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Forward & Executive Report

On behalf of the Organizing Committee of the 5th International Conference on Systematic Innovation (ICSI), we are pleased to report that the conference presents 66 papers in the field of systematic innovation. The authors and non-author participants are from 18 countries - even though some authors from Africa and middle-east countries failed to get the American visa to enter the USA. There are also 27 projects from 7 countries participated in the associated Global Competition on Systematic Innovation. At the end, 20 projects enter the final round of presentation and can be witnessed in the presentations.

This conference is organized by The Society of Systematic Innovation (SSI) and the Journal of Systematic Innovation (IJoSI). Whether the papers included in the proceedings are work-in-progress or finished products, the conference offer their authors an opportunity to disseminate the results of their research and receive early feedback from colleagues, without the long waiting 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 form for publication in a special issue on Systematic Innovation of the Computers and Industrial Engineering or an issue of the IJoSI.

The organizers are indebted to a number of people who gave their time and efforts to make the conference a reality. The list of organizations and working team contributed tremendous to this conference are acknowledged at the end of this program brochure. In particular contributions of the local host, ISE depart of the San Jose State University coordinated by Professor Jacob Tsao, the College of Engineering, the International TRIZ Association, the Altshuller Institute of TRIZ Studies, and the Bay area Chapter of IIE are noted.

The conference is annual and international. The 6th ICSI and 5th GCSI will be in Hong Kong during July 15-16, 2015. 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. In addition, you are cordially invited to join the Society of Systematic Innovation. There are many benefits associated with the membership. For details, please see the "Call for members" flier included in your participant package. From next year on, members of the society will enjoy the author rate of which the savings will already more than twice the annual membership fee – not to mention other membership benefits.

Again, thank you for your participation. Enjoy the rich program this ICSI/GCSI have to offer.

With best regards,

D. Daniel Sheu, Ph.D., MBA, CMfgE (sheu.daniel@systematic-innovation.org)
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Paper List

Part 1. Full Papers in English

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

Paper ID: 05

Using Psychological Assessments to Improve TRIZ Problem Solving

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Abstract

TRIZ never enters into an organization in a vacuum. There are existing processes, approaches, and attitudes among its potential users. These factors must be taken into account in optimum use of TRIZ.

Many organizations use various psychological assessment tools, primarily for individual and career counseling. They are rarely used for effective team building and almost never used in an integral fashion with problem solving efforts. People are different. They think, behave, and relate to each other in very different ways. Some are introverts, some are extroverts. Some solve problems with the box of what they know while others prefer and excel at making disparate connections. Some are concerned about the impact of problem solving on the bottom line while others care about the effects on people. Many prefer deadlines, schedules, and agendas while others prefer to keep the door open and provide flexibility for changing events. All of these preferences can be measured very accurately and used pro-actively in problem solving activities.

This presentation will overview these various styles and their importance in TRIZ problem solving

Keywords: Social style, problem solving style, team formation

Many TRIZ problem solving teams are assembled based on personnel availability, technical expertise, and appropriate knowledge of the necessary TRIZ tools. These are basic requirements, but they do not take into account that people are different in their social and problem solving styles. These factors can significantly affect the output of a team. It is possible to measure and use these characteristics in a pro-active way in a TRIZ problem solving session.

When a team is assembled to utilize TRIZ as a problem solving process, it is normal to identify subject matter experts and possibly “parallel universe” experts in similar technology areas as well as TRIZ experts knowledgeable in the aspects of TRIZ that are anticipated to be used. However, there is often little thought given to the personal styles of the individuals are how they relate to each other in the process of team interaction.

There are two basic types of individual styles that characterize how individuals interact with each other as well as how they problem solve. Conflicts in these areas can have significant effects, both positive and negative, on the productivity and output of a TRIZ problem solving team. The first of these areas is personality style, most often measured by a psychological assessment instrument known as the Myers Briggs, though various variations and improvements have also been developed. They all measure a person's style in four different ways. The first is the tendency toward extroversion or introversion. We all know people who are very quiet and introverted and are difficult to draw into a conversation or discussion. We also know people who "take over" a conversation, not allowing anyone else to contribute. The second of these characteristics is the manner in which a person assesses and takes in information regarding a problem, described as "sensor" or "intuitor". The sensor does this very analytically, concentrating on facts and data or indirectly in the sense of effects and impacts of these physical aspects. The "feeler" sees indirect aspects and impact. An example would be someone seeing a leaf as "green" or "light and fluffy". The third characteristic is how a person digests and analyzes input data. Is the primary concern the technical effects ("thinker" or the effects on people ("feeler")? For example, a cost reduction effort could be analyzed with its effects on an organization's financial health or its impact on the individuals who may be downsized or their salaries reduced and the indirect effect on their families. The last of these characteristics is the preference toward deadlines and closure on activities (a "judger") vs. leaving possibilities open ("perceiver").

Let's look at the other aspect that characterizes a person's behavior and preference in problem solving. This is measured by an assessment instrument known as the Kirton KAI™. At one extreme are those individuals who prefer to use proven solutions, take little risk, and prefer structure in their approach to problems and solutions. At the other extreme are those individuals who have a tendency to express and try ideas and concepts that may not be proven, enjoy risk taking, and are perfectly comfortable with unstructured situations and solutions. They also have an ability to combine concepts and ideas across multiple areas of science and technology. This assessment is characterized as "adaptive" on one end to "innovative" at the other. And of course there are many people in the middle.

Let's consider the impact of varying the type of participant in a TRIZ session. If we were to include only social introverts and strongly "adaptive" in a session, what is the likelihood that there will be open sharing of ideas and the willingness to consider "parallel universe" suggestions from a TRIZ facilitator? Though not impossible, it will be very difficult for the TRIZ expert to motivate such a group for a productive outcome. Let's also consider the opposite. If everyone is a social "extrovert" and are full of their own ideas, control of the session will be very difficult and managing the idea output, as well as staying within the structure of the TRIZ algorithm, will be challenging.

