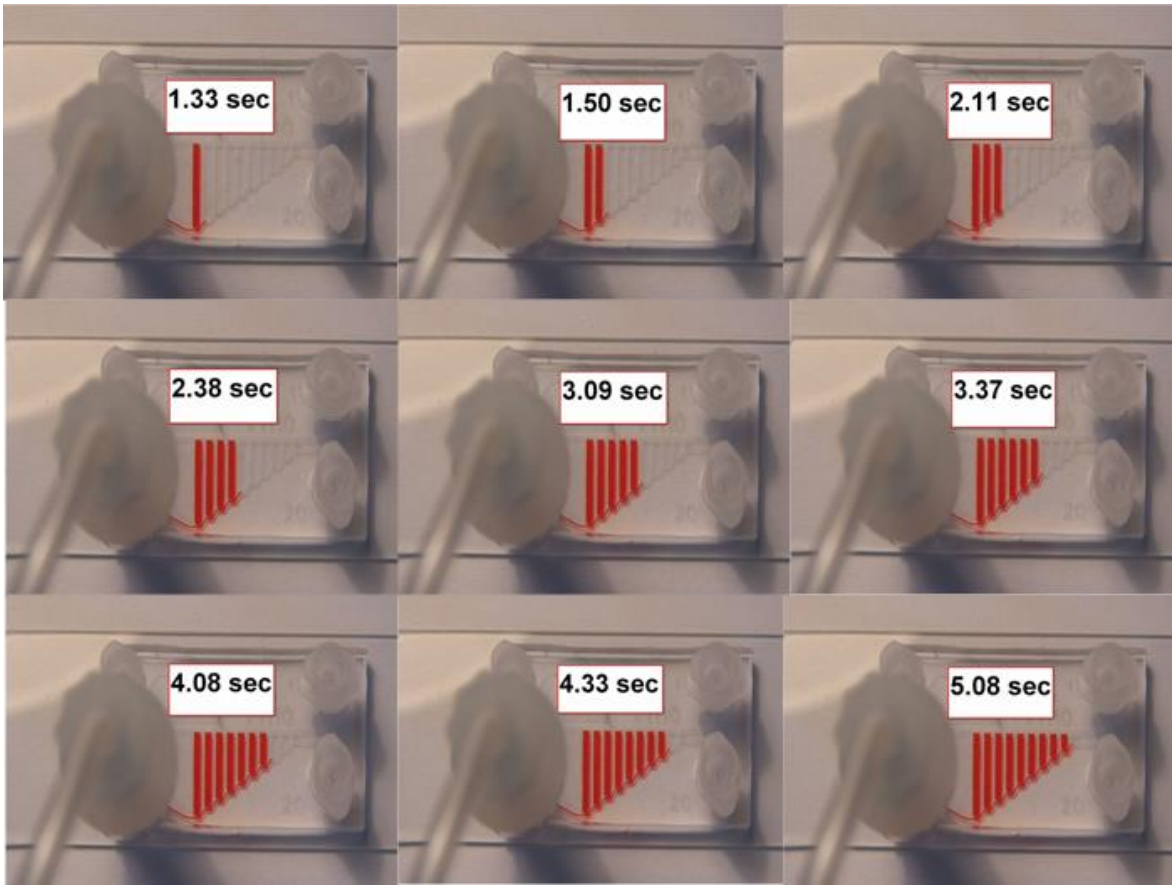


Figure 12. A demonstration of the fluid with red dyes sequentially injected into different cell culture wells under time-lapsed images(Shih, Tseng et al.).

3-3 biological result

To show the effectiveness of the designed system a four day HA22T cell culturing experiment was conducted. Fig. 13 show biological results of the formation of the shear stress barrier with the design of our multi-row square-pillar PDMS microstructure, and the experimental results with cells. The barrier functions to protect the cultured cells at the culture well from shear stress damage and facilitate the entering and exiting exchange of the culture medium and waste. The HA22T cells showed similar results when operating under a pressure of 0.03 psi. Therefore, the results validated the biological friendliness of our multi-row square-pillar PDMS microstructure design, which can effectively reduce shear stress and protect cells from high shear stress.

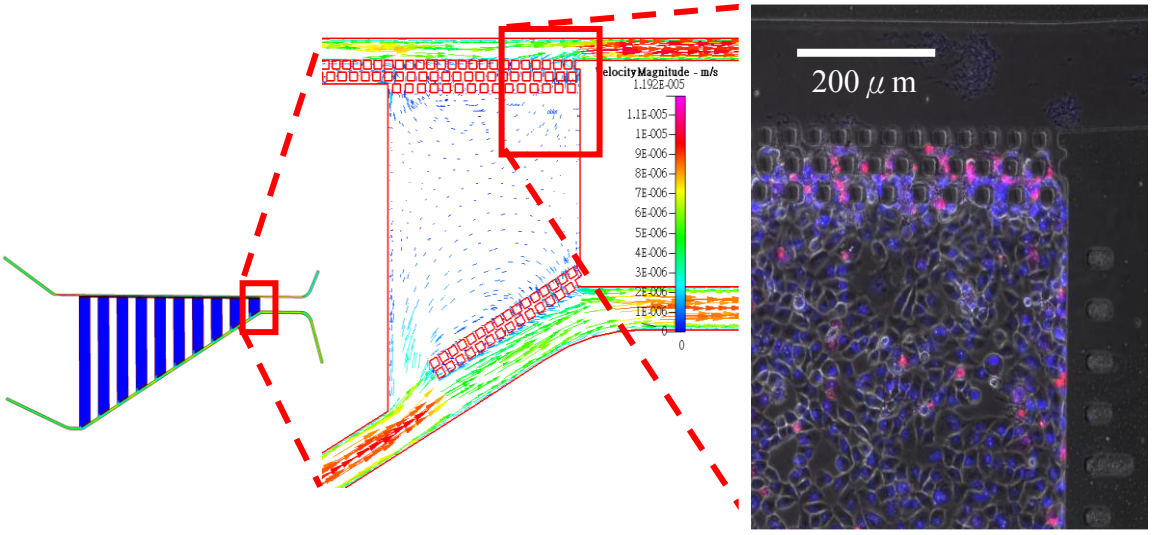


Figure 13. multi-row microstructure stop shear stress(Shih, Tseng et al.). The cells (HA22T) were automatically loaded into the culture well and constrained by the multi-row square-pillar PDMS microstructure. The active cells and the non-viable cells are stained in blue (DAPI) and pink (PI), respectively. The fluorescence image shows the cultured cells around the top of the cell culture well near the top flow channel.

Figure 14 shows a summary of the cell-loading number versus the length of the cell culture well. For cell culture wells with varying lengths, the cell survival rate is different. First, the cell viability of a shorter culture well was superior to that of a longer culture well under a fixed cell-loading density. The fresh medium in the top and bottom flow channels has a lower mass-transfer rate because of a higher flow resistance for the longer culture well, resulting in the cell waste in the culture well being unable to be transported with ease to the top and bottom flow channels. Oxygen and the fresh medium are also difficult to get in and exchange between cultured cells. All of these factors contributed to the observed result.

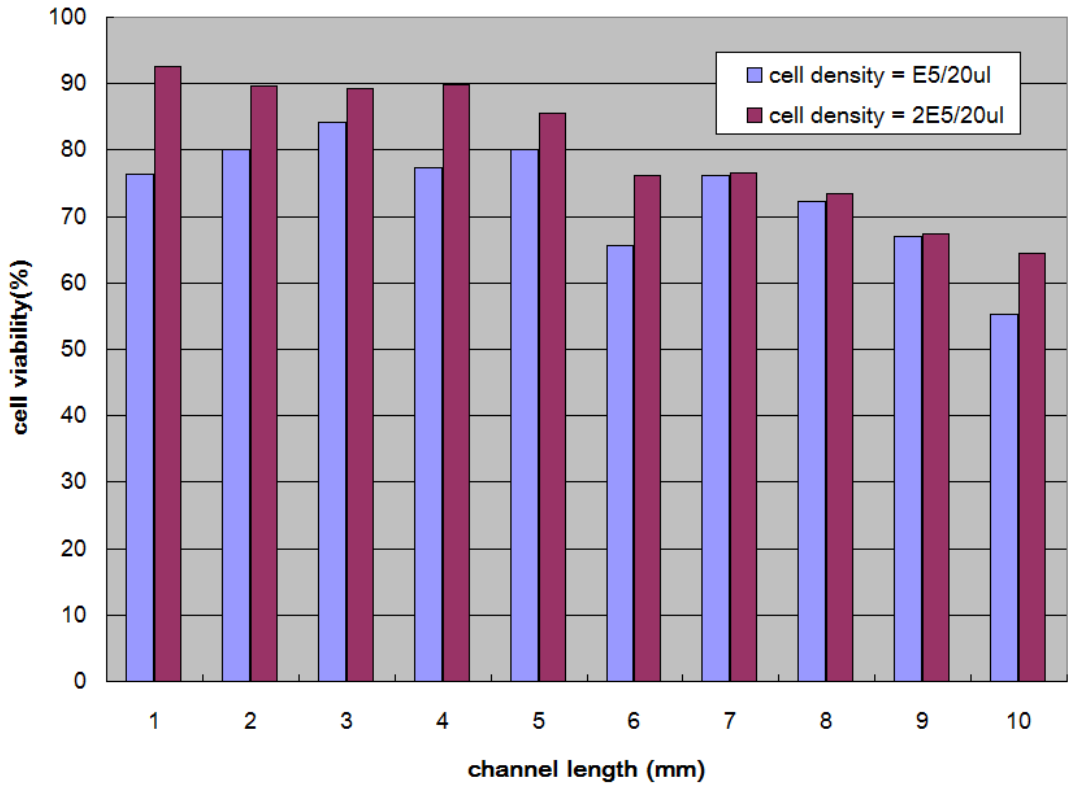


Figure 14. cell viability(Shih, Tseng et al.) The cell viability rate versus the length of the cell culture well. The width of the cell culture well is 1 mm. The length varies from 1 to 10 mm. The loading cell density of 2 x 10^5/20 μl results in a higher cell viability rate for all cell culture wells.

The overall cell density across the well length is as follows: The highest cell viability was 92% in the 1-mm-long culture well, and the lowest cell viability was 67% in the 10-mm-long culture well for the loading cell density of 10E7/ml. The highest cell viability was 85% in the 3-mm-long culture well, and the lowest cell viability was 55% in the 10-mm-long culture well for the loading cell density of 5 x 10E6/ml. The average cell viability with a cell density of 10E7/ml is higher than that with a cell density of 5 x 10E6/ml. This result is similar to that found in traditional culture dish experiments for suitable cell density. For the conventional 2D dish cell culture method, determining optimal cell density requires calculating the dish surface area at the initial cell-seeding stage for different cell cultures. Cell density affects the cell morphology, function, metabolism, growth rate, and viability (Ozturk and Palsson 1990; Dvir-Ginzberg, Gamlieli-Bonshtein et al. 2003). Similarly, the cell culturing in the microfluidic device must test the initial cell density to ensure that the cell waste and the fresh medium achieve a proper balance. Figure 3-12 shows that cell viability for a cell density of 2 x 10E5/20 μl is higher than that for a cell density of 10E5/20 μl. This indicates that a higher cell density such as 10E7/ml is more suitable and may enhance cell-cell interaction more for HA22T cells.

4. Conclusion

This research is focused on the TRIZ su-field analysis method in finding the solution to an engineering dilemma. Using the method, the physical dilemma of the small and large gap micro-structure of the design can be solved by identifying the different existing fields and forces within the system. The effectiveness of the design was verified by using the multi-well red dye injection into the system and observed under florescence microscopy to determine the viability of the cultured cells. The result indicated that the critical elements: decreasing shear stress, increasing mass transfer, reducing cell seeding steps, and reducing the complexity of the system components for manufacturing, can all be combined into one system.

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Popularization and application of Triz theory towards the enterprises of Guangdong Province

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Abstract

Triz theory is strongly popularized by the government of China in recent years, and how to popularize TRIZ theory effectively in Chinese mainland is still being probed. In this paper, it aims at the research of the popularization and application in Guangdong Province based on the analysis of the successful application experiences in the United States, Germany and South Korea. According to the present situation and the existing problems during the popularization of TRIZ theory in the small and medium-sized enterprises of Guangdong Province, some proposals are put forward.

Keywords: Innovation method; Triz theory; Pattern of popularization and application; small and medium-sized enterprises

TRIZ理论在广东省企业的推广应用

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摘要:
TRIZ 理论是目前我国政府大力推广的一种创新方法，其推广应用模式是我国各省市探讨的一个热点。本文以国家创新方法试点省份----广东省为例，通过分析国内外引进 TRIZ 理论进行自主创新的成功模式，根据广东省创新方法在中小型企业的推广现状，探讨适合广东省企业创新方法 TRIZ 理论的推广思路和模式。
关键词: 创新方法；TRIZ 理论；推广应用模式

1 引言

TRIZ 理论是前苏联人根·里奇·阿奇舒勒在对 250 万件专利研究的基础上得出的发明和解决问题的规律。在面对矛盾或冲突时，不是采取折中的方法，而是彻底解决矛盾。因此，TRIZ 理论可以帮助研发人员快速发现问题本质，激发创新思维，打破知识领域的界限，从而实现技术突破[1-4]。可见，TRIZ 理论是一种具有科学和可操作性的解决问题的方法体系。
近年来，TRIZ 理论作为一种先进的创新方法，在一些发达国家和知名企业中得到了很好的应用。因此，TRIZ 理论的推广应用在国内外引起了广泛的关注和重视。如何有效切实地推广 TRIZ 理论，使更多的企业从中受益，是各国政府共同关心的问题。但迄今为止，有关 TRIZ 理论推广应用模式的文献还是很少。因此，本文通过分析国内外成功的 TRIZ 应用经验，结合广东省 TRIZ 理论的推广现状，探讨一种适合广东省企业经济发展的 TRIZ 理论推广模式。

2 TRIZ 理论成功推广经验

前苏联解体后，美、德、日、韩等国家积极引入 TRIZ 理论专家，建立 TRIZ 理论研究机构和团队，开展 TRIZ 理论的应用和研究，并取得了显著的效果。如美国波音公司、德国西门子、韩国三星电子等著名企业在产品创新中应用了 TRIZ 理论，取得了巨大的成功，引起了国际上的广泛关注[5-6]。

(1)美国波音公司推广经验：

美国对 TRIZ 理论的引进始于 20 世纪 90 年代初，自 1999 年美国阿奇舒勒研究院成立后，美国对 TRIZ 理论的推广应用工作进入了正式阶段。美国波音公司始终坚持自主创新，注重团队合作创新，其 CEO 认为“创新是一个团体项目，而不是个人项目。”2001 年，波音公司邀请前苏联 25 名 TRIZ 专家，对 450 名工程师进行了

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为期两周的培训和讨论。利用 TRIZ 理论，成功解决了波音 767 飞机改成空中加油的关键技术问题，从而战胜了法国空中客车公司，为该公司赢得了 15 亿美元的订单。波音公司的推广经验可归功于“公司领导的重视，良好的创新氛围，团队的协作精神”。

(2)德国西门子推广经验

德国于 1973 年引入 TRIZ 理论，自 1997 年在理工科大学开设了 TRIZ 理论课程。德国西门子公司十分重视先进的创新方法，在 20 世纪 90 年代初，西门子开始应用 TRIZ 理论进行产品开发，聘请了前苏联的 TRIZ 理论专家和 TRIZ 工程师，开展国际交流和产学研合作，引入计算机辅助创新软件，提高解决问题的效率。此外，西门子也特别注重整合资源优势，加强与高校和科研院所进行产学研合作。因此，TRIZ 理论在西门子得到了很好的推广应用，产生了大量具有自主知识产权的创新成果。2004 年，西门子的研发人员实现了约 9000 项的发明，申请专利 6000 多项，并有 3800 多项专利转化为产品。专利数量在德国高居榜首，在欧洲名列第二。西门子的推广经验可概括为“公司领导的重视，资源优势的整合，创新工具的应用”。

(3)韩国三星公司推广经验

韩国于 1997 年引进 TRIZ 理论，得到了一些如三星公司、LG 等知名企业的积极响应，并将 TRIZ 理论广泛应用于产品开发中。特别是三星公司，于 1997 年引入 TRIZ 理论，引进一些前苏联的 TRIZ 专家对产品创新进行指导，同时也对公司员工进行 TRIZ 理论培训，自主培养 TRIZ 大师，取得了显著的经济效益。2003 年，三星公司通过采用 TRIZ 理论节约产品成本 15 亿美元，指导 67 项研发项目中有 52 项成果成功申请了专利。2004 年，三星公司创造了全球市场份额第一的成绩。2006 年，三星公司获得美国发明专利 2453 项，公司市值突破了 1000 亿美元，超过索尼公司 410 亿美元。三星的推广经验可概括为“引入外部 TRIZ 专家，自主培养 TRIZ 大师，建立 TRIZ 研究团队，形成创新氛围”。

3 TRIZ 理论在广东省的推广现状

中国大陆引入 TRIZ 理论的研究和推广应用工作还刚刚起步。自 2007 年以来，国家科技部相继批准黑龙江、四川、广东、江苏等省为第一批创新方法试点省。2009 年 12 月，广东省被确定为第二批创新方法试点省份之一。几年来，广东省采取以政府为主导的推广模式，开展了持续稳步推进创新方法推广应用工作，取得了一定的进展。将创新方法的培训工作重点面向中小型企业，通过开展多层次、多形式的培训，提高企业对 TRIZ 理论的认知度，培养创新型人才。

2010 年至 2012 年度，共培育了创新方法推广应用试点企业 46 家，试点示范企业 5 家。开展了两期创新工程师的培训工作，将来自各个企业约 140 名的一线技术研发骨干培育成为创新方法的传播者和实践者。开展了一期创新方法师资人员的培训，来自企业、高校和科研院所约 60 名人员参加了本次培训。

为提高企业自主创新效率，广东省科技厅依托华南理工大学和广东工业大学联合建设广东省创新方法与决策管理系统重点实验室（培育基地），依托广东工业大学引入最新的计算机辅助创新软件，建立了创新方法公共技术服务平台，实现资源共享，从而为企业的自主创新提供有力的创新工具。实践证明，通过近三年的创新

方法的推广应用工作，广东省试点示范企业的创新能力得到明显提升。自 2010 年以来，应用创新方法帮助试点企业解决实际技术难题 338 项，提交专利 344 项，获授权专利 209 项，为企业创造经济效益累计逾 3 亿元，企业的整体研发速度提高 50%以上[7]。

尽管 TRIZ 理论在广东省的推广应用工作取得了一些成绩，尚存在不少问题。首先，广东省是一个工业大省，企业数量众多，尤其是中小微型企业的数量庞大。产业分布面广，地域分布很不平衡，主要分布在珠三角地区。因此，创新方法如何有效地向众多中小型企业进行推广，如何因地制宜，结合地方行业特色找到适合广东省企业的推广应用途径是政府迫切亟待解决的问题。其次，TRIZ 理论的推广应用在我国尚处于初级摸索阶段，可借鉴的成功经验较少。存在的问题主要体现在[8]：

(1)企业对创新方法认识不足，重视程度不高，大多数企业还处于尝试阶段，在政府的倡导和资助下被动接受 TRIZ 理论的推广应用，缺乏积极主动性。

(2)由于 TRIZ 进入中国大陆的时间较短，无论从 TRIZ 专家的数量还是质量来说都是很薄弱的，具有工程背景和实践经验的 TRIZ 专家很少，无法满足企业的实际需要，这大大制约了 TRIZ 理论的推广应用。

(3)试点示范企业应用 TRIZ 理论产生的高水平成果少，其成功应用案例典型示范作用不明显。提交的专利多，但质量不高。此外，社会的创新氛围尚未形成，企业的自主创新意识还需进一步加强。

(4)现有的 TRIZ 理论推广体系和模式有待进一步探索，还未真正形成适合各地自身特点和发展情况的区域推广体系，这制约着 TRIZ 理论推广工作的可持续性。

4 TRIZ 理论在广东省的推广应用模式探讨

TRIZ 理论来源于工业界，是一门面向工程领域的发明创造理论。TRIZ 理论的价值主要体现在能够为企业提供解决技术难题的创新方案。因此，TRIZ 理论的推广是否成功依赖于在企业的实际应用是否成功。广东省是一个工业制造大省，如何结合广东企业现状，探索有效的 TRIZ 理论推广模式是值得探讨的话题。针对目前在广东省推广过程中存在的问题，提出以下建议：

通过各种渠道加强 TRIZ 理论的宣传推广，包括创新方法刊物、网站，举办创新方法理论培训班，邀请企业领导及骨干技术人员参加培训，使其认识到 TRIZ 理论的重要性和应用价值。

(1)加强创新人才队伍的培养和建设，着力提高创新方法的培训师、咨询师的业务能力，以满足众多企业的迫切需求。通过既引进优秀的 TRIZ 专家，又加强本地师资和技术咨询团队培养的方式，为企业提供高质量的服务团队，和企业建立长期合作关系，为 TRIZ 理论的推广应用提供有力的保障。

(2)加强企业特别是中小型企业创新服务公共技术平台的建设，实现创新方法推广应用的远程资源共享，为企业解决应用创新辅助软件的困难。将服务平台设点在高校

或科研院所，通过产学研项目等合作形式，建立高校或科研院所与企业的紧密联系，不仅可实现多个企业资源共享，也可提高高校教师和科研人员的实践能力。

(3)按照行业分类遴选和培育试点企业，通过各行业具有代表性的企业征集具有产业关键共性技术难题的项目。邀请国内外相关专家对行业的技术难题进行分析整理，并挑选企业的骨干人员开展行业技术难题攻关。通过对各行业的试点企业进行创新方法的应用和推广，带动行业内的其它企业主动学习和应用TRIZ理论，起到以点带面的作用。

(4)加强政府、高校和中介机构的密切合作，在以政府为主导的推广模式的同时，积极发展TRIZ理论的咨询中介机构，通过盈利性机构的介入，可为企业提供不同阶段的多元化服务。

5 结论

本文通过分析TRIZ理论在美国波音公司、德国西门子、韩国三星电子等知名企业中的推广应用经验，结合 TRIZ 理论在广东省的推广现状，探讨 TRIZ 理论在广东企业的推广应用模式。提出了加强 TRIZ 理论在企业中的宣传和推广、师资队伍的培养、搭建公共服务平台、试点企业的遴选和培育、发展中介咨询机构等方面的建议。

6 致谢

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Theory and Practice of TRIZ & Patent Analysis Integration

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Abstract

TRIZ and patent information has a very close relationship and the two-way interaction. The Systematic approach of TRIZ and patent analysis combined can play an important role in the whole process of enterprise innovation，which includes fuzzy front end, new product development and commercialization., and its effect is far better than alone TRIZ or patent intelligence analysis.This paper describes the application of TRIZ and patent analysis integrated systemic innovation in new product development stage, and applies the approach to solve the problem of a flat plate solar collector design.

Keywords: TRIZ; patent information analysis; flat plate of solar collector

TRIZ 与专利分析相结合的产品开发设计方法

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摘　要

TRIZ 与专利信息有着极为密切的关系和双向互动作用。TRIZ 与专利分析相结合的系统性创新方法在企业模糊前端、新产品开发和商业化的企业创新全流程中都能发挥重要作用，其效果也远胜于单独应用 TRIZ 或专利情报分析。本文介绍了 TRIZ 与专利分析相结合的系统性创新方法在新产品开发阶段的应用，并将理论方法与实际案例相结合，解决了平板式太阳能集热器产品的设计难题。

关键词：TRIZ；专利情报分析；平板式太阳能集热器

一、发明功效分析与 TRIZ 发明原理相结合的方法

将发明功效矩阵与 TRIZ 相结合，帮助技术人员能够迅速聚焦当前领域的技术聚集点（热点技术）和技术空白点，使技术人员在全面了解技术领域发展现状和趋势的基础上应用 TRIZ 方法， 极大地提高应用 TRIZ 方法的效果。

发明功效矩阵与 TRIZ 相结合的方法包括以下流程：

首先，获取有效专利信息。通常在检索某一技术领域的专利时会获得大量专利信息，很难一个一个进行详细分析，需要利用专利文献定量分析方法对专利文献进行分析和排除，筛选关键性专利。例如通过 IPC 分类、时间分析、引证分析等手段，过滤出当前时期某一特定技术领域的核心专利。

第二，建立专利功效矩阵。对专利功能结构进行分析和提取，按照效果—手段（方法）建立矩阵关系，分析本领域重点专利可以实现的功能有哪些，他们所使用的原理或方法、结构是什么。

第三，聚焦功效矩阵中的技术焦点或技术空白点进行逐层分析。所谓技术焦点，即众多专利都集中在功效矩阵中的某一点。当聚焦技术焦点的时候，说明某一方法的技术可行性高，众多企业都在应用相似的方法来解决某一问题或提高产品的某一参数，但方法背后的原理、结构并不相同。通过聚焦技术焦点，能够针对定位当前解决方法中存在的问题，准确定位应用原理或系统结构中存在的深层次原因，更有效地应用 TRIZ 方法解决技术系统中存在的矛盾冲突。聚焦技术焦点的具体方法是，对功效矩阵中某一点的专利进一步分析，按照“方法—原理—结构”的顺序层层分解。而当聚焦功效矩阵中的技术空白点，则表明目前尚无专利应用某种方法实现特定功能，但并不意味该该技术手段无法实现相对应的技术效果，有的可能是难度极高，所以才一直保持空白。能够获悉当前技术的空白点意义重大，技术人员可以同样应用 “方法-原理-结构”对应关系尝试对若干方法进行可行性分析，一旦确定空白区域是可以研发的，就能够知道企业进行专利布局。

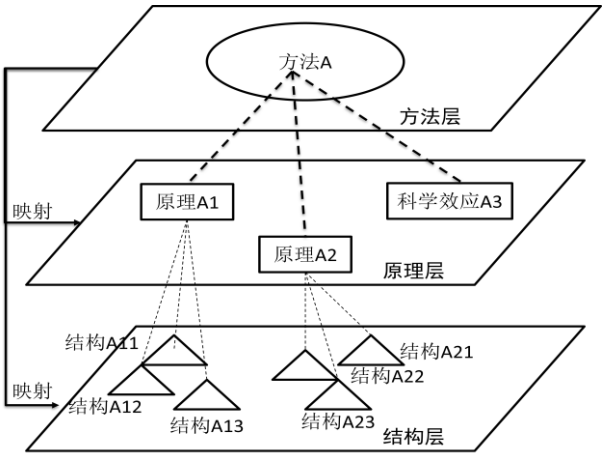

图 2：“方法—原理—结构”对应关系

第四，应用 TRIZ 方法解决技术矛盾、优化创新设计。通过应用“方法—原理—结构”确定技术系统中的矛盾和结构冲突后，需要通过 TRIZ 理论，选择相应的创新工具解决创新问题。针对原理层存在的问题，可通过矛盾分析、因果分析查找技术系统中存在的根本矛盾，再应用矛盾矩阵、分离法则、创新原理和科学效应库找到解决矛盾的方向；如果问题处在结构层，则需要应用功能结构分析、物场分析等分析工具对技术系统进行分析，再应用标准解、进化法则等解题工具解决问题。

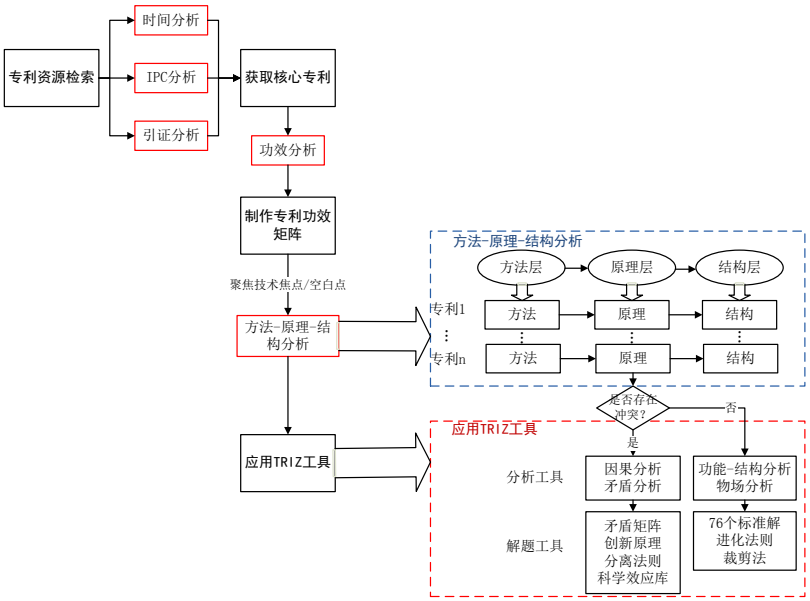

图 3：功效矩阵与 TRIZ 相结合的创新方法解题流程

二、基于 TRIZ 的专利规避设计方法

正如阿奇舒勒所言：“人类所面临的发明问题是无限多的，而解决问题的方法是有限的”。而通常跨行业领域进行方法借鉴往往会取得突破性的创新成果。通过大量阅读其他行业领域解决相似问题的专利文献，可以启发技术人员利用前人的智慧解决自身面临的技术难题，达到“他山之石可以攻玉”的效果。

很多时候，由于行业技术本身的特性或技术问题的复杂性，其他行业的做法难以参考借鉴，这时往往需要“借用”本行业竞争对手的专利技术，这就需要进行专利规避设计。所谓专

利规避设计，是指针对竞争对手的专利权利要求，找出其在保护内容等方面的漏洞，利用这些漏洞，实现在不侵犯专利权的前提下，“借用”该专利技术。利用 TRIZ 方法进行专利规避设计，包含以下步骤：

首先，目标专利检索。通过综合应用创新原理专利检索词表、IPC（或德文特手工代码）、专利权人分析等手段，设定检索公式，筛选出本行业或市场竞争对手应用某一方法解决领域内特定问题的目标专利（群）。

第二，针对目标专利进行分析。逐一列出其权利要求，判断每一项权利范围，与市场现有产品的新颖创新性进行比较，查找是否有可以删除的专利有效范围。

第三，对专利技术进行功能-结构分析。研读参考专利的权利要求、说明书及附图，并对专利技术进行功能-结构分析，分析内容包括：

是否能够增加在系统中的功能项目；

是否能够删减或重组元件，以增加新的功能或者减少有害效应（资源消耗）；

是否能够将功能转移到其他系统组件中，以减少有害的效应（资源消耗）；

是否能够激将某些功能转移到子系统或超系统上；

是否能够利用已有内外在资源而不增加组件。

第四，应用 TRZI 优化参考专利。利用创新原理、76 个标准解法、进化树等 TRIZ 工具，改善现有技术系统，使其达到系统组件数量减少，而功能并不减少；或系统组件数量不变，而功能增加或资源消耗、有害作用减少。