If we measure and have knowledge of these characteristics ahead of time, they can be used in a pro-active way at appropriate times. For example, in the use of TRIZ software, pictures or descriptions of invention examples from parallel universes are shown in an attempt to stimulate ideas. Analogic thinkers are frequently thought of as non-creative, but these are exactly the kind of people most likely to make appropriate connections that others cannot see.

If a facilitator is aware of the ratio of extroverts to introverts, a pro-active plan can be made to draw ideas out of the introverts. If it is important to analyze facts and data relating to a TRIZ problem, and the group is primarily made up of "intuitors", this will present a barrier and probably slow the process down. On the other hand, if a potential breakthrough TRIZ solution will possibly have major effects on the people within an organization, then "sensors" may be oblivious to this and when implementation plans are made, unanticipated resistance may sabotage the intended result.

These are just a few examples of the possible effects of different social and problem solving styles on the effectiveness of a TRIZ session. If these styles can be assessed prior to a session, it can be made much more effective and less stressful.

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Paper ID: 06

Analogies: Why Can't We See Them

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Abstract

The Key to TRIZ problem solving is the ability to take a general problem solving algorithm and apply it to our own problem. A subset of this is the ability to see a solution to a similar problem and apply it in different circumstances. These challenges have both a technical and human side to them, both of which we will discuss.

Keywords: Analogies, problem solving style, barriers to solutions, ARIZ

The ability to see and recognize analogies is an inherent trait that varies with individuals. It is a characteristic that is possible to measure with psychological assessment tools, the most famous of which is the Kirton KAI adaptive-innovative index. The application of TRIZ problem solving algorithms and standard solutions require that the user of these tools in a problem solving session be able to relate a more general solution path to their own problem and to be able to relate a specific solution to a similar problem outside their technology area to their won.

There are many versions of the ARIZ algorithm that are used by TRIZ problem solvers and the ARIZ algorithm is the basis for most of the commercial TRIZ software in use today. In essence a user of TRIZ is expected to generalize their problem (similar to the generalization of quadratic equations in algebra) and then look for where this general type of problem has already been solved. Some of the more sophisticated TRIZ software also provides a mechanism to search the web in real time looking for analogies in functional terms; other TRIZ software has pre-selected examples from the patent literature to accomplish the same result. The success of these approaches, as well as the general acceptance of the TRIZ approach to problem solving, depends on the belief that there are a limited number of problem solution paths. Why is this so difficult for people to do? I propose two simple reasons, both of which I have observed in my TRIZ training and consulting work over the past 12 years.

The first is simple ego. This is the single most important variable in determining the success of TRIZ acceptance. If a problem owner truly believes that they are the only person who has ever encountered such a problem, the likelihood of their accepting any process based on generalizing the problem solving literature is slim to none. How do we observe such an attitude? One is the excessive use and reliance on very unique and obscure words and acronyms, reinforcing the belief that the problem to be solved is unique and that no one could possibly have dealt with such a thing before. The use of acronyms is frequently justified on the basis that they shorten the number of words needed to communicate a thought or phrase, and that is often true. However, the use of acronyms must be modified and their use curtailed when using a tool such as TRIZ. This is a switch that is difficult for many people to turn and off at the appropriate time. The use of obscure words, however, is a clearer sign that problem owner is trying to make their problem more unique than it really is. A classic example of this was, during a TRIZ session with the Bank of Montreal, a problem with “defalcation” was needed to be solved. This is an actual word used in the banking industry and it means more generally, “fraud”. If we do a web search under these two words, we find an order of magnitude difference in ideas and areas to review. If however, we use our TRIZ brains and generalize the problem to be “the substitution of one thing for another”, this opens up another order of magnitude worth of ideas in a web search for where this occurs and where and how people and businesses do this. The ability of a problem owner to generalize their problem (my approach is to describe the problem to a ten year old) is far more difficult than it first appears. Sometimes the barrier is ego, but more often it is the simple inability to think outside the bounds of a multi-year career and education in a specialty area.

The second barrier is the technical ability to link parallel uses and applications. There are many people for whom this is very difficult. And the further away the parallel universe is, the more difficult is the challenge. For example, the practice of planting lemon trees around orange groves to prevent apes from eating the oranges is exactly the same solution to the problem of preventing cavitation in ships by allowing an ice barrier to form. Someone from either of these industries, not able to see analogies, would not be able to see how either solution would apply to them.

People who are very good at seeing analogies are frequently not perceived as creative, since they are building on others’ work and ideas. This is an erroneous and unfortunate perception, especially when it comes to TRIZ problem solving. This capability can be measured very accurately by an assessment instrument known as the Kirton KAI™. This assessment is characterized as “adaptive” on one end to “innovative” at the other. Excellent analogic thinkers can be accurately identified with this assessment. If the ability to use this assessment is lacking, other means of identifying good analogic thinkers are:

1. Ask a participant how many uses for their current product there are that have not been commercially developed. If someone can only mention a few, then they are not strongly analogic.

2. Ask a participant what else their most recent patent could be used for. Again, if many ideas surface, the analogic thinking skill is high.

The recognition of the importance of analogic thinking capability during TRIZ problem solving is very important. The ability to generalize both problem models and apply parallel universe solutions can make the difference between a good TRIZ session and an outstanding one.

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Paper ID: 19

A User Interface Technology Foresight Study with Scenario Planning Approach

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Abstract

While the importance and value of Innovative User Interface (IUI) have gradually being realized worldwide, user interface related technologies and the priority of adopting these technologies have so far not been clearly recognized. To fill this gap, this paper focuses on the technology planning strategy of organizations that have an interest in developing or adopting IUI related technologies.

Based on the scenario analysis approach, a technology planning strategy is proposed. In this analysis, thirty user interface related technologies are classified into six strategic clusters, and the importance and risk factors of these clusters are then evaluated under two possible scenarios. The main research findings include the discovery that most brain–computer interface (BCI) related technologies are rated high to medium importance and high risk in all scenarios, and that scenario changes will have less impact on voice based as well as gesture based IUI technologies. These results provide a reference for organizations and vendors interested in incorporating emerging user interface related technologies.