第五，检查设计方案。是否能够避开目标专利（群）的权利要求各个要项。

第六，专利申请。如果能够成功规避目标专利（群），则对改善的设计方案申请专利，否则须要重新对专利进行功能-结构分析，转换改善方案。

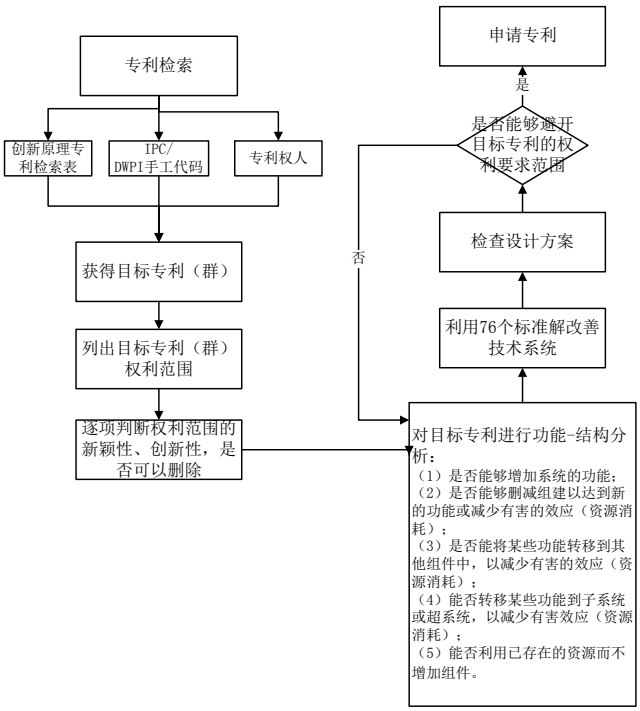

图 4：利用 TRIZ 方法进行专利规避设计的流程

三、 TRIZ 与专利分析相结合的创新方法解决平板太阳能集热器设计问题

（一）问题描述

平板太阳能集热器是一种吸收太阳辐射能量并向工质传递热量的装置，它是一种特殊的热交换器，集热器中的工质与远距离的太阳进行热交换。平板太阳能集热器是由吸热板芯、壳体、透明盖板、保温材料及有关零部件组成。当平板式太阳能集热器工作时，阳光透过透明盖板照射到吸热板芯上，其中大部分太阳辐射能为吸热板芯所吸收，转变为热能，并传向吸热板芯内的传热介质，传热介质循环工作，升温后作为集热器的有用能量输出。

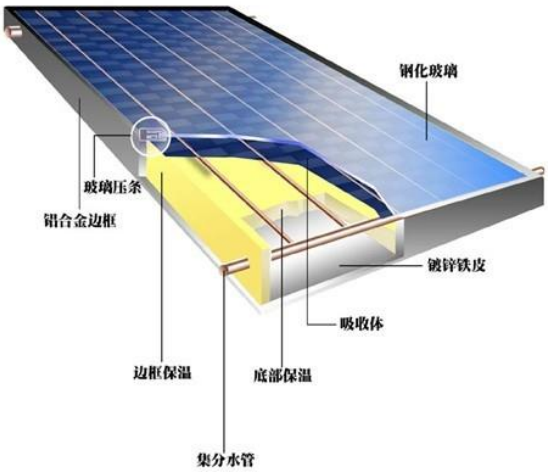

图 5：平板式太阳能集热器结构

由于集热器内部密闭空腔的气温非常高，高温膨胀空气必然在集热器内部产生压力；在户外环境下，由于昼夜温差、降雨、气候湿度等影响，集热器透明盖板迅速冷却，缸内气温下降，从而在集热器内部密闭空腔内形成较大的负压。集热器内空腔的正、负气压交替现象会引起壳体 变形，降低密封条的密封性，此外还会在集热器内部会产生冷凝效应。即集热板内部高温气体在降温时遇冷而凝结，气体中的水蒸气遇冷变成水。由于集热板内部的封闭结构，冷凝水无法排出，会累积到冷凝版底部。长期形成的冷凝水会腐蚀保温层和底部边框，降低集热效率，影响集热板的寿命。

（二）应用 TRIZ 与专利功效分析相结合的方法

1. 专利检索与功效方法分析

通过专利检索，查询不同行业领域解决空气中水分冷凝问题的相关专利文献。经 Thomson Innovation 国际专利数据库检索，共检出专利 833 件，去除同族后，共检出有效专利 439 件。对专利按德文特手工代码（DWPI）进行分析，筛选出解决空气冷凝问题的前十大技术领域：

DWPI 手工代码	对应领域
L01G04C	无机材料玻璃膜
D09C03	婴儿尿布
D09C06	吸水材料应用
D09C04B	胶布、绷带、伤口敷药

F04E04	手术和医疗产品（包括假体、缝合线、血液透析、绷带）
L01L02	交工工具玻璃材料应用
L01L01	建筑玻璃材料应用
L01L04	电子材料玻璃材料应用
A12W13	超强吸收材料
LO1L05	光学（含光线）玻璃材料应用

表 1: 解决空气冷凝问题专利的主要技术领域

通过DWPI手工代码分析，可以了解到目前抗冷凝技术主要应用于玻璃材料、医疗产品、吸水材料等领域。结合太阳能即热器设计的需求和具体工况，对行业领域进行初步筛选，决定重点研究无机玻璃膜、玻璃材料在交通工具、建筑和电子材料应用和光学玻璃材料、吸水材料六大领域的专利信息。在每一个行业领域，再通过专利引证分析查找出本领域平均被引次数最多的核心专利文献。

2. 参考专利分析

通过对各领域核心专利的阅读，发现在以上领域中，普遍采用吸收法（吸水材料）、绝缘材料层（例如硅或硅衍生物层）、结构法（改变材料的微观结构）。其中通过阅读一项去除空气中湿气的纤维材料的专利对于解决太阳能集热板设计问题有较大启发：

专利名称：Moisture-remover and moisture-removing apparatus（一种去除湿气装置）

专利公开号：US4826516A

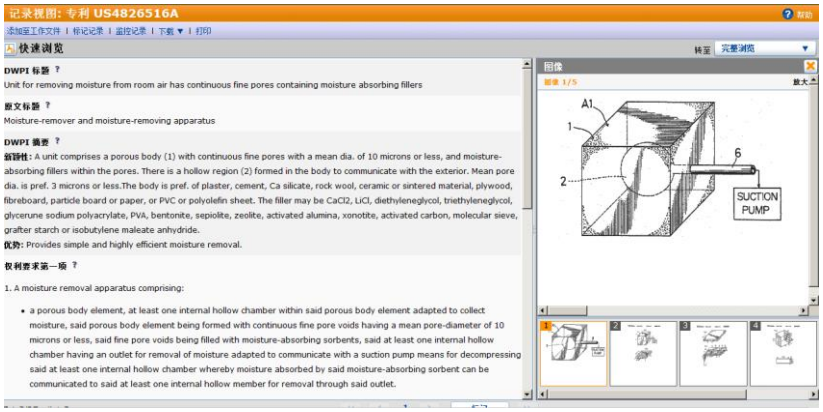

图 6：参考专利——一种去除湿气装置（截图）

通过对专利所应用的创新原理进行分析，该专利是利用微孔结构和吸湿材料相结合。这个装置是一个带有连续微孔结构的多孔体，这些微孔平均直径为 10 微米，且期内田庄了吸湿材料（如氯化钙、氯化锂）。多空体装配有一个中空段，中空段与环境介质连接。使用抽气泵减除中控段内的压力，压力差促使空气中的湿气通过微孔，水分以其泰兴市从孔内转移到中空段内，并被抽气泵吸走。中控段内降低的水汽压力防止了水汽饱和，并可以实现连续取出空气中的水分。因此，连续微孔内的填料和压力差去除了空气中的水分。其实质是应用了 TRIZ 理论中的多孔材料原理（原理 31）和等势原理（原理 12）。

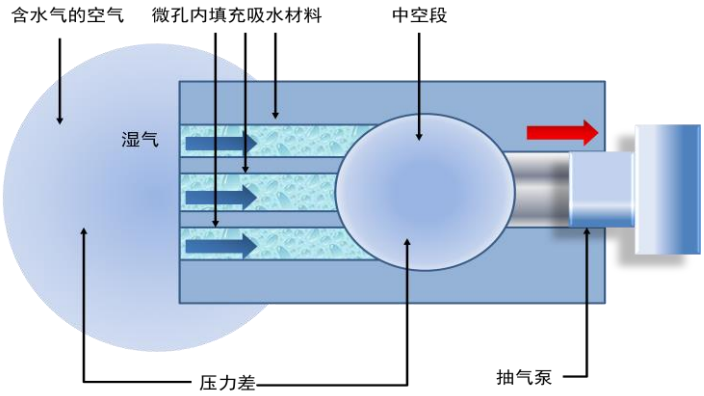

图 7：参考专利的方法原理示意

3. 解决思路

在参考专利的启发下，应用 TRIZ 原理将多孔材料原理和等势原理应用于解决平板式太阳能集热器的设计当中。将平板式太阳能集热器吸收体（条带）的下方安装微孔结构的吸湿保温层，吸湿保温层的微观结构是连续微孔形态，材料应含有碳酸钙、氯化钙等吸湿保温材料，这样能够起到微孔内填充吸湿材料的效果。微孔结构的保温层安装于集热吸收体和底部铁皮之间，应与底部留有间隙。

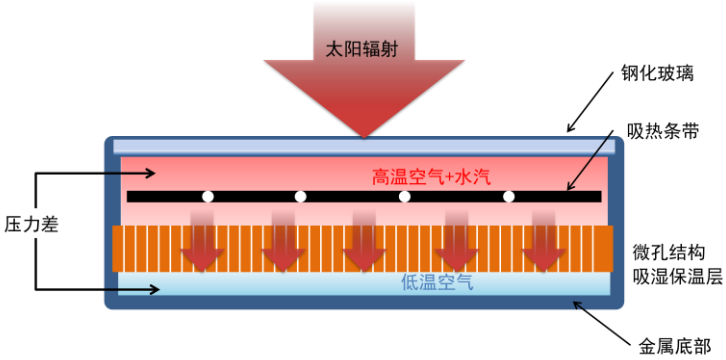

图 8：带微孔结构吸湿保温层的太阳能集热器示意图

在太阳辐射作用下，吸湿保温层上方的空气升温快于下方空气，由于温度差产生了巨大的气压。由于空气的热膨胀原理致使吸湿保温层上方和下方空气之间存在压力差，在气压的作用下，膨胀的含水气的高温空气会通过微孔结构流向保温层下方的中空段，在这个过程中保温层的吸湿材料就能够吸收高温空气中的水汽，降低集热板内部的水分子含量，从而预防冷凝水的出现。

这种带微孔结构吸湿保温层的太阳能集热板，是在对已有专利信息的研究基础上，应用 TRIZ 原理进行创新。通过应用热膨胀原理（创新原理 37），利用温度差导致气压差的现象，在没有加装抽气泵的前提下，利用自然资源实现了湿热空气通过多孔吸湿保温结构，从而起到对集热板内部空气的干燥效果。

（二）应用基于 TRIZ 的专利规避设计方法

1. 参考专利检索与分析

通过利用关键词和德文特手工代码相结合的方法进行检索，查找太阳能集热板本行业企业解决相同问题的参考专利，并试图通过 TRIZ 对现有产品和解决方案进行优化设计，从而规避已有专利。

通过检索，在平板式太阳能集热器领域解决冷凝问题的专利共 38 项，通过对这些专利进行 IPC 分析，发现解决太阳能集热器冷凝问题的主要方法包括：

（1）带有蒸发器和冷凝器装置（例如热管）

（2）带有冷却、光反射和光收集装置

（3）太阳能集热器零部件设计

（4）太阳能热利用

（5）太阳能源收集装置

（6）将光辐射直接转化为电能的装置（如太阳能电池板）

经过对专利文献的阅读和筛选，最终选择了一个对现有技术系统改动最小的技术方案作为参考案例，即“一种带呼吸阀的太阳能集热器”专利号 CN 201983478 U。该专利在太阳能集热器顶部固装有呼吸阀，外接触处设有密封圈，呼吸阀的底部通气孔穿过集热器保温层直接到达集热器的内部空腔，呼吸阀的上部透气孔与室外环境相通，呼吸阀的透气通道中设有透气憎油憎水薄膜。这种设计利用呼吸阀达到集热板内外空气的流通，避免了潮气在集热器内聚集。

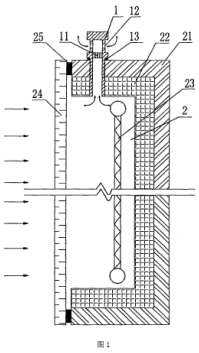

图 4.10： 参考专利—带呼吸阀的太阳能集热器图示

2. 对现有技术方案分析

应用“方法-原理-结构”的方法对参考专利进行逐层分析，发现应用呼吸阀解的方法，实质是应用了 TRIZ 原理中的局部特性原理（原理 3），即将原本是同质结构的集热器外壳变为异质结构，使集热器外壳不同部位具有不同功能（通气孔作为空气流动的通道，其余部位作为保温和支撑作用）。通过对这项专利进行进一步分析，发现应用局部特性原理解决问题时存在物理矛盾，当需要排湿的时候，则需要将通气孔尺寸尽量加大，提高排湿的效率；但同时空气流通量加大则影响了集热器的保温性，从而降低了集热器的工作效率。因此，呼吸孔的尺寸既要大又要小，构成了这个技术系统中的物理矛盾。应用 TRIZ 原理可以帮助解决物理矛盾，在改善技术系统的同时，规避掉参考专利。

应用物理矛盾引导表，解决静止物体尺寸设计的问题可参考 7 条创新原理（原理 17、原理 35、原理 3、原理 28、原理 15、原理 4、原理 1），在研究上述原理对本问题的适用性后，最终在原理 15—动态性原理和的启发下，对技术方案进行改善。动态性原理是指将刚性不动的物体变为可活动的，使其能够根据本身或外部环境变化，均能达到最佳性能。

3. 解决思路

由于排气孔的存在会造成热量散失，因此可以改变设计思路，将排气孔的功能转变为排水。冷凝水的形成是在温度低的情况下（阴雨、黑夜），因此，排水的过程不会造成集热器温度的过度散失，只要能够及时将冷凝水排除，就可以有效避免对集热板底部的腐蚀。

优化后的设计方案为，在集热器两侧接近底部，设置两个半月形排水口，并且在排水口安置一个半月形的排水口盖。同时，应用多维化原理（原理 17）将原来平直的集热板底部变为有坡度的水槽，目的是能够使冷凝水在重力作用下流向排水口。

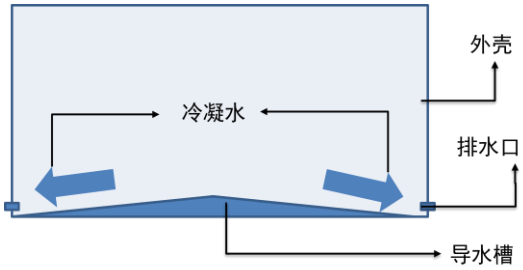

图 4.11： 带排水口、导水槽的太阳能集热器图示

当集热器内部水汽冷凝成液体后，会在重力作用下经水槽流向排水口，水流能够推开半月门盖流出集热器，之后半月门盖随后又会自然闭合。这样使排水口能够根据冷凝水的流量控制开闭，避免了热量的散失。也就是说当白天集热器加热的过程中，排水口实际是不存在的；而当低温环境需要排除冷凝水的情况下，排水口才会存在，这也符合 TRIZ 分割原理中的时间分割和条件分割的设计思路。

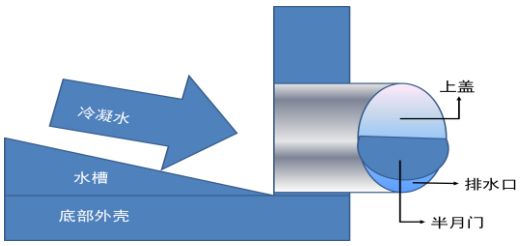

图 4.9： 改进专利的工作原理示意图

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Paper ID: C-08

THE PATENT CIRCUMVENTION OF DISAPPEARING HINGING DEVICE FOR WINDOWS AND DOORS - EXEMPLIFIED BY US7484270

ABSTRACT

This research uses component analysis of the patent US 7484270 and TRIZ inventive principle 13, reverse, to do the patent circumvention for the hidden hinge of aluminum window. First one analyses the components of the first independent claim US 7484270, followed by the investigation of the animation of hinge operation. Then component analysis of the first claim of US 7484270 is performed and inventive principle 13 is applied to the main lever. The US patent has the functions of tilt and turn. During the design process, European patent EP 1918498 and the hidden hinge of the current China market are referred to trigger two new design models of hidden hinge. The characteristics of the new design lie in that in the US 7484270 it has the articulating support of main lever which is located on one end of the first support element, whereas the corresponding articulation of new design is in the middle of first support element. The difference between the two designs is on the connecting point between main lever and second lever, where the connecting point of one is fixed and the other is movable.