Keywords: innovative user interface, scenario analysis, technology portfolio, strategy

1. Introduction

The term "user interface" refers to the methods and devices that are used to accommodate interaction between artificial devices and the human who use the devices. The user interface of a mechanical system, a vehicle, a ship, a robot, or an industrial process is often referred to as the human–machine interface. In an industrial control system, the human–machine interface can be used to deliver information from machine to people, allowing them to control, monitor, record, and diagnose the machine system through devices such as image, keyboard, mouse, screen, video, radio, software, etc.

User interface technologies are diverse and numerous. The main stream of development currently includes eye tracking (Kondou and Ebisawa, 2008; Mamatha and Ramachandran, 2009; Muensterer et al., 2014), touch screen (Nilsson, 2009; Browne and Anand, 2012; Cuin and Honkala1, 2013; Broll et al., 2013; Neira et al., 2013; Tesoriero et al., 2014), brain-machine interface (Ferreira, 2007), voice based (Chua et al., 2003), gesture based (Kurita and Nishikubo, 2009) and context–aware interface (Mascarenas et al., 2013).

The user interface industry can be considered to include vendors of technologies, products and services that enable users to access other products, resources and services. User interface technologies have a major impact on the products, services and business models of the IT software and hardware industries. User interface has therefore become the emerging science and technology that has drawn the most attention from the IT software and hardware industries in the wake of mobile computing era. The broad scope of the industry, as well as the fact that it spans both the enterprise and consumer markets, has led to much discussion on its future business potential as well.

Presently, major IT firms worldwide are exploring possible business opportunities in the user interface generated market. However, what is the scope of user interface technologies? And what are the possible outlooks in terms of the importance as well as the risks of these technologies? These key questions need to be answered before one can have confidence in the accuracy of technology strategy planning. To assist IT vendors moving forward in the emerging user interface market, this research aims to explore possible planning strategies for adopting or developing user interface related technologies. To achieve this objective, a systematic approach of scenario analysis followed by technology strategy planning is conducted.

2. Literature Review

Various research works have been done in this filed. This study investigates six types of user interface technologies. In the following, research highlights of each category of UI technologies are elaborated. The listing of literature is not intended to be exhaustive, but rather to provide chronological progress, major breakthrough, and recent status of each category.

2.1 Voice based User interface technology

This category of UI technology enables computing devices to receive, interprete and respond to human voice or natural languages. Takao et al. (2002) provide unique concepts called acoustic user interface to co-ordinate and communicate more effectively multimedia information. Chua et al. (2003) propose a design solution of integrating both voice and data communications wireless applications, such as mouse, headset and data port, into a single device based on Bluetooth technology. The results show that the new mouse design is introduced to reduce the data rate needed for the mouse through wireless link.

Rodger and Pendharkar (2007) investigate database communication issues peculiar to users of a voice activated medical tracking application. The study exams the impact of gender, speech speed, user's technical experience and their interactions, on the performance of speech recognition system in a mobile field environment. The results indicate that the user's gender and computer experience has a significant impact on the use of voice interface as an input to a medical database of patient signs and symptoms in a mobile healthcare fieldwork environment.

Chleborad et al. (2013) evaluate the voice-based data entry to an electronic health record system for dentistry by comparing three methods of storage data of the patients in the field of dentistry, including the paper dental card, a lifetime dental health record controlled by keyboard and a lifetime dental health record controlled by voice. The results indicate that the paper dental card is the most rapid method, but not the best for medical documentation and dentists.

2.2 Visuals based User interface technology

Visuals base UI technologies deal with the utilization of human vision and eye activities to interact with computing devices. Morimoto and Mimica (2005) presents a review of eye gaze tracking technology, including the requirements for constant system calibration and very limited head motion. According these review, the conclusions showed that eye trackers were laboratory instruments, and many intrusive techniques could be tolerated.

Kondou and Ebisawa (2008) propose a precise head-free eye-gaze detection method with easy calibration. The experimental results show that the eye gaze precision is improved by using the moving target, rather than by using the two points on the screen. Sawahata et al. (2008) use eye-gaze tracking method to investigate the relationship between the viewer's comprehension of a program and their gaze direction in a real experimental TV educational program. The results show that the variances of the gaze direction for scenes that gave better comprehension tended to be lower.

Mamatha and Ramachandran (2009) propose an automatic face orientation interpretation system for vision-based eye-wink control interface to benefit the severely handicapped people. Experimental results have illustrated improved performance of the proposed methods in terms of both accuracy and speed.

Leuthold et al. (2011) use eye tracking technologies to compare the influence of different navigation designs, including vertical and dynamic menus, and task complexity, including simple and complex navigation tasks on user performance, navigation strategy, and subjective preference. The results show that the vertical menus fit better to perception and cognition than dynamic menus, and navigation systems should be extended with different kinds of navigation items adapted to the complexity of the users' navigation tasks.

Li and Mao (2012) build the framework for Emotional eye movement generation based on Geneva Emotion Wheel for virtual agents. The results showed a higher rate of recognition of the agent intended emotion. Ramakrisnan et al. (2012) evaluate user interface design of Leaning Management System by analyzing student's eye tracking pattern though the gaze plot and heat map. The analysis from the student's eye tracking pattern indicated some interface design issues in Leaning Management System.

Wu (2012) review the representative theory of interactive behavior, eye tracking technologies and related studies to discuss the utilizing of interactive teaching and integrated application in technology has revolutionized ways of teaching and learning. The results indicate that the eye tracking technique can be expected to link directly together with computer and apply the immediate feedback to the learners, or teachers.

Jowers et al. (2013) explores the potential of eye tracking as a Computer-aided design interface for a two-dimensional sketch editor. The results are positive and indicate the potential for eye tracking as an interface for supporting shape exploration in Computer-aided design. Rashid (2013) assessed three Occupational Safety and Health websites namely DOSH, NIOSH, and OSHA using eye tracking system and both subjective and moderator ratings. The results show that the eye tracking data together with user feedback has help reveal the cognitive process. Vela´squez (2013) introduces eye-tracking technologies for collecting and processing data originated by web user ocular movements on a web page. This eye-tracking tool can improve the effectiveness of the current methodology for identifying the most important web objects from the web user's point of view.