Keywords: Hidden hinge, Tilt and Turn, Patent circumvention,Component analysis, Functional analysis

門窗之隱藏式合頁的專利迴避－以美國 US7484270 為例

黃建勳、鄧志堅

摘要

本研究乃是使用專利分析中的元件分析和 TRIZ 發明原則 13 反向操作原理的方法來作鋁門窗隱藏式合頁的專利迴避。首先分析 US 7484270 專利權利範圍的第一獨立項所使用的元件，並探究其作動原理，之後用動畫呈現其操作方式。該美國專利設計的隱藏式合頁具有內倒及內開的功能。之後，利用該美國專利第一獨立項中的元件分析和 TRIZ 的發明原則 13 於主槓桿來作迴避設計。在迴避設計過程當中，參考歐洲專利 EP 1918498 和目前中國市場使用的隱藏式合頁的結構，發想出兩種新型的設計。新設計的特徵在於主槓桿的作動支撐原點不在第一支撐元件的末端，而是在中間的位置。這兩種新型設計的差異在於主槓桿和第二槓桿的樞接點一個是固定的，而另一個是滑動的。

關鍵詞：隱藏式合頁，內開內倒，專利迴避，元件分析、功能分析

一、前言

在科技日新月異快速進步下，愈來愈多的產品走向簡約藝術性與實用便利性並進的趨勢，因而造就許多企業更加重視品牌觀念與消費者使用模式，進而為各種產業帶來一線商機，而建築業也不例外，從外觀綠化到內部裝修，無不訴求舒適、通風、安全、防盜、節能、隔音、環保…等特質，所以建材的選用也特別的注重，故以內開內倒窗(Turn & Tilt Window)為例，進行研究分析及創新改良。所謂內開內倒窗是指窗戶可以向內開啟，並且在關閉後又能夠使窗戶向內傾倒。其優點為當居家的主人在家時可以藉由內開使得外面的空氣大量流入室內以加強室內的空氣循環和維持室內空氣的新鮮。但是有一個缺點就是外人很容易藉由打開的缺口爬進室內。而內倒的窗戶就是針對以上的缺陷設計的，不只是外面的人很難爬進來。裡面的人也很難掉出去。這對於家中有小孩的家庭是非常適用的。因此內開內倒窗兼具有加強空氣流通和容易清洗裡外的優點，並且可以避免家中的小孩掉出去或是外人爬進家裡面來。

二、文獻回顧

(一)窗戶歷程

窗戶的進展與建築的發展習習相關。早期的建築物是沒有窗戶的。因為窗戶是鑲在牆上，而早期的建築物牆是用來支撐重量的，因此在牆上打一個洞來裝窗戶是會影響牆支撐重量的功能。藉由科技的進步，鋼筋混泥牆的出現，使得牆的支撐功能轉移到鋼筋的結構上面。因此牆可以自由的開放出空間由窗戶來取代。窗戶的優勢在於讓光進到屋子。而本研究合頁的設計與窗戶本身習習相關，因此在深入探討合頁設計之前會描述窗戶的歷史進展以及未來的可能發展。

(二)專利迴避概念

所謂「專利迴避」可用字面上的意思來看，就是一種如何避開他人專利的學問。由於專利的權利範圍和該專利的元件數目以及這些元件所提供的功能（function）、操作方式（way）和結果（result）有關。因此，藉由一些元件的刪減，或是修正原來的元件使得該元件的功能、操作方式和結果與原來的有顯著的不同就可以達到專利迴避。

根據專利法針對專利侵害的定義得知：專利是否侵權的判定其關鍵在於他人製造、為販賣之要約、販賣、使用或進口之「物品」或其使用之「方法」

是否落入系爭專利之專利權範圍。

進而在製造方法專利權上有特別的規定，專利權人主張其專利權被侵害時，必須負舉証責任，並証明下述二點，即可推定他人係以專利方法製造，而構成侵權：1.其方法專利所製成之物品在該專利申請前，相同物品均未見於國內、外。2.他人製造之物品與方法專利所製造之物品相同。

為判定是否侵權，於專利法中其鑑定流程分為兩階段：1.解釋申請專利範圍。2.比對解釋後之申請專利範圍與待鑑定對象（物或方法）。比對解釋後之申請專利範圍與待鑑定對象有下列步驟：1.解析申請專利範圍之技術特徵。2.解析待鑑定對象之技術內容。3.基於全要件原則（all-elements rule/all-limitations rune），判斷待鑑定對象是否符合「文義讀取」。4.基於全要件原則，判斷待鑑定對象是否適用「均等論」。

(三)TRIZ 手法迴避原則 13

創新的障礙在於衝突，衝突分為兩種：技術衝突和物理矛盾。技術衝突是指兩個工程參數的需求無法獲得同時的滿足，例如：在飛機輪胎的摩耗過程當中，當飛機起飛的時候，速度要加快到一定的程度使得機翼下面的氣壓大於上面的氣壓造成向上的浮力使飛機能夠起飛。此時輪胎的摩耗就非常嚴重；在這個過程當中，如果要使飛機起飛，則飛機的速度要加快，這意味著飛機的輪胎的轉速要加快，但確惡化了輪胎的摩耗。這裡有兩個工程參數是互相矛盾的。改善的工程參數是（輪胎轉動的）速度（工程參數 9），惡化的工程參數是摩耗（物質的損失，工程參數 23）。若要解決此矛盾問題，換句話說，則要同時改善速度，但確又可以減少摩耗，故可以使用矛盾矩陣找出相對應的發明原則 10（預先作用）、13（反向操作）、28（取代機械系統／使用另外感知）、38（相的轉變）。這些發明原則可以幫助找出觸發解來解決目前的問題。

(四)US7484270 的閱讀

本研究根據作者在業界的實務經驗，藉由專利的搜尋和判讀選出美國專利 US7484270 作為專利迴避的標的。這個專利主要強調的是隱藏式合頁，它可以作內開內倒的功能。目前在市面上有相對應的商品。由於個人服務的公司也在從事合頁的設計與製造，因此希望藉由專利迴避的技術來突破該專利權利範圍。將描述該專利的特徵，除了比對原來專利內的附圖外，更以 Solidworks 繪製立體圖形並且用動畫說明其作動方式。

除此之外，一般的槽口形式有三種：U 型槽口(塑鋼槽口)、C 型槽口(歐標槽口)、和 L 型槽口(無槽口)。目前僅前二者有相對應的內開內倒合頁裝置，而且這是從外面看得見的；若是對應隱藏式合頁裝置的槽口，目前就只看到 C 型槽口有在使用。一般 U 型槽口又稱螺接式槽口，而 C 型槽口又稱夾持式槽口，其是根據安裝的形式下去分的，螺接式顧明思義就是用螺絲固定的，而夾持式顧明思義就是用兩片板子夾緊固定的。若以整組隱藏式內開內倒五金件的成本下去考量，當然隱藏式內開內倒五金件的價格就相對的變高，以目前在中國大陸的市場價格大約為人民幣 400 至 450 元整，折合台幣約為 2000 至 2250 元。若是可以將這三種槽口共用一種隱藏式內開內倒五金件的話，當然量就變大，相對於成本就降低，利潤就會提高。

但是，國內尚未正式開發類似的產品，現在大都跟國外購買該產品，而在中國大陸某些大廠也積極在開發相關的隱藏式合頁，所以反觀國內更需要將隱藏式合頁開發出來，這是窗戶未來的世界潮流。

三、研究方法

(一)專利 US7484270 一般性描述

首先將美國專利 US7484270 權利範圍的第一獨立項閱讀分析，以釐清本專利的權利範圍。由於權利範圍和先前技術有關，因此需要仔細閱讀專利說明書的歷史文獻所陳列的各項專利，以及它們所

涵蓋的範圍才能確定本專利的權利範圍。之前的專利所宣告的權利範圍應該視為專利範圍的第一獨立項的前言。之後，將第一獨立項所揭示的元件用元件階層表描述，這個階層表可以界定本專利所需要的元件，換句話說可視為本項專利的權利範圍。所使用的元件越少，權利範圍就愈大。但是元件的數目也不可以小到本專利所欲執行的功能無法完成，如果這樣則專利就有無法致能的缺陷，使得該專利 無效。之後，描述每個元件的功能及相互間的關係，這個關係可以用元件功能分析表示出來。之後，使用簡約原則將原來的專利所使用的元件所完成的功能作轉換或者取代，使得新的元件產生出來可以執行原來專利的功能，並且元件數目可以減少，或使數目不減少但是某些元件有顯著的改變使得這元件的功能、操作方式、和結果與相對應的原來專利元件不一樣。結果，新的設計就產生了，這個新的設計或許可以獲得新的專利，即或不行也可以迴避原來專利產品的權利範圍，以達到專利迴避的目的。

以下先就 US7484270 的專利作一個描述說明。

本專利的目的是要提供一個隱藏式的合頁使得窗戶的移動框架可以作內開（Wing Opening）和內倒（Swievl Wing Opening），並且內開的開啟角度為 90 度，而內倒的傾斜角度為 10 度。如圖 1 和圖 2 為參考原專利的圖 1 和 2，號碼 10 是標示本發明一個合頁機構，它是用來窗戶或是門的下方完成內開或內倒的動作。原專利圖 2 機構 10 指出安裝門或窗戶 12 的狀況，這個窗戶包括固定框架 14 和可移動框架 16。這個固定框架 14 和可移動框架 16 包括個別的底下的橫部件 18 和 20 以及個別的直立式部件 22 和 24。這些部件僅僅部份的陳列在原專利圖 2 上。

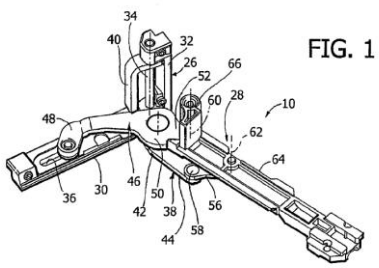

圖 1. 專利 US7484270 的圖 1

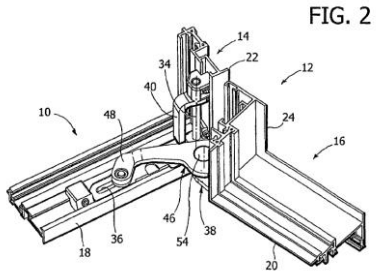

圖 2. 專利 US7484270 的圖 2

(二)專利 US7484270 的第一獨立項分析

以下針對專利 US7484270 的權利範圍之第一獨立項內容用圖表及相對描述分段說明，而內容描述是根據該專利在中國大陸申請的 CN1715605 之中文專利部份內容。因本研究是以美國專利為主，為使讀者知悉原文內容便將其置於附錄一，且依中文描述方式分段。其中文擷取內容如下：

一種用於包括固定框架(14)和活動框架(16)的窗和門的鉸鏈裝置，包括：

要被緊固到所述固定框架（14）上的第一支承元件（26），承載主鉸接軸線（34）和與所述主鉸接軸線（34）正交的滑動引導件（36）；如圖 3、圖 4、圖 5。

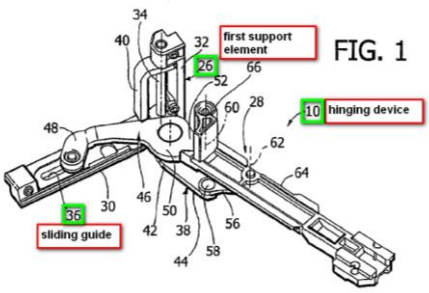

圖 3. 專利 US7484270 的第一支撐元件

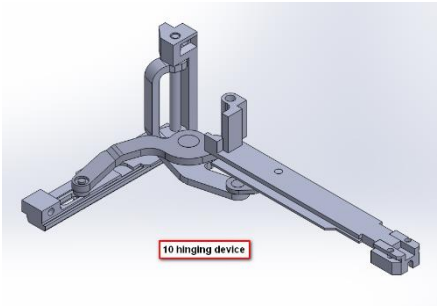

圖 4. 專利 US7484270 的圖 1 之內開立體圖

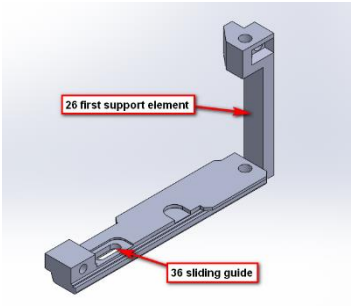

圖 5. 專利 US7484270 的圖 1 之滑動導槽

要被緊固到所述活動框架（16）上的第二支承元件（28）；如圖 6、圖 7。

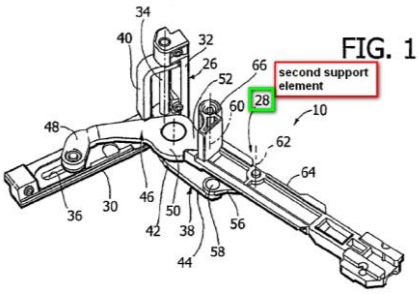

圖 6. 專利 US7484270 的第二支撐元件

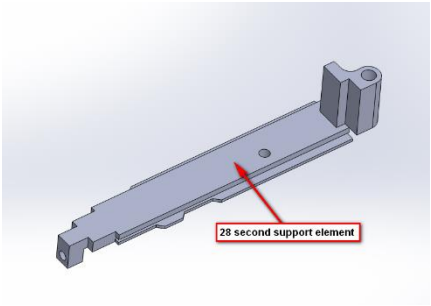

圖 7. 專利 US7484270 的第二支撐元件之立體圖

具有第一端（40）、中間區域（42）和第二端（44）的主槓桿（38），其中所述主槓桿（38）的第一端（40）圍繞所述主鉸接軸線（34）被鉸接到所述第一支承元件（26）上；如圖 8、圖 9。