Muensterer et al. (2014) look forward to evaluate the next generation Google Glass device and provide feedback to help with the future development of a specialized Glass for tomorrow's medical and surgical community.

Wang et al. (2014) use eye-tracker to track the eye-movement process for investigating how website complexity and task complexity jointly affect users' visual attention and behavior due to different cognitive loads. The results show that task complexity can moderate the effect of website complexity on users' visual attention and behavior.

2.3 Tactile based user interface technology

This category of technologies provides human interactions with devices through touching interfaces. Wu et al. (2011) compare the direct-touch and mouse input for navigation modes of the web map by using two-way analysis of variance (ANOVA) to determine the six types of operational performance. The results show that the mouse performed remarkably better than the touch screen in terms of task completion time in all of the navigation modes.

Browne and Anand (2012) investigated the effectiveness and enjoy-ability of three user interfaces used to play an iPod Touch scroll shooter video game. The empirical results show that the accelerometer based interface was the preferred interface and the interface in which participants performed best.

Irwin and Sesto (2012) evaluate performance and touch characteristics of individuals with and without a movement disorder during a reciprocal tapping touch screen task, where the outcome measures include number of correct taps, dwell time, exerted force, and impulse. The results indicate that the non-disabled participants had 1.8 more taps than participants with fine motor control disabilities and 2.8 times more than those with gross motor impairments.

Rydström et al. (2012) compare two contemporary types of in-car multifunctional interfaces, including a touch screen interface and an interface maneuvered by a rotary control. The simulation results show that both interfaces affected the lateral control performance, but lateral control performance deteriorated to a greater extent when the touch screen interface was used.

Radhakrishnan et al. (2013) compared the performance of two finger touch-based interaction techniques, including drag state finger touch and track state finger touch, and a standard mouse device for 3D computer aided design modeling operations. The results indicated that both the task completion time and error rates are statistically the same for both the finger touch-based techniques. The mouse device outperformed both the finger touch-based techniques and yielded statistically better results in terms of task completion time and error rates.

2.4 Gesture based user interface technology

Gesture based UI are innovative technologies originated from gaming devices. This category of technologies employs sensing devices to detect, recognize and predict human hand, arm or body movement. Nilsson (2009) presents the collection of user interface design patterns for mobile applications. One important finding indicated that the patterns collection is best suited for experienced UI developers wanting to start developing mobile UIs.

Kurita and Nishikubo (2009) propose a non-contact technique for the measurement of human hand motion for applications human-machine interface. This technique can be used to detect the difference of electrostatic induction current, and the direction and velocity of subject's hand movement.

Alvarez-Santos et al. (2014) present the gesture-based interaction with voice feedback for a tour-guide robot. The guide robot was successfully tested in several real world environments.

2.5 Brain based user interface technology

This category of technologies aims at transforming human brain activities into instructions for conducting devices. Ferreira (2007) presents a Human-Machine Interface (HMI) based on the signals generated by eye blinks or brain activity. In the experiments, a robotic wheelchair is used as the device being commanded. The HMI system was tested by volunteers who could command a robotic wheelchair after about five minutes of training.

Tonet et al. (2008) introduce a method by matching interface performance with device requirements for pointing out effective combinations of interfaces and devices for creating real-world applications.

Coffey et al. (2010) overview of brain–machine interfaces approaches and explore suggestions for space applications. The study suggests that the performance limitations of current Brain–machine interfaces may reflect the incomplete information of non-invasive signals rather than merely a lack of maturity of the technology. Iáñez (2010) describes a spontaneous non-invasive electroencephalography based brain–machine interfaces. The results show that the efficiency and accuracy with six users have been evaluated making different experimental tests. Lee et al. (2010) propose a new brain computer interface method combined with eye tracking for 3D interaction to analyze depth navigation, including selection and two-dimensional gaze direction. The results indicate that the feasibility of the proposed 3D interaction method using eye tracking and a brain computer interface.

Leeb et al. (2013) transfer brain-computer interfaces beyond the laboratory, and application control for motor-disabled users. The results show that all participants who achieved good BCI performances could also control the applications successfully. Úbeda et al. (2013) describe a Shared control architecture based on RFID to control a robot arm using a spontaneous brain–machine interface. In this study, a six degrees of freedom robot arm with a gripper attached on its end effector is controlled using an spontaneous brain–machine interfaces to perform pick and place operations. The results show that four volunteers have successfully controlled the robot arm.

Vourvopoulos and Liarokapis (2014) evaluate the commercial brain–computer interfaces in real and virtual world environment. The results indicate that robot navigation through commercial brain-computer interfaces can be effective and natural both in the real and the virtual environment.

2.6 Context based user interface technology

Context based UI technologies make use of possible sensing and recognition of context information to interact with devices. Perrin et al. (2010) propose a novel semi-autonomous navigation strategy designed to minimizing the user involvement. The results show that the navigation strategy is successfully tested both in simulation and with a real robot for low throughput interfaces.

Mascarenas et al. (2013) explore a new paradigm-cooperative human-machine structural health monitoring. The premise of this paradigm is the idea that a human cooperating with a machine will always significantly outperform a machine or human acting independently. Cuin and Honkala1 (2013) experimented with integration of Web-based social networking services into mobile devices' main user interface. The results indicate that it is feasible to construct an alternative device UI that supports integration of Web content across applications and services via hyperlinking.

Broll et al. (2013) investigate the design, usability and user experience of multi-user interactions on dynamic Near Field Communication (NFC)-displays, and evaluated the performance of dynamic NFC-displays, interactions among users and the interplay between mobile devices and large displays. Neira et al. (2013) propose an Adaptive Human Machine Interfaces (HMI) Builder to incorporate in most of the Android devices in the market.

Tesoriero et al. (2014) propose a novel solution that combines social software with context awareness to improve users' interaction in public spaces, such as mobile devices and RFID.