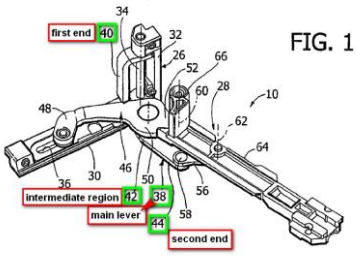

圖 8. 專利 US7484270 的主槓桿

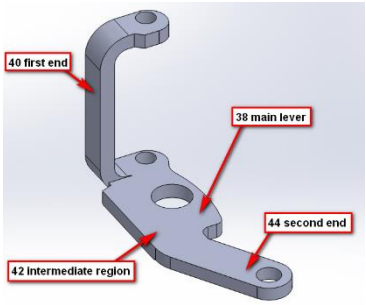

圖 9. 專利 US7484270 的主槓桿之立體圖

具有第一端（48）、第二端（52）和中間區域（50）的次級槓桿（46），其中所述次級槓桿（46）的第一端（48）能滑動地鉸接在所述第一支承元件（26）的滑動引導件（36）中，其中所述次級槓桿

（46）的中間區域（50）圍繞與所述主鉸接軸線（34）平行的第二軸線（54）被鉸接到主槓桿（38）的中間區域（42）上，且其中所述次級槓桿（46）的第二端（52）圍繞第三鉸接軸線（60）被鉸接到所述第二支承元件（28）上；如圖 10、圖 11。

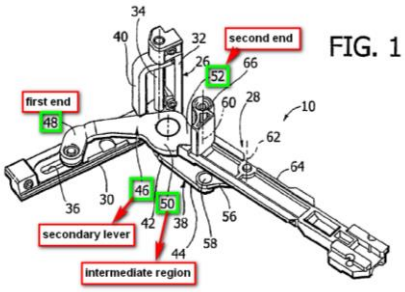

圖 10. 專利 US7484270 的第二槓桿

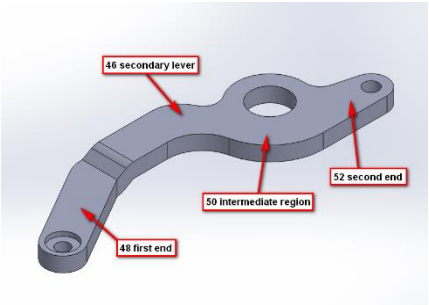

圖 11. 專利 US7484270 的第二槓桿之立體圖

具有被鉸接到所述主槓桿（38）的第二端（44）上的第一端和圍繞第二鉸接軸線（62）被鉸接到所述第二支承元件（28）上的第二端（94）的連接桿（56）；如圖 12、圖 13。

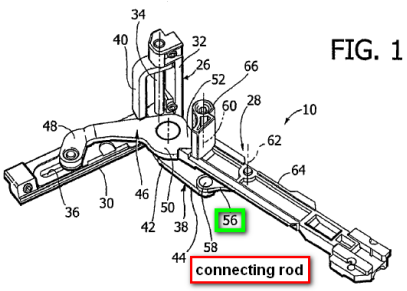

圖 12. 專利 US7484270 的連接桿

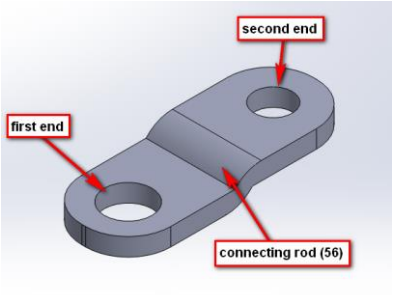

圖 13. 專利 US7484270 的連接桿之立體圖

其特徵在於所述第三和所述第二鉸接軸線（60、62）處於相對於所述第二支承元件（28）的固定位置且它們能夠以使得允許所述第二支承元件（28）在與閉合或翼式打開的活動框架（16）的位置對應的第一位置和與旋轉打開的活動框架（16）的位置對應的第二位置之間移動的方式相對於所述次級槓桿（46）的第二端（52）和相對於所述連接桿（56）的第二端（94）傾斜，其中所述第三鉸接軸線（60）由第一樞軸銷（72）限定出，所述第一樞軸銷與所述第二支承元件（28）的垂直部分（66）中形成的孔（68）可旋轉地接合，其中所述第一樞軸銷（72）具有以使得允許所述樞軸銷（72）在第一和第二位置之間傾斜的方式與所述次級槓桿（46）的第二端（52）的孔（80）接合的部分（78）；如圖 14、圖 15。

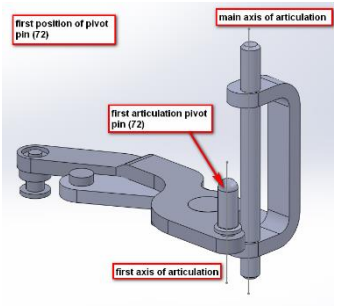

圖 14. 專利 US7484270 的第一樞接插銷之第一姿態圖

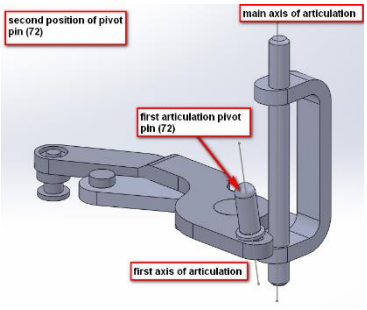

圖 15. 專利 US7484270 的第一樞接插銷之第二姿態圖

並且其中所述第二鉸接軸線（62）由被緊固到所述第二支承元件（28）上的第二樞軸銷（86）限定出，且所述第二樞軸銷（86）具有以使得允許所述第二軸銷（86）在第一和第二位置之間傾斜的方式與所述連接桿（56）的第二端（94）的孔（92）接合的部分（90）；如圖 16、圖 17。

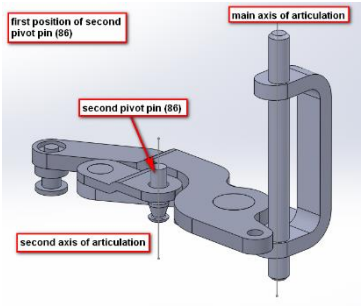

圖 16. 專利 US7484270 的第二樞接插銷之第一姿態圖

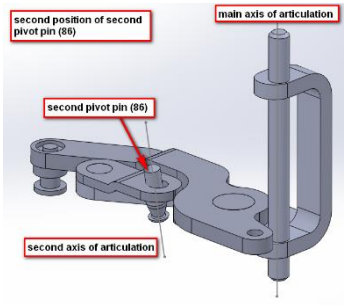

圖 17. 專利 US7484270 的第二樞接插銷之第二姿態圖

(三) 專利 US7484270 第一獨立項的元件及功能分析

以下依專利 US7484270 先製作第一獨立項的元件階層表，如表 10。

第一層	第二層	第三層
Hinging device (10)	1. first support element (26)	1.1. main axis of articulation
		1.2. sliding guide (36)
	2. second support element (28)	
	3. main lever (38)	3.1. first end (40)
		3.2. intermediate region
		3.3. second end (44)
	4. secondary lever (46)	4.1. first end (48)
		4.4. intermediate region
		4.4. second end (52)
	5. connecting rod (56)	5.1. first end
		5.2. second end
	6. first pivot pin (72)	
	7. second pivot pin (86)	

表 1. 專利 US7484270 的第一獨立項之元件階層表

由表中得知，本產品包含七個元件：第一支撐元件(first support element, 26)、第二支撐元件(second support element, 28)、主槓桿(main lever, 38)、第二槓桿(secondary lever, 46)、連接桿(connecting rod, 56)、第一樞接插銷(first pivot pin, 72)和第二樞接插銷(second pivot pin, 86)。

(四)先前技藝分析

根據上一節的分析，並將簡化如圖 18，進行該專利 US7484270 的迴避設計。並曾嘗試用功能分析以比較大的範籌來群組美國專利 US7484270 裡面第一獨立項的元件功能，企圖用元件的刪減和功能的轉移來產生結構較大的改變的新設計。

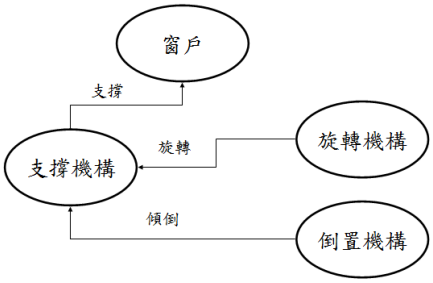

圖 18. 專利 US7484270 的簡化功能分析圖

但是並未成功，之後用專利分析的元件關係圖

來了解每個元件之間的互動，並嘗試改變它們互動方式，而產生新的結構。故根據 TRIZ 原則 13，反向操作原理，A. 使運動的部份或環境靜止；使靜止的部分運動；B. 將物體顛倒放置，或以相反的方式操作。因而發想使主槓桿原本用插銷固定在第一支撐元件的一端作旋轉的運動，而嘗試將這樣的元件的插銷位置固定在第一支撐元件的中間位置。經參考歐洲專利 EP1918498 和目前市場上做隱藏式合頁的機構，因而發想出新的專利迴避設計。

(五)新的設計發想

新的創意發想結果如下：

利用 Solidworks 來設計，共有兩種發想模型，第一種模型如圖 19，第二種模型如圖 20。

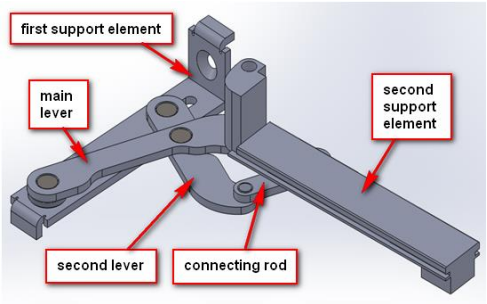

圖 19. 新型設計 1 的內開圖

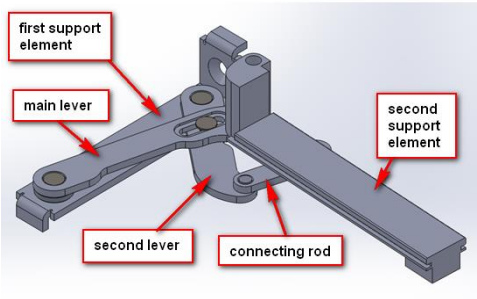

圖 20. 新型設計 2 的內開圖

其中新型設計 1 和 2 之間的主要差別乃在於主槓桿和第二槓桿的樞接處在新型設計 1 是固定的插銷，而在新型設計 2 是活動的插銷，在主槓桿的滑槽內移動。並且這兩個設計都是使用相同的機構作內倒的動作。其機構包括一個球狀定位銷；另一個是可以在滑槽內作小幅移動的插銷，這個插銷的功能是加強內倒的固定強度。由於兩個新型設計所使用的內倒機制是一樣的，因此以新型設計 1 的插銷來說明，如圖 21。

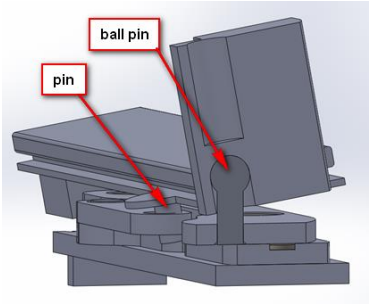

圖 21. 新型設計 1 的內倒插銷剖面圖

四、結果與討論

本研究探討美國專利 US7484270 的權利範圍，並且根據專利的元件分析作專利迴避。雖然無法藉由功能分析作出簡約設計的迴避設計。但是在此退而求其次，使用 TRIZ 的發明原則 13 反向操作原理，將原本美國專利 US7484270 的主槓桿由固定在第一支撐元件的一端轉移到其中間的部位，來進行迴避設計。且參考歐洲專利 EP1918489 和市場上隱藏式合頁的設計，終於設計出兩款迴避的新型設計；這兩款的設計所使用的元件及數量和之前美國專利 US7484270 相較之下，其所使用的元件數量是差不多的，若是從結構、作動與部件材質三大方向來看，可看出明顯的差異。

從結構上來看，主要差異在於原專利 US7484270 與這兩種創新設計的主槓桿和第二槓桿樞接位置不同，原專利 US7484270 是將第二槓桿其一端在溝槽內樞接及滑動，而本研究的創新設計 1 是將主槓桿其一端樞接固定，而創新設計 2 是將主槓桿與第二槓桿在中間溝槽內樞接及滑動。其次差異在於原專利 US7484270 的第一支撐元件中有一個主要樞接插銷作為轉軸的樞鈕，而本研究兩種創新設計的第一支撐元件並沒有這個主要樞接插銷結構。再次差異在於原專利 US7484270 內倒

的樞軸支撐結構，與本研究中兩種創新設計內倒的樞軸支撐結構不同，因兩種創新設計的內倒結構是相同的，故用創新設計 1 來表示。最後差異在於原專利 US7484270 與此兩種新設計的內倒樞接插銷不同，原專利 US7484270 所使用的插銷是一般常見的圓柱銷，而本研究所使用的是球柱銷，因兩種創新設計的樞接插銷是相同的，故用創新設計 1 來表示。

從作動上來看，主要差異在於原專利 US7484270 內開內倒之平開開啟角度為 90 度，與一般其他廠家作的平開開啟角度雷同或更小。而本研究在創新設計時，將其考量並設計可開啟大於 90 度的平開開啟角度，以此兩種創新設計的模擬圖得知平開開啟角度約略為 120 度。

從部件材質來看，以作者在業界的經驗來判斷，原專利 US7484270 支撐件材質為鋅壓鑄件，連桿材質為 SUS304，插銷材質為 SUS304，鉚釘材質為 SUS302；而兩種創新設計的部件，支撐件材質為鋅壓鑄件、SUS304，連桿材質為 SUS304，插銷材質為 SUS304，鉚釘材質為 SUS302。其中支撐件的設計與原專利差異最大，為降低業界所耗費的成本，選擇使用沖壓製程的鈑金件作為連桿支撐結構，而此構想來自重型摩擦鉸鏈的設計，以及送驗英國 BBA 檢測所需要通過的載重分析經驗。

五、結論與展望

本研究經由專利分析和功能分析產生出迴避美國專利 US7484270，整個過程參考先前技藝 EP1918498 和中國大陸的隱藏式合頁。功能分析所提供的發想方式可以大幅度的迴避原來的設計，然而困難度較高。本研究並沒有依照功能分析的方式得到觸發解。退而求其次本研究使用元件階層表和先前技藝，並且應用 TRIZ 的發明原則 13，反向操作原則，來變更主槓桿的支點位置以完成迴避的設計。本設計原則上使用的元件和美國專利 US7484270 的第一獨立項使用元件數目一樣，但是仔細比較還是減少了第一支撐元件所使用的插銷。

未來研究的展望是發展新的隱藏式合頁，其具有內開內倒的功能，並且能夠滿足研究步驟所使用的功能分析所產生出來的觸發解。當然這條道路是漫長的，因為此產品還可再新增其他功能，例如：共用槽口結構、角度定位功能、氣密性微調結構…等。

六、誌謝

本研究由大葉大學鄧志堅教授協助完成。

Reference

English Refernce

Balbo Di Vinadio, Aimone. 2009. Disappearing hinging device for windows and doors with wing and swivel wing opening. U.S. Patent 7,484,270, filed June 21, 2005, and issued February 3, 2009.

Remi Emiel. 2008. Hidden hinge. EP Patent 1,918,498, filed September 17, 2007, and issued May 7, 2008.

Chinese Refernce

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王耿斌（民 99 年 8 月）。中小企業智財專欄-專利侵害鑑定理論簡介。台北市：經濟部。民 101 年 12 月 18 日，取自：http://ipcc.moeasmea.gov.tw/index.php?option=com_content&view=article&id=504:column20101014&catid=92:2010-07-12-06-49-56&Itemid=143

專利侵害鑑定要點（無日期）。台中市：達穎專利師事務所。民 101 年 12 月 18 日，取自：http://www.dwip.com.tw/exec/msg.php?mid=36&cid=22&pid=36&lg=T

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Paper ID: C-17

Service Innovation in Public Sector – the Application of TRIZ in Household Registration

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Abstract

The ICT technology leads the business doing R&D and innovation continuously to increase their profits, and encourages the government public sector actively improving service quality in respond to public opinions. The Executive Yuan of Taiwan held Government Service Quality Award annually to evaluate and choose the departments with best public service performance. Many Service Awards winners are featuring with providing effective research and innovation services that positively earned people's high satisfaction. This paper will explore how to apply TRIZ into possible service innovation in the business process of the household registration office, in order to improve service quality and performance. Although household registration is no more limited to administration support and initiates various services considering innovation, technology, and user-friendly development, the service quality is still uneasy to meet customer demand and results in service bottleneck. This paper adopts TRIZ 39 parameters and 40 principles to solve the encountered bottleneck in creating win-win innovative service. Finally, we suggest six innovative proposals in establish the performance indicators to follow-up the implementation effectiveness regularly, and achieve win-win situation for both internal and external customers. Through continuous learning and imitation, and with the help of technology, internet and deregulation, the business process of household registration can be simplified. In the future, combining the information systems over the offices of household registration, judiciary, land, medical, health care, taxation, transportation, motor & vehicles etc., the government can provide cross-departmental integrated services with one-stop window and achieve the goal of one-stop service.

Keywords: household registration service, service innovation, service quality, TRIZ 40 principles

公部門的服務創新方法-TRIZ 在戶政之應用

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摘要

隨著 ICT 科技領先的時代，企業界不斷研發創新增加利潤，而政府公部門也重視民意，積極改善措施提升服務品質，行政院每年舉辦政府服務品質獎考評，評選出為民服務績效最佳的公部門機關。其服務品質得獎原因有許多是以研發創新服務為特色，舉凡機關的獨特性創新，提供效益性的服務，而獲得民眾的高滿意度與肯定者。本文將以戶政機關為例，探討如何應用 TRIZ 方法在戶政業務流程進行可能的服務創新，以提升服務品質與成效。近年來，戶政雖已跳脫過去以供給行政為主支援性功能，不斷以創新、科技及人性化發展各項服務措施，但在現有組織上仍然有員工服務品質不易符合顧客需求，產生為民服務問題的瓶頸。從本文研究採用 TRIZ 39 項管理參數與管理創新原則，可解決戶政服務過程發生的瓶頸，達到員工與市民雙贏的創新服務。尤其，藉由多對多的管理參數矛盾矩陣，得出 6 項高頻率管理創新原則；應用 TRIZ 39 項管理參數與 40 管理創新原則得到 6 項創新建議方案，制定績效指標與定期追蹤執行效益，達到內、外部顧客雙贏局面。未來可秉持不斷觀摩學習模仿創新，戶政業務藉由科技化、網路化的配合，簡化業務作業流程與法令鬆綁，結合戶政、司法、地政、醫療、健保、稅務、交通、監理等資訊系統，以跨機關、跨部門整合式服務、達到單一窗口申辦綜合服務，落實政府一處收件、全程服務之目標。

關鍵詞： 40 管理創新原則，戶政服務，服務品質，服務創新

1. 前言

就傳統政府機關的角色而言，戶政機關主要的功能是供給行政，扮演著資料提供者的角色，顯示社會狀況的重要資訊，不僅是政府施政的重要參考，同時兼具學術研究的價值，從供給行政之角度看，戶政的確對政府施政提供非常重要的資訊，但在政府再造、電子化政府、知識經濟及顧客導向服務之潮流下，戶政已跳脫過去以供給行政為主的支援性功能，不斷以創新、科技及人性化來發展各項服務措施，不但全面提升了戶政服務品質，更增進市民對於戶政職能之認識與重視；劉鏡清進一步說明「顧客專注型政府」，是指以人民的需求爲起點，再將政府部門與第一線的服務單位進行劃分，以滿足客戶為目的之策略性作法。一個以市民為核心的政府，需具備六種特色，包括：一、對客戶需求的洞察，二、增加與客戶對談的機會，三、能整合政府內部執行能力來支援客戶，四、以客戶為出發的組織型態，五、政府內部人員對提升服務的自我體認，六、提供完整解決方案的能力。其中，如何善用資訊科技以整合跨部門的業務流程，為政府轉型的成功關鍵，政府先將民眾的需求進行分類，再分析客群特性、訂定服務客群目標及成果，找出最佳的服務方式，針對每一特定客群，提供跨部會的整合式服務，最後制定績效指標與定期追蹤效益，因為所有的服務、組織設計、人員編制等決策，都必須以市民的需求為導向，資料的整合、即時性與正確性，戶政機關提供的服務與民眾息息相關，每個人從出生到死亡的過程都離不開戶政的服務，「便民、效率、創新、尊重」是戶政對市民的承諾，也是戶政品質的自我要求，朝向「科技化、法制化、人文化」等三大目標邁進，科技化方面配合網路新都的打造，逐步開放線上申請及業務查詢作業，配合政府各機關需求，提供戶籍資料庫，便民工作橫向推展，期望快速整合戶政、司法、地政、醫療、健保、稅務、交通、監理等資訊系統，達成資訊交換與應用，繼而提供市民方便的查詢與服務，確實做到一處收件，全程服務之目標；法制化方面配合戶政案例及法令的檢討，淘汰過時的法令，民眾的權益將更有保障；人文化方面則是考量在制度運作層面加入市民參與精神及地方特色的闡揚，未來戶政將持續創新作法，提供市民最優質的服務。

2. 文獻探討

2.1 TRIZ 簡介及應用

Theory of inventive probIem solving 發明問題的解決理論簡稱 TRIZ（俄文的第一個字母簡寫）。TRIZ 是解決問題的一種方法，其針對問題點的所在加以分析，並找出矛盾，再將矛盾分為物理矛盾與技術矛盾，進而採取不同的解決方式。以問題矛盾區域的解決方式來看，TRIZ 將問題歸納為物理矛盾與技術矛盾，在物理矛盾方面，將採取 「時間」、「空間」、「物質的物理狀態」，利用這三方面將矛盾給予分離，以解決物理矛盾的問題；而在技術矛盾方面，將依循已經過整理的因果圖、39 個參數及 40 項原則，來解決問題。TRIZ 最大的優點，在於將矛盾與衝突點轉化為利益點，並歸納問題解決的有效方法，以及系統進化的原則，以快速地解決問題；在解決問題期間，也運用了系統結構與轉移、問題確定技巧、問題抽象化技巧、想像等知識，使研發人員能夠做過程改善與問題解決的工作，TRIZ 是一個包括由解決技術問題，實現創新開發的各種方法到演算法組成的綜合理論體系。

Altshuller 的第一個 TRIZ 工具─矛盾矩陣，是 Altshuller 花了七年之久的時間，看遍了當時全球專利 40 萬餘件，將其提煉成 39 個工程參數。並由源自於從大量好專利裡的分析，Altshuller 抽取出種種構想的本質，這些本質正是構成傳統技術的各種突破，並將它們精心整理成 40 個創新發明原理，他再將這兩者連結起來並指出在創新發明上，我們所遭遇的其實是兩種矛盾：一是所謂的『技術矛盾』、一是所謂的『物理矛盾』。至於『技術矛盾』，乃指我們產業界在使用各種技術時，通常會遭遇到這樣的情況：當我們想要改善系統中的某一方面時，系統卻在另一方面變差。TRIZ 將上述的情境定義成技術矛盾，並試圖透過消除該矛盾的方式來找到突破性的解決方案。而好的專利正是這類突破性解決方案用在消除各種矛盾的歷史紀錄。所以，Altshuller 相信從這樣的解決方案中學習，必定能提供我們大量的提示而可用於消除在我們的問題上出現的各種矛盾。至於『物理矛盾』，乃指系統在問題上被要求要朝向某一方向發展，但同一系統的同一面向卻又要求要朝向反方向發展，這被稱之為物理矛盾。譬如說，有一個需求是要能清楚的看見而在此同時，卻又有著相反的需求是不要被看到，當我們被要求要在同一時間裡同時滿足這兩個對立的需求時，我們典型的思考答案是這是不可能的。

Altshuller 採用 39 個面向（例如：移動件的重量、可操作性等）將描述系統問題方式加以標準化，然後作成一個改善中面向 vs.變差中面向的 39 x 39 矛盾矩陣，接著他一個個地分析好專利去找出哪一個矛盾問題在此一矩陣哪一個專利被涉及以及這個矛盾就這 40 個創新發明原則方面來說是如何被運用來解決問題的。就技術系統而言（泛指產品、製程、服務等），其最小的單元是「執行單一機能」的單元，所謂的機能，TRIZ 的定義是：兩個物質之間的互動，而且有一個「場」在其間作用。這三者之間的互動存在著許多的可能性，其中最重要的就是「有利的互動」與「有害的互動」這兩種。當技術系統不以專業名詞去陳述表達，而採簡化的質一場模型來表示時，就有可能透過以質一場模型有關的「共通問題的模型類別」來辨認目前系統所存在的問題，有利機能的改善與有害機能的消除，是使用質一場模型改善系統問題的主要考量。在 TRIZ 的想法中，一個理想化的系統可以被定義成：一個可以執行其預期的功能但卻不存在的系統。當系統越趨進理想化時。它花的成本也越少，越簡單、越有效率等等。因此當遭遇到某個問題時，就可以透過對理想最終結果的追求而獲得突破性的創意，換言之，以理想最終結果作為目標來努力。

2.2 TRIZ 應用於服務系統

目前政府在數位化簡化文書處理或公文流程，利用網路將分屬不同單位的工作人員以任務或市民需求為導向予以編組創造出高效率工作團隊；也就是說網路不僅要將個別部門間的資訊介面標準化，讓橫向資訊流通變為可行，更藉網路將部門間本位主義的藩籬打破，數位化政府就是藉網路將過去政府提供機關供給導向的個別服務轉換為以市民需求為導向的整合型服務。就技術系統而言，在數位化政府下，由於橫向資訊流通變為可能，橫向協調就變得非常重要，尋找問題答案的方式不再是過去向上請示或部門內的討論，而是由跨部門橫向討論，共同找出答案，就會產生「有利的互動」與「有害的互動」，由於政府的職能分散由具彈性的工作團隊來發揮，整個政府運作呈現最有效率的虛擬狀態，在虛擬的行政作業，政府各項申請作業流程及相

關資訊都置於網路上，讓民間部門和市民都能共同參與，達到資訊透明化，由網路建構的虛擬行政單位可因市民或社會的需要而被創造，一旦完成任務或達到目標後，市民只要在線上即可申辦行政事務，而服務人員亦可線上提供所需服務。

兩個物質之間的互動，有一個「場」在其間作用，長期以來，政府缺乏行政效率的問題，已非由削減人員、調整組織、簡化層級、更換部會機關的首長就可解決，其中最大的障礙在於執政者的心態仍未調整，應扮演公正的裁判者，保障多數市民的權益，不應是一個資源、資訊、科技發展的控制者及主導者，政府應由過去的管制性、主導性角色轉換為服務性、協助性的角色，綜上所述檢討戶政機關在服務瓶頸面向，可能透過以質一場模型有關的「共通問題的模型類別」來辨認目前系統所存在的問題，提出員工服務品質不易符合顧客需求為解決問題的面向。在 TRIZ 的想法中，有利機能的改善與有害機能的消除，解決問題的流程上，須先拋開各式各樣客觀的限制因素，當系統越趨進理想化時，它花的成本也越少，越簡單、越有效率，TRIZ 發展有共通的方向且是跨技術和產業服務領域的，透過這些技術發展的趨勢，可以了解產品或服務在問題方面發展目前所處的階段和解決問題的能力。

2.3 公部門創新意涵

管理大師彼得杜拉克(Peter Drucker)指出：「創新是使用新的知識以提供顧客新的服務和產品，是一種以創造更高的附加價值為目的的活動」(Hsiao & Lee, 2002)。而提出創新擴散理論的 Everett Rogers (1995)則認為：「當一種觀念、做法或事物被接受的一方認為是『新的』，並且付諸行動，就稱為創新。」因此，創新並不一定是全新或前所未有的，只要與原有事物存在某種程度的差異且被採行，包括在制定和執行過程中某種程度的修正和發明，並不一定需要改變組織現狀，就可謂之創新。其後，哈佛大學的 Alan A. Altshuler 和 Marc D. Zegans 兩位教授對創新提出一個簡潔的定義：「創新即是將新奇的想法付諸行動」(Yang & Shih, 2004)。公共行政學者 Mulgan 和 Albury (2003)也指出：「創新就是新想法的實行」，皆強調了創新必須有「付諸行動」的特質。

最廣泛的創新界定，認為只要是因應新市場、新需求或者是新的服務機會等外在刺激，其最終目的在使得整個組織、機關或是社會能在作業流程、服務提供、經濟效益乃至社會文化上能有所提升和轉變，因而所付諸實行的各項發明或改善措施，皆可被稱之為是創新。

Liao & Lu (2010)提出公部門的創新服務指的是以具有創意的或獨特的方法解決問題，創新可能是新的服務型態、新的組織變革或流程的改善；而成功的創新服務通常是藉由導入新的流程、產品、服務或方法，在服務的效能、效率、品質方面產生明顯的改善。除此之外，澳大利亞審計部(Australian National Audit Office, ANAO)也對公部門創新下了一個簡單的定義，其認為公部門的創新服務可以被定義為創新流程的生產和執行，藉由流程的改善以增進政府效能、提升效率及提升服務品質(ANAO, 2009)。簡言之，就是應用新的想法來產生更好的結果。

公部門創新仍有其特殊之處，如 Moore 和 Hartley (2008)曾指出，公部門創新與一般文獻僅強調組織內部的產品與服務創新過程有很大的差異，在於：公部門創新通常是超越組織層次，需要透過更廣泛的社會參與，以及跨組織或跨部門的合作網絡來推動；其次，公部門創新也不僅是著眼於公共服務內涵與過程的創新，更涉及到服務生產過程中，有關人事與財務資源的運作方式、以及更複雜的政治與社會文化的系絡背景因素。

Zegans (1992)將創新在公部門中所代表的意義，歸結出下列四項基本觀點：

(1) 創新是提高機關績效的工具，它本身並非提高績效的目的。
(2) 創新是新想法的執行、或在既有體制上採用一項新技術。
(3) 成功的創新有賴於執行技巧的運用及政治上的支持，更甚於創新的構想。
(4) 創新是公共管理者既有的職能。