3. Research Method

▪3.1 Scenario Analysis

Scenario Analysis (SRI, 1996) has been used in various domains for analyzing and forecasting trends in the development of technology. Many versions and variations of the SRI scenario analysis methods have been proposed (Mietzner & Reger, 2005). The technology portfolio planning process (Yu, 2006) is a systematic procedure used to assist in the strategic decision necessary to find the cluster set of resource allocations among available technologies that best fits the goal of an organization. Scenario planning is a key technique used by futurists to develop future models in order to facilitate this process and to develop strategic action plans and policies, as well as create a vision for the future (Erdogan et al., 2009).

The major steps of the technology strategy planning process are as follows (Bishop et al., 2007).

1. Identify decision criteria, which are the motivational forces for the resource allocation decision.

2. Propose possible future scenarios by exploring combinations of significant impact variables.

3. Compose a set of technology alternatives and classify them into clusters.

4. Generate a set of technology assessment indicators from mutually exclusive dimensions.

5. Find the best plan for a technology portfolio.

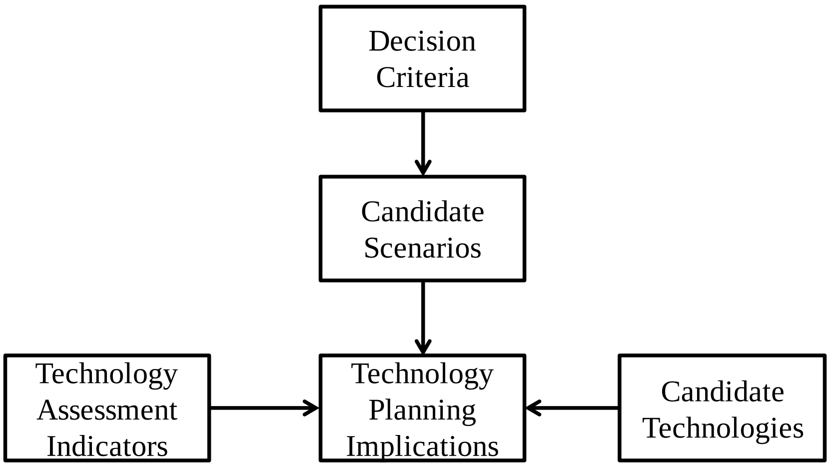

Figure 1. Research Framework of a Technology Foresight study.

▪3.2 Expert Panel

To conduct the technology foresight study, an expert panel was formed with eleven domain experts selected from both the IT industry and the academic world. This expert panel consisted of the following members:

1. Three consultant managers of publicly listed IT services firms.

2. Four CEO and VP level executives of independent software vendors.

3. Two R&D managers of publicly listed IT device manufacturers.

4. Two project managers of publicly listed telecom operators.

A facilitator led the expert panel discussion sessions by following the steps in Figure 1 above. Activities in these sessions included open discussions, anonymous voting, as well as the administration of surveys.

4. Result

▪4.1 Decision Criteria

To identify decision making criteria, expert panel discussions were conducted concerning decision making factors from the social, political, economic and technological perspectives. Possible decision factors were discussed, such as the market outlook for a technology, as well as the competence of the industry to acquire this technology. The final set of indicators is summarized in Table 1.

Table 1. Major decision factors

Decision factors	Issues
Social factors	1. Availability of cloud services for quality of life improvement for general public
Technological factors	1. Entrance barrier level of user interface technology 2. R&D strength of the local industry
Economic factors	1. Strategic benefit of the enterprises adopting cloud technologies 2. New business opportunity for the local industry
Political factors	1. Strength of user interface industry promoting policies of government

▪4.2 Candidate Scenarios

There are many different scenario alternatives which organizations may select for user interface technology trends. Impact variables which are most likely to affect the scenario development were identified by the expert panel. Through evaluations from different combinations of these variables, final choices of scenarios were then determined. After the Expert Panel discussions, the scenarios were labeled and elaborated upon. The results are illustrated in Table 2.

Table 2. Candidate Scenarios

Scenario Code	Global IT Spending Outlook	UI Technology Breakthrough	Vendor Competition Level	Final Scenario Choice and Naming
000	High	High	High	Big Demand
100	Low	High	High	
010	High	Low	High	Slow Progress
110	Low	Low	High	
001	High	High	Low	
101	Low	High	Low	
011	High	Low	Low	
111	Low	Low	Low	

A detailed description of the scenarios is as follows.

1. Scenario 000: Big Demand

In the Big Demand scenario, the foreseen global economic situation is strong, and the worldwide IT spending outlook is in good shape. At the same time, with the progress of continuous research in both industry and academia, the development of user interface technology is experiencing a major breakthrough.

2. Scenario 010: Slow Progress

In the Slow Progress scenario, the foreseen global economical situation is strong, and the worldwide IT spending outlook is in good shape. However, the progress of academic and industrial user interface technology research and development is slow. As a result, potential users may relocate their resources to other areas with more promising technologies.

▪4.3 Candidate Technologies

To assess the possible user interface Analytics technologies for the proposed scenarios, another technology expert panel of ten members was formed. This panel differed from the previous panel. The purpose of a different expert panel was to assure independence between technology planning activities. User interface technology data were collected by interviewing these panel members, as well as from secondary data which included vendor propositions and research literature. The final list of the most promising user interface technologies is exhibited in table 3.

Table 3. Candidate User interface Technology

Cluster	Technology
Voice based UI (VO)	VO1: Voice recognition VO2: Voice synthesis VO3: Natural language processing VO4: Audio display VO5: Acoustic user interface
Visual based UI (VI)	VI1: 3D visualization and 3D printing VI2: Eye tracking VI3: Video streaming VI4: Eye gaze based interaction VI5: Infographics
Tactile based UI (TC)	TC1: Touch screen technology TC2: Finger-based multitouch interface TC3: Wearable computing TC4: Fingerprint interface TC5: Haptics feedback technology
Gesture based UI (GS)	GS1: Hand and arm gesture interface GS2: Hand recognition interaction GS3: Gesture and motion based gaming GS4: Data glove technology GS5: Motion capture technology
Brain based UI (BR)	BR1: BCI (brain-computer interface) BR2: EEG (electroencephalogram) applications BR3: Brain-robot interface BR4: Neural network technology BR5: Steady State Visually Evoked Potentials (SSVEP) applications
Context based UI (CT)	CT1: Facial tracking CT2: Virtual reality CT3: Multimodal interaction CT4: Augmented reality CT5: Perceptual user interface
Total items	30

4.4 Technology Assessment Indicators

The expert panel on technology then applied the scenario analysis approach to assess the candidate user interface technologies of the six major clusters in two dimensions: importance and risk. These two dimensions are quantified by selected indicators summarized in Table 4.