Levin 和 Sanger 將政府組織的創新作為比喻為一種「平凡的奧妙」(prosaic profundities)，且具有以下三項特徵(Liu, 1996)：

(1) 公部門的創新是漸進發展而非臨時拼湊而來的：例如，美國麻薩諸塞州財政局的稅務創新工作，是在既有的稅務法規和組織編制下進行，只是其主事者 Ira Jackson 懂得為該機關凝聚一項革新行動，而使得稅務工作得以創新。

(2) 公部門的創新是在例行的路徑上運用創新的管理策略：亦即，運用既有材料，以新的方法使其發揮更好的效用。例如美國紐約市的少年法庭結合了非營利組織的力量，共同做好拘留中心的社會服務工作，使得原本被認為虛擲光陰的居留期，變得更具有真正教化青少年的功能。

(3) 公部門創新經常是將熟悉的相關事務加以重新組合(novel combination of familiar things)，使其產生令人意外的效果：例如，費城反塗鴉網路組織，即是將屬行法治與社區美化的工作，加以巧妙地組合起來。費城市政府原來對青少年在公共場所到處塗鴉感到憤怒，且由於塗鴉的速度始終比清除的速度快，使得市政府在處理上極為棘手。後來市政府將這些非預期的要素加以結合，由警察、志工、專業藝術家和社區組織共同召喚那些嗜好塗鴉的年輕人，一起美化原本被破壞的市容。從這項行動中，費城得以維護法律尊嚴、青少年過剩的精力有處宣洩，而社區除了美化之外，鄰里關係也更形密切，達到了三贏的效果。

Koch 和 Hauknes (2005)認為可以由下列三種方式來區分公部門創新的型態：

(1) 漸進式創新(incremental innovations)─突破式創新(radical innovations)：由「創新的程度」來判斷。在公部門中，多數的創新皆來自於既存的物品、流程或服務的逐漸改善，也就是由漸進式創新的模式所產生。

(2) 由上而下的創新(top-down innovations)─由下而上的創新(bottom-up innovations)：由「啟動創新者的階層」來界定。所謂上層，意指層級節制的機關或組織中的高層管理者；而下層則指一般公務人員或中層的政策制訂者。

(3) 需求導向的創新(needs-led innovations)及效率導向的創新(efficiency-led innovations)：由創新作為所欲「解決的問題」來區分。創新的產生是為了解決特定的問題？或是為了促使既有的產品、服務或流程更有效率？

綜合以上所述，廣義而言，任何一個國家公部門運作之改變均可視為「公部門創新」，因此，公部門應用 TRIZ 方法以改善服務品質，解決戶政服務過程發生的瓶頸，皆屬公部門的創新服務。認為行政機關只要是因應環境變遷、新需求或面對新問題等外在刺激，為了能在機關為民服務的工作上有所轉變或改善，所能啟動觸發的各項發明或革新措施，皆可稱之為行政機關創新。

3. 服務創新流程與模型

3.1 SIPOC 分析方法

SIPOC 模型是戴明提出來的組織系統模型，此方法最常用於流程管理和改進的技術，可作為識別核心過程的方法，係一組跨越職能部門界限的活動，不論一個組織的規模有多大，SIPOC 圖都可以用一個框架來勾勒其業務流程。供應者(Supplier)：向核心流程提供關鍵信息、材料或其它資源的組織，因為戶政業務流程中上有主管下至業務或櫃台人員，對價值創造起重要作用的供應者；輸入(Input)：供應者提供的資源，例如輸入機具設備、硬體設施、辦公場所、專業設備等資源滿足的要素；流程(Process)：輸入發生變化成為輸出的一組活動，戶政業務透過綜合受理、專案服務、法令函釋、審核驗證、個案處理、危機處理流程使輸入增加價值；輸出(Output)：流程的結果即服務，例如產品標準或服務標準，輸出可能是多樣的或只選擇一種輸出，例如案件完成、提供補證、公文回覆等，輸出可以為顧客創造價值；顧客(Customer)：接受輸出的人、組織或流程，不僅指外部顧客，而且包括內部顧客，例如一般民眾、行政機關、法院或學校等。流程圖看出戶政機關的業務過程和問題，通過流程分析發現問題找出瓶頸消除流程中的無價值、監督迴圈，提升服務效率與機關競爭力，繪製出戶政業務的 SIPOC 如圖 1。

3.2 創新服務模型

服務業的創新，由被動服務邁向主動式服務，藉由 SIPOC 模型導入戶政業務技術層面之研發，創新乃是指使用新的知識、方法，提供顧客所需新的服務及產品，戶政機關對於創新方法，在 OECD (2011)的研究報告指出，流程創新是指公部門在製造或提供公共財貨和服務時，採用一個全新的、或是相較過去有明顯改善的方法；而此方法廣義而言也包括了技術、設備和實體系統、作法或程序上的提升(Koch & Hauknes, 2005; Hartley, 2005; IDeA, 2005; Windrum, 2008; Bloch, 2010; Hertog, 2000; Wen & Hsu, 2004)，透過 e 化技術的創新，戶政機關所能提供的服務也更加多元化，有助於增加服務的幅度和深度，在服務項目包含有形的產品和無形

的服務，而服務項目的創新則包含了提供不同於以往的產品或服務或改善其服務和產品的特色和內容，也可謂之服務項目的創新(Koch & Hauknes, 2005; Hartley, 2005; IDeA, 2005; Windrum, 2008; Bloch, 2010; OECD, 2011)，其創新服務包含四個構面：(1)以顧客為導向、創新服務、新服務呈現、創新呈現；(2)以顧客為導向、激進的創新、新服務呈現、創新呈現；(3)合作導向、創新服務、新服務呈現、創新呈現；(4)合作導向、激進的創新、新服務呈現、創新呈現、此四種構面的關係模型如圖 2，來解決員工服務品質不易符合顧客需求的問題。

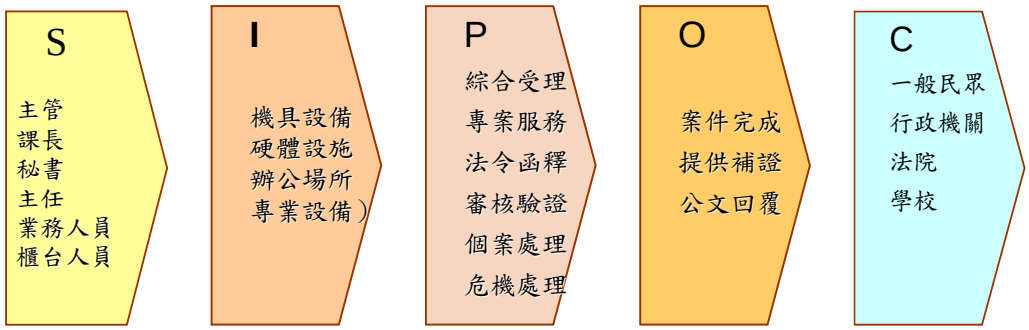

圖 1. 戶政業務的 SIPOC

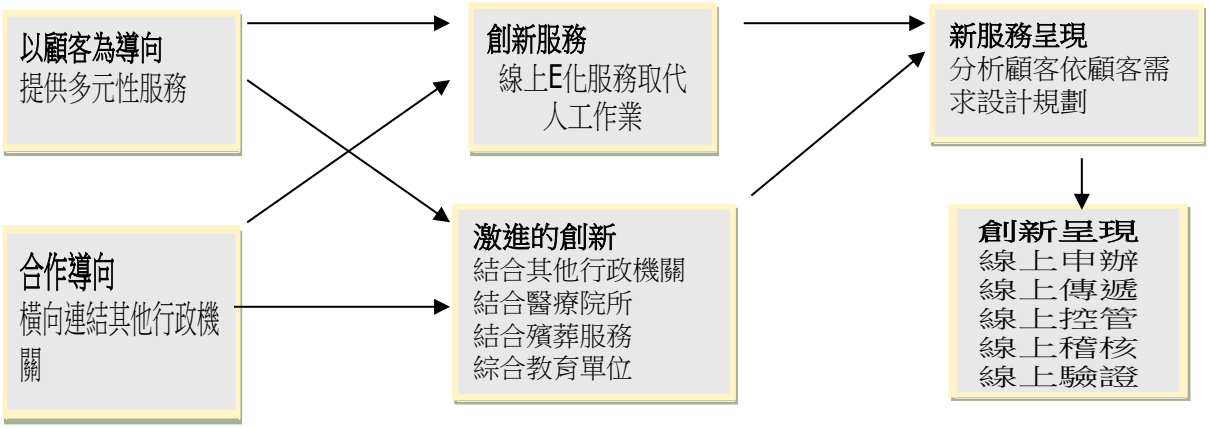

圖 2. 創新服務模型

4. TRIZ 創新應用範例

4.1 應用 TRIZ 39 項管理參數與 40 管理創新原則

例如對員工服務品質不易符合顧客需求問題，採用多對多管理參數矛盾矩陣，可先刪除欲提昇之工程參數與惡化之工程參數對應出管理創新原則不相關且出現次數較少的參數。TRIZ 管理參數對應之創新原則，表中「+」數代表正相關，亦即可以同時擴大提昇或改善，「-」數代表負相關，亦即產生矛盾項，欲改善某一參數而會惡化另一參數，空白則無相關性。查閱多對多矛盾矩陣之相交儲存格「+」數代表兩參數正相關，無需列創新原則，「+」數管理參數愈早提昇好處愈多，TRIZ 管理參數對應之創新原則詳列說明如下。

員工服務品質不易符合顧客需求，可採用如提升工程參數 5 轉化為管理參數內容為顧客類型、員工類型、主管類型，會導致惡化之工程參數 9，轉化為管理參數內容為受理時間、審核時間、操作時間、解說時間、驗收時間、簽收時間、營業時間、服務時間。參考 40 管理創新原則可採用如 14.3.34.29.28.30.4.13 項創新原

則思考，可得到顧客類型如解決方式為預約服務、到府服務、流程簡化、縮短時效、視訊 E 到家、智慧型分流叫號系統、客製化服務、主動服務、線上申辦、線上繳費、綜合受理、表單連結、免書證免謄本、反稽核查詢、顧客滿意度，可以提升顧客滿意度，多數採線上申辦 e 化服務，降低臨櫃申辦時間。員工類型解決方式為品管圈、提案小組，組織氣氛、團隊合作、激發創意、門牌檢索系統、線上教學、戶役政資料庫、線上領物、薪資轉帳、電話拓充、掌紋簽到簽退系統、線上差勤系統、門禁管制。透過集思廣益創意思考提升服務品質，機關舉辦休閒活動提振員工工作士氣，同時採線上 e 化操作流程縮短工作時效，提高工作效率；主管類型解決方式為實地查證、職務輪調、電子簽章、任務編組、下午茶時間、員工旅遊、尾牙聚餐、心理諮商、輔導獎勵、組織氣氛、組織架構、戶政百年展、員額編制、年度預算，採取職務分工、分層負責方式，帶動機關組織氣候，讓員工有向心力，組織團體合作提升服務與管理效能。

表 1. 改善服務品質在時間因素方面

<table>
<tr><th>欲提昇之工程參數</th><th>惡化之工程參數</th><th colspan="7">管理創新原則 【5-9】</th></tr>
<tr><td rowspan="2">顧客類型
員工類型
主管類型</td><td rowspan="2">受理時間
審核時間
操作時間
解說時間
驗收時間
簽收時間
營業時間
服務時間</td><td rowspan="2">預約服務
實地查證
到府服務
職務輪調
績效評估
品管圈
提案小組
巡迴服務</td><td>流程簡化
縮短時效
電子簽章</td><td rowspan="2">任務編組
組織氣氛
團隊合作
激發創意
組織架構</td><td rowspan="2">戶政百年展
門牌檢索系統
線上教學
戶役政資料庫
視訊 E 到家
線上領物
薪資轉帳
電話拓充</td><td rowspan="2">掌紋簽到簽退系統
線上差勤系統
門禁管制
智慧型分流取號系統</td><td>員額編制
年度預算
客製化服務</td></tr>
<tr><td>任務編組
下午茶時間
員工旅遊
尾牙聚餐
心理諮商
輔導獎勵</td><td>主動服務
線上申辦
線上繳費
綜合受理
表單連結
免書證免謄本
反稽核查詢
顧客滿意度</td></tr>
</table>

員工服務品質不易符合顧客需求欲提昇之工程參數 5 轉化為管理參數內容為顧客類型、員工類型、主管類型，會導致惡化之工程參數 24，轉化為管理參數內容為資訊傳遞、宣導不足、公文遺失、便民措施服務落差、專業知能不足，40 管理創新原則中朝向創新原則 3.2.17.24.26.30.13.14 思考，得到顧客類型解決方式為流程簡化、縮短時效、申訴管道、總機服務、值星服務、志工服務、引導服務、協談服務、訴願視訊服務、簡訊服務、1999 視訊服務、E-MAIL、線上滿意度、主動服務、線上申辦、線上繳費、綜合受理、表單連結、免書證免謄本、反稽核查詢、顧客滿意度、預約服務、到府服務、智慧型分流取號系統，可以提升顧客滿意度，採線上申辦 e 化服務，降低臨櫃申辦時間，現場由專人引導解說，縮短等候時間；員工類型解決方式為行政協助，職務代理，公文線上系統，掌紋簽到簽退系統、線上差勤系統、門禁管制、品管圈、提案小組、巡迴服務，透過集思廣益創意思考提升服務品質，採線上 e 化操作流程縮短工作時效，提高工作效率；主管類型解決方式為實地查證、標竿學習、溝通協調管道、職務輪調、外包制度、電子簽章、神秘客、績效評估，採取職務輪調、不易產生工作倦怠，學習績優單位的優點與巧思，提升服務與管理效能。

表 2. 改善服務品質在資訊運用方面

<table>
<tr><th>欲提昇之工程參數</th><th>惡化之工程參數</th><th colspan="6">管理創新原則【5-24】</th></tr>
<tr><td>顧客類型</td><td>資訊傳</td><td>流程簡化</td><td>標竿學習
溝通協調管</td><td>訴願視訊服務
數位化系統</td><td>掌紋簽到簽退系統</td><td>主動服務
線上申辦</td><td>預約服務
實地查證</td></tr>
</table>

員工類型 主管類型	遞 宣導不足 公文遺失 便民措施服務落差 專業知能不足	縮短時效 電子簽章	道 申訴管道 外包制度 神秘客 實地查證	簡訊服務 1999 視訊服務 E-MAIL 線上滿意度 公文線上系統	線上差勤系統 門禁管制 智慧型分流取號系統	線上繳費 綜合受理 表單連結 免書證免謄本 反稽核查詢 顧客滿意度	到府服務 職務輪調 績效評估 品管圈 提案小組 巡迴服務
		行政協助 職務代理 外包制度	總機服務 值星服務 志工服務 引導服務 協談服務				

員工服務品質不易符合顧客需求欲提昇之工程參數 9 轉化為管理參數內容為受理時間、審核時間、操作時間、解說時間、驗收時間、簽收時間、營業時間、服務時間，會導致惡化之工程參數 11，轉化為管理參數內容為應變能力、駕馭能力、危機處理、防禦能力，40 管理創新原則中朝向創新原則 28.14.6.40.38.18.12.35 思考，得到受理時間、審核時間、操作時間、解說時間、驗收時間、簽收時間、營業時間、服務時間解決方式為線上申辦 e 化服務，縮短臨櫃申辦時間，民眾在家透過網頁連線得知現場等候人數，減少現場等待時間，員工下午茶時間、員工旅遊、尾牙聚餐、心理諮商、透過集思廣益激發創意，採線上 e 化操作流程縮短工作時效，提高工作效率；主管重視員工的在職訓練與多元建議管道、激勵措施，提升員工工作士氣與管理效能。

表 3. 改善服務品質在時間與應變方面

欲提昇之工程參數	惡化之工程參數	管理創新原則【9-11】					
受理時間 審核時間 操作時間 解說時間 驗收時間 簽收時間 營業時間 服務時間	應變能力 駕馭能力 危機處理 防禦能力	戶政百年展 門牌檢索系統 線上教學 戶役政資料庫 視訊 E 到家 線上領物 薪資轉帳 電話拓充	預約服務 實地查證 到府服務 職務輪調 績效評估 品管圈 提案小組 巡迴服務	跨機關服務 聯合服務 網路票選 跨部門合作 談判協商 網路投票	AI 小秘書系統 調整薪資 調整工時 休閒旅遊 進修學習 創意團隊 情緒管理	教育訓練 激勵員工 標竿學習 在職訓練 標準作業流程 專案小組	行政協助 職務代理 外包制度
			自然人憑證 網路查詢 線上申辦	任務編組 組織氣氛 團隊合作 激發創意 組織架構		業務分工 分層負責 授權制度 職務分配 課室部門 層級節制	介面連結 專業指導 規劃服務流程 多元建議管道 激勵措施

員工服務品質不易符合顧客需求欲提昇之工程參數 29 轉化為管理參數內容為員工訓練、實地演練、組織再造，會導致惡化之工程參數 24 資訊傳遞、宣導不足、公文遺失、便民措施服務落差、專業知能不足，轉化為管理參數內容為 40 管理創新原則中朝向創新原則 13.10.2.34.7.1.24 思考，得到員工訓練、實地演練、組織再造，解決方式為任務編組、檢討機制、觀摩學習、線上教學，機關員工定期檢討任務編組是否需要重新規劃分配、同時向績優機關學習，將所學習的優點運用在機關內作業流程方面，提升員工辦事效率。

表 4. 改善服務品質在組織與資訊方面

欲提昇之工程參數	惡化之工程參數	管理創新原則【29-24】

員工訓練 實地演練 組織再造	資訊傳遞 宣導不足 公文遺失 便民措施服務落差 專業知能不足	任務編組 激勵措施 檢討機制 線上教學 網路預約	保養維修 專案規劃 年度計畫 假日服務 延長服務 彈性服務	行政協助 職務代理 外包制度 任務編組 下午茶時間 員工旅遊 尾牙聚餐 心理諮商 輔導獎勵	橫向聯繫 書表下載 線上測驗 觀摩學習 專業團隊	業務分工 分層負責 授權制度 職務分配 課室部門 層級節制	總機服務 值星服務 志工服務 引導服務 協談服務

綜合上述因應 21 世紀已邁向多元化服務，面對時代需求的多變性與人際關係的複雜性，政府部門提供的服務，應朝向客製化，同理心與解決人民的問題為依歸，政府部門服務民眾的前提是依法行政，人民提出需求後，服務人員書面審查應具備證件是否齊全外，另一項重點是申請人是否適格，兩項要素缺一不可，缺少其中一項要件，服務人員將無法為市民提供服務，市民所提出的申請無法辦理，認為服務人員刁難、沒有同理心，不便民等等抱怨，然而政府部門的服務與產品行銷實體服務性質相異性大，實體服務注重產品的品質實用性、穩定性、優質性、需求性等，而政府部門的服務注重適法性、程式性、便利性、公正力等，因此兩者主要的差別在於軟性與硬性的服務，政府部門服務人員礙於法令限制無法提供服務時，市民(顧客)既抱怨又非常不滿意，當然不符合市民的需求；服務人員對市民提供服務的前提是業務的熟稔度，應有足夠的教育訓練，定期的在職訓練與案例教育，彙整日常發生的相關案例，透過小組討論或召開會議加強宣導，增加業務處理的行政效率，在最短的時間辦好申辦事項，當服務人員業務處理流程或法令不熟，需要請求他人協助，民眾會質疑服務人員的專業，對於等待辦理的時間太長而抱怨，這種情形下當然不符合市民的需求；另一種情形是服務人員對於市民所提出的申請，在法令非常熟悉、辦事效率非常迅速、節省市民許多時間，唯一令市民不滿意的是服務態度與肢體語言，市民期待的服務是處理事務的快速正確外，期待的是親切、貼心、同理心的服務，多點關懷或多提供相關資訊，市民在最短時間內完成所需要申辦的事項，市民對於服務人員的加值服務感到滿意，這樣的服務就是符合市民的要求。

4.2 應用 TRIZ 解決員工服務品質不易符合顧客需求問題

市民對於申辦戶政業務礙於法令無法辦理，表示戶政人員的服務不能解決民眾問題，對於服務感到不滿意，法令是硬性規定無法在短期內修法，而服務人員依法辦事原則不能改變，再則服務人員對於業務與法令的熟稔度，會影響到辦事效率與服務品質，民眾期待申辦過程的快速與正確，更希望藉由服務人員在服務過程中告知更多相關權利與義務，公務部門制式化服務之下，如何應用 TRIZ 解決服務過程所發生的瓶頸，才能讓服務人員與市民獲得雙贏的服務，藉由多對多的管理參數矛盾矩陣，得出高頻率出現管理創新原則為 24,7,17,37,1,13。

(1) 管理創新原則 24 緩衝器即在物體間或動作間加一物體以利於工作進行，管理方式為總機服務、值星服務、志工服務、引導服務、協談服務，透過總機及助理分機隨時回答市民問題，巡迴值星走動式服務，志工代填書表服務，入口處引導市民臨櫃辦理，紛爭或疑難問題至戶政協談室詳談。

(2) 管理創新原則 7 巢狀結構即將物體依次堆疊或將某一物體安置在另一物體內部，管理方式為橫向聯繫、書表下載、線上測驗、觀摩學習、專業團隊，透過連結地政、稅捐、區政等免書證免謄本服務、各項業務所需表單連結下載服務、所有測驗題目線上點選測驗成績自動統計、學習績優機關或單位的優點、結合團隊力量發揮所長。

(3) 管理創新原則 17 維度改變即將事物向上調整一個維度，以利於工作進行，管理方式為標竿學習、溝通協調管道、申訴管道、外包制度、神秘客、實地查證，透過學習他機關優點用於本機關、提供協調溝通管道減少抱怨發生、提供申訴管道解決疑難問題或錯誤事情、提供電話、機具設備外包服務、神秘客隨時出現找問題、定期或不定期交叉查證作業。

(4) 管理創新原則 37 熱膨脹即利用熱漲冷縮膨脹或縮小，管理方式為激發潛能、服務熱忱、配合支援、授權

程度，透過不斷腦力激盪激發潛能、提升同理心的感動服務、政策需要員工的配合與長官的支持、主管適度授權員工職權處理。

(5) 管理創新原則 1 分割即將一種大的物體分為各小部份，卻不失其原本功能性，管理方式為業務分工、分層負責、授權制度、職務分配、課室部門、層級節制，透過相同業務分配不同人員負責處理、按業務性質難易度分屬不同層級負責、主管授權部門業務衡量職權、按專長職等分配職務、機關按業務區分課室別、機關依職等層級管理部屬業務處理。

(6) 管理創新原則 13 反其道而行即將物體或工作反向，以便於工作進行，管理方式為主動服務、線上申辦、線上繳費、綜合受理、表單連結、免書證免謄本、反稽核查詢、顧客滿意度。

5. 結論與建議

綜合上述對應高瀕率出現管理創新原則，可得解決員工服務品質不易符合顧客需求方案，其結論與建議事項分述如下：

(1) 管理創新原則 24 緩衝器，管理方式為總機 24 小時語音宣導服務、現場值星人員巡迴走動式解說服務、志工人員協助代填書表且至社區廣為宣導、引導解說相關作業流程與受理櫃台、市民對於法令有疑義或任何問題，可以透過協談機制，由單位主管級以上人員引導至戶政協談室詳談協助處理問題，並藉由總機及助理分機隨時回答市民問題，輔助戶政法令宣導不周，市民臨櫃無法辦理情形。

創新建議：原被動服務改為主動服務，中間的緩衝器是里辦公室之里長與里幹事，因為里長與里幹事與里民的關係最密切，與轄區內各里辦公室合作將相關戶政法令上傳里辦公室網頁或里幹事手機簡訊，告知里幹事透過下里服務時周知里民，統計臨櫃無法辦理之里別數最多之里，透過主管會報或區務會議時公布宣導情形，請該里加強協助宣導。

(2) 管理創新原則 7 巢狀結構，管理方式係透過連結地政、稅捐、區政等免書證免謄本服務，市民攜帶證件不齊全或其他因素不便至各單位辦理時，戶政單位即可透過介面連結查詢其他機關資料，各項業務所需表單連結下載服務，彙整所有相關業務一次可點選全部表單節省市民因不諳法令往返相關機關時間、定期舉辦法令測驗，所有測驗題目皆上傳網頁，提供同仁線上點選，測驗成績自動統計列入平時考績參考，增加同仁法令的熟稔渡、學習績優機關或單位的優點、改進機關內缺點，定期召開會議檢討改進。

創新建議：機關內定期舉辦法令測驗，所有測驗題目皆上傳網頁，除提供同仁上線測驗外，亦提供市民線上點選，測驗市民對於戶政法令知曉度，市民輸入姓名、手機號碼、E-MAIL、密碼代號等，全部答對的市民可以參加抽獎活動，每季舉行公開抽獎，得獎名單公布在網頁同時簡訊通知領獎，市民可以學習戶政法令。

(3) 管理創新原則 17 維度改變，管理方式透過學習他機關優點及創新部份用於本機關、提供協調溝通管道減少抱怨及訴訟案件發生、提供申訴管道解決疑難問題或錯誤事情、透過電話、機具設備等外包服務，節省服務人力，員工可以專心服務市民，硬體設施交由外包服務、神秘客(上級機關及戶政督導員)隨時出現找問題，定期或不定期交叉查證(區戶所)作業，隨時檢討缺失事項，將各區現場查證成績公布，做為機關改進依據，解決市民對於服務品質的滿意度與超乎期待的品質。

創新建議：神秘客建議由專家學者擔任，因為上級機關及戶政督導員及區戶所同仁彼此認識，又不願破壞彼比交情，且現場交叉查證採循環式，彼比都會輪到單位互評，就可以藉機報仇，這樣的考核機制顯失公平性，若由專家學者扮神秘客現場考核，員工不會識破具公平性，考核成績列入為民服務品質獎考核參考，列入平時稽核的項目，對於提昇服務品質具有效益。

(4) 管理創新原則 37 熱膨脹，員工透過不斷腦力激盪方式激發潛能、提升同理心的感動服務、往往一項政策的推行需要主管與員工的支持與配合、主管可以適度授權員工職權處理，創新服務可以提供超乎市民期待的服務。

創新建議：腦力激盪是公務員最不喜歡的事情，領固定薪資何必多找麻煩，員工抱持此種心態是無法創新與進步，建議首長領隊邀請專家學者或業界擔任輔導員，由三至五人組成提案小組，對於提出創新建議且經本機關或他機關採用具實質效益者，對該小組給予實質獎勵，除了考績甲等之外，可以提供出國旅遊，創新提供超乎市民期待的服務外，亦可作為礙於法令無法辦理的解套措施。

(5) 管理創新原則 1 分割，透過相同業務分配不同人員負責處理、按業務性質難易度分屬不同層級負責、主管授權部門業務衡量職權、按專長職等分配職務、機關按業務區分課室別、機關依職等層級管理部屬業務處理，一項大的業務分為各小部份，市民只要在一個櫃台即可辦理所有業務，但是戶政業務約計四十項之多，每位員工都要熟悉各項業務，除了教育訓練之外，內部業務劃分與權責分配，是協助員工快速進入業務狀況的方式，像接力戰一樣，櫃台員工單一窗口服務，後線同仁同時提供支援服務，增加業務的熟稔度。

創新建議：所有員工每年輪調職務，課室之間人員與主管互調，每位主管與員工熟悉各課室業務，亦可打破課室壁壘，主管與員工才能瞭解各課室的業務的難易度，減少員工對工作內容的抱怨，也可提升員工對各項業務熟稔度，提高辦事效率。

(6) 管理創新原則 13 反其道而行，透過管理方式為主動提供服務、推動 E 化線上申辦、線上繳費作業、表單連結、機關之間橫向連繫、運用免書證免謄本查詢、防止國民身分證偽冒辦之反稽核查詢、每季舉辦顧客滿意度調查、單一櫃台綜合受理服務。

創新建議：臺北市民 E 點通推動自然人憑證可線上申辦、線上繳費、表單下載服務，目前線上繳費方式有超商、信用卡線上繳款或郵局、銀行繳費等，但是入帳時間需要三個工作日，且收到款項後才會寄出戶籍謄本，所以市民使用線上下載戶籍謄本，有一組辨識密碼不必繳費，直接拿到使用機關使用較便利，建議市民線上下載戶籍謄本及辨識密碼，可以上傳至使用機關，由使用機關下載認證，亦可透過反稽核方式驗證是否有冒領情事，減少市民往返使用機關的時間，落實多用網路少用馬路的政策。

政府部門礙於法令規定及服務人員對業務處理流程或法令不熟，需要請求他人協助，市民會質疑服務人員的專業，對於等待辦理的時間太長而抱怨，市民對於服務人員的服務態度與肢體語言感到不滿意，市民所期待的服務是處理事務的快速正確基本條件外，期待的是親切、貼心、同理心的服務，多點關懷或多提供相關資訊，套用以上創新原則增加業務處理的行政效率與效能，得到以上解決方案與建議事項，仍應持續回饋檢查與再以 TRIZ 手法修正，以達完美最佳結果。

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Peer review assists editors in making editorial decisions and, through editorial communications with authors, may assist authors in improving their manuscripts. Peer review is an essential component of formal scholarly communication and lies at the heart of scientific endeavor.

Promptness

Any invited reviewer who feels unqualified to undertake the task or knows that a prompt review will be impossible should immediately notify the editors and decline the invitation so that alternative reviewers can be contacted.

Confidentiality

Any manuscripts received for review are confidential documents and must be treated as such. They must not be shown to or discussed with others under any circumstances. This applies also to invited reviewers who decline the review invitation.

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Reviews should be conducted objectively and observations formulated clearly with supporting arguments. Personal criticism of the authors is inappropriate.

Acknowledgment of sources

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3. Duties of Authors

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Authors of original research should present an accurate account of the work performed and the results, followed by an objective discussion of the significance of the work. Review articles should be accurate, objective and comprehensive, while editorial 'opinion' or perspective pieces should be clearly identified as such. Fraudulent or knowingly inaccurate statements constitute unethical behavior and are unacceptable.

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Authors should ensure that they have written and submit only original works, and if they have used the work and/or words of others, that this has been appropriately cited. Plagiarism takes many forms, from "passing off" another's paper as the author's own, to copying or paraphrasing substantial parts of another's paper (without attribution), to claiming results from research conducted by others. Plagiarism in all its forms constitutes unethical publishing behavior and is unacceptable.

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