Table 4. Technology Assessment Indicators

Dimensions	Indicators	Low Level	Medium Level	High Level
Importance	Compound annual growth rate of global market size for the next 5 years	< 10%	10%~20%	> 20%
	Global user	< 10%	10%~60%	> 60%

Dimensions	Indicators	Low Level	Medium Level	High Level
	adoption ratio			
Risk	Compound annual growth rate of local production value for the next 5 years	> 10%	10%~5%	< 5%
	Local R&D over revenue proportion	> 9%	9%~3%	< 3%

4.5 Technology Planning Implications

Based on the important indicators and risk indicators in Table 4, the expert panel assessed the user interface technologies compiled in Table 3 with respect to the four scenarios. The assessment results are exhibited in figures 2-3 and discussed as follows.

1. Technology Planning Implications for Scenario 000: Big Demand

For the Big Demand scenario, the assessment outcome is depicted in Figure 2. In this scenario, the gesture based (GS) UI technologies would be of high importance and low or medium risk in general. This is mainly because the gesture based UI technologies, based on the development of gaming devices, mobile devices and location based services, are becoming popular on new mobile devices as well as wearable devices, and have a large base of users worldwide. Also note the brain based (BR) UI technologies are positioned in both high importance and high risk. Though these technologies are viewed as the big opportunity for the IT industry, these technologies are also new and highly competitive to most enterprises, and the adoption of them is considered highly risky.

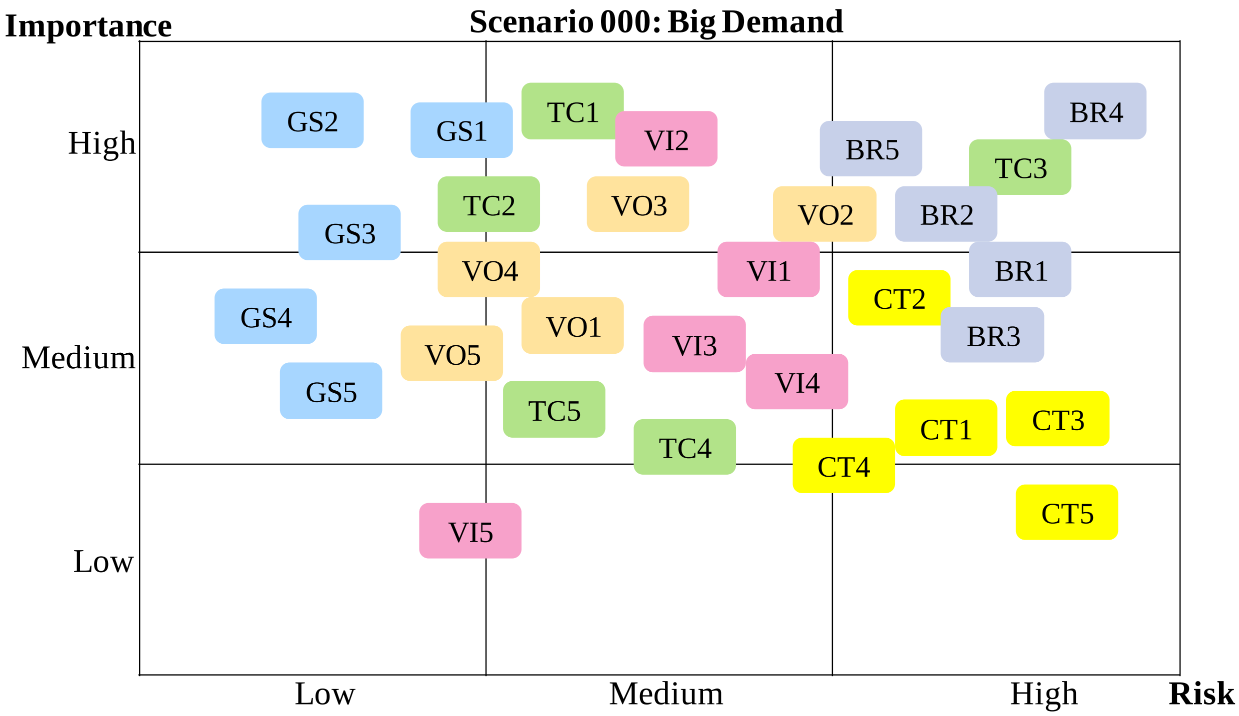

Figure 2. Technology assessment for Scenario 000: Big Demand

2. Technology Planning Implications for Scenario 010: Slow Progress

For the Slow Progress scenario, the assessment outcome is depicted in Figure 3. In this scenario, the risk of most technologies would increase in general compared with the Big Demand scenario. The context based (CT) UI technologies, based on the development of context computing model, would have decreased importance. In general, the visuals based (VI) UI technologies would also have lower importance, due to the possible slow advancement of 3D technology development.

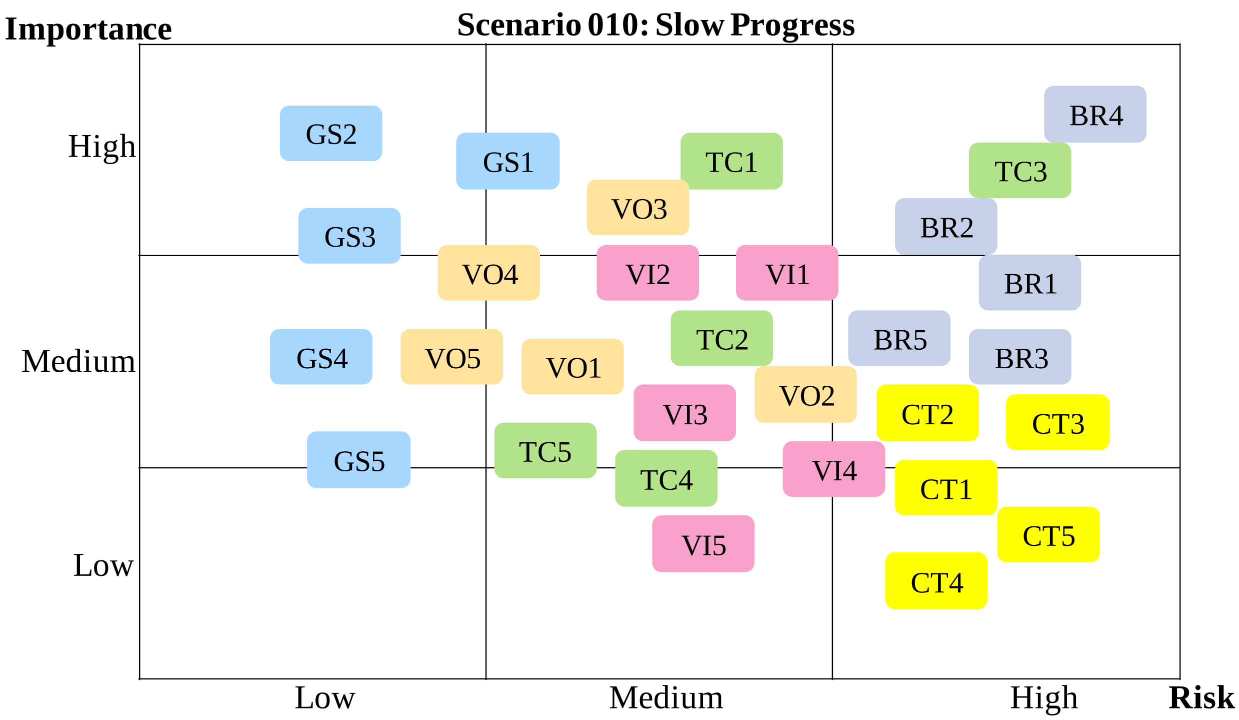

Figure 3. Technology assessment for Scenario 010: Slow Progress

5. Conclusion

In this study, a systematic approach geared towards deriving foresight towards possible user interface technology developments over the next five years was conducted. Highlights of the research findings are summarized in Table 5. Based on these results, the strategic thinking of an organization toward developing or adopting user interface technologies for competitive advantages can be initiated. For example, these findings suggest that voice based (VO) and gesture based (GS) UI technologies should have a higher priority for organizations in the pursuit of new market opportunities.

Table 5. Results and Implications

User interface Technology Cluster	Result	Implication
Voice based UI (VO)	Voice based UI technologies are mainly of medium importance and medium risk. The importance rating will have slight decline in Slow Progress scenario.	If the progress of technology development is slow, users will tend to stick with the traditional non-voice solutions, and be more cautious about adopting these technologies.
Visual based UI (VI)	Most visual based UI technologies are rated low to medium importance and medium risk in both	These technologies are mainly dominated by global major retail marketing vendors. It is considered more risky for the local industry to compete with major players for the

User interface Technology Cluster	Result	Implication
	scenarios.	market opportunity.
Tactile based UI (TC)	These technologies are rated medium to high risk in general. Smart-phone, tablet and wearable devices are the key adopting devices of the technologies.	Smart-phones and tablets are currently the two most popular mobile user devices with ongoing market opportunity. Wearable devices are viewed as the next big thing in IT industry. However, the high competitiveness of the market is also highly risky.
Gesture based UI (GS)	These technologies are rated low risk in general. They are also rated medium to high importance in both scenarios.	Integrating gesture computing, mobile app, location based service and social media, these technologies represent application software of a new era. Innovative applications are evolving with opportunities.
Brain based UI (BR)	These technologies are of medium to high importance and medium to high risk. The importance ratings drop slightly in the Slow Progress scenario.	The demand of these technologies depends on the maturity level and feasible applications. The global major device vendors also play dominant role in brain based UI technology development.
Context based UI (CT)	These technologies are rated medium to low importance and high risk in general.	Users of these technologies are mostly innovative device and service developers. The high risk reflects the monopoly power of global major vendors in these technologies.

On the other hand, vendors interested in exploring the market opportunities of user interface technologies can use the analysis framework and outcome of this research as a reference for their strategy planning, thereby avoiding many unnecessary trial and error marketing efforts. In particular, with a clear picture of the user interface technologies scenario analysis, vendors can better position themselves for the most suitable market sector in terms of importance and risk.

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TRIZ-BASED PLATFORM FOR SOFTWARE SUPPORTED INNOVATION

Section III: Computer – Aided Innovation

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Abstract

Among the main reasons for the slow dissemination of TRIZ are the following:

- Long learning curve
- Complexity of tools and methods of their utilization

The long learning curve is necessitated by the large amount of knowledge that must be acquired from various sources and through substantial practice before becoming a successful practitioner. TRIZ has many tools of various degree of complexity, yet there are no clear rules as to which tools should be applied to a particular case. Typical TRIZ knowledge includes numerous examples and illustrations (learned from instructors and accumulated from one's own experience) and other (mostly tacit) knowledge about how to successfully utilize TRIZ methods and tools.

The first attempt to facilitate utilization of TRIZ was made by G. Altshuller in the mid-1960s when he built an electromechanical version of the Contradiction Matrix with the 40 Innovation Principles. The first ideas for utilizing a computer for TRIZ-based inventive problem solving occurred back in the 1970s . Since then various software packages have been developed, mostly converting various TRIZ tools into electronic format and offering limited value as they still required substantial TRIZ education for effective use. Others offer ways to search for information with various degree of effectiveness [1 - 6].

New approach to TRIZ computerization was introduced in the early 1990s. It was based on the following considerations.

1. The computerization is a part of the automation of human activity. Studies in the history of automation show that the most common mistake in the automation process is the attempt to build machines that copy the human ways of operation. For example, the first locomotives had "legs," the first sewing machines had "hands," etc. History has shown that attempts such as these do not succeed; real success comes only after the old technology (process) is replaced with one that has been invented with automation in mind. In the case of the sewing machine it was the invention of a needle with the hole in the sharp end and the use of two threads instead of one.

2. There are two main issues in every computerization attempt: a) the existing process that has to be computerized and b) available software developer tools. These two issues are connected like two communicating vessels: the clearer and better defined the process, the less sophisticated software tools are necessary for its computerization.

Given the above, the new approach was focused on substantial restructuring of existing multiple TRIZ processes and tools originally created for mental utilization and development of new ones to ensure successful computerization and thus facilitating mass utilization of TRIZ [7, 8].

Keywords: TRIZ, systematic innovation, knowledge base, operator, software, computer programs, knowledge management.

Analytical and Knowledge-based tools of TRIZ

Classical TRIZ[1] included the following set of tools:

1. 40 Principles & Contradiction Matrix
2. Separation Principles
3. The System of (76) Standard Solutions
4. Effects
5. Patterns/Lines of Evolution
6. Selected Innovation Examples
7. Substance-Field Analysis
8. ARIZ

The first step in restructuring TRIZ was dividing all tools into three groups:

- Knowledge-based – tools offering knowledge extracted from patents and other sources of information representing the best innovation practices (1-6 from the list above).
- Analytical – tools helping to analyze the initial problem situation and formulating directions for solutions (Substance-Field Analysis).
- Combinations from the first two groups (ARIZ).

This understanding of the existing tools' nature helped identify the main directions for improvement:

- Integration of existing tools to avoid confusion caused by their multiplicity

[1] *TRIZ developed during the 1946-1985 period.*

- Development of “missing” analytical tools to provide complete support of all steps in the problem-solving process, including problem definition and formulation.

One of the results was development of two new analytical tools: Innovation Situation Questionnaire® and Problem Formulator®. The other results included development of the System of Operators – an integrated knowledge-based tool.

Integrating and structuring TRIZ knowledge base

Historically, various TRIZ knowledge-based tools such as the 40 Innovation Principles, the Separation Principles, Effects, and others were developed as independent tools [9, 10]. The expectation existed that older tools would eventually be replaced or absorbed by more advanced and effective tools (such as a complete System of Standard Solutions). As a result, in 1980s many TRIZ schools practically stopped teaching the 40 Innovation Principles providing only brief information about this tool.

Later, it became apparent that excluding the 40 Innovation Principles from a practitioner’s “toolbox” had a negative impact on one’s practical problem-solving abilities, primarily due to the fact that the older tool had its own advantages, like simplicity. Also, several very effective recommendations from the 40 Innovation Principles were not included in the System of Standard Solutions (for example, “transformation of harm into a benefit”). On the other hand, simple reinstating all 40 Innovation Principles would result in duplication, because in many cases similar recommendations were included in different tools.

All of the problems mentioned above have been resolved through the development of an integrated operational knowledge-based tool (System of Operators) that includes all recommendations contained in the 40 Innovation Principles, System of Standard Solutions, Utilization of Resources, etc. This new System should work with any problem model known in TRIZ: Technical Contradictions, Physical Contradictions, Substance-Field models, etc.

It is also interesting to note that the original Principles were much more specific than the 40 Innovation Principles known today. Many of them had adaptations to specific characteristics they were intended to deal with. For example, the Principle “Segmentation” for the purpose of weight reduction differed from the “Segmentation” used to reduce dimensions [11]. Later, Altshuller withdrew such specifics from the

Principles, apparently for the sake of universality and compactness of the Contradiction Matrix. However, this “detailization” can now be reconsidered in the light of the possibility of utilizing computers.

Besides “picking up” (selecting for use) an Operator based on a particular characteristic, it would be useful to do this based on the type of drawback involved or on a desired function. Providing such “entrances” to the System of Operators requires that the Operators be classified according to their possible application. For this, a complete redesign of all existing Operators (Principles, Standard Solutions, etc.), making them much more detailed and specific, can be achieved. This work has been started by Lev Pevzner [12] and proved to be extremely useful. Such “detailization” can be accomplished in two ways: through segmentation of the existing Operators (from the top down); and through the generalization of illustrations associated with each Operator (from the bottom up).

The first TRIZ knowledge-based tool – 40 Innovation Principles didn’t have any structure – just a set. To offset the lack of structure, Altshuller has created Contradiction Matrix to allow selecting from one to four principles from the set for a particular pair of parameters in conflict. The next knowledge based tool – seven separation principles didn’t require any structure because their number was rather small. There were several attempts to increase the number of innovation principles (within TRIZ and outside [13]) with limited or no success, mainly because extended number of principles required certain structure to help with their utilization.

The System of Standard Solutions was the first knowledge-based tool with a structure corresponding with SF-models and certain problem-solving and innovation needs. At the same time, a need to build SF-model prior to selecting an appropriate group of solutions substantially limited its effectiveness as it required extensive training. In addition, this tool was lacking the technical language typical engineer was used to.

Based on the considerations above, a general list that included all Operators derived from the existing Principles, Standard Solutions, Lines of Evolution, etc. was developed. After excluding instances of duplication, a preliminary structure of the Operators was suggested as follows:

Table 1 Main groups of Operators

Group name	Area of application	Example
Universal	Any	Inversion
Semi-universal or General	Wide	Increasing function efficiency
Specific (i.e., specialized)	Narrow	Increasing convenience

Later, several additional groups were introduced:

- Auxiliary (smart introduction of substances and fields)
- Selected patterns/lines of evolution

Table 2. Structure of the System of Operators

Group name	Sub-group name (number of purposes/specific factors were applicable)[2]	Number of Operators	
		Direct	Associated[3]
Universal	Inversion	3	
	Integration	3	
	Segmentation	5	
	Partial/excessive action	4	
Semi-universal (general)	System synthesis (3)	9	
	Increasing effectiveness	8	
	Eliminating harmful effects (6)	30	
Specialized[4]	Improve useful features (12)	91	100+
	Reduce an undesired factor (18)	148	150+
	Improve a system for management/ control (3)	23	25+
Auxiliary	Introducing substances (11)	41	45+
	Introducing fields (3)	18	8+
	Utilization of resources (7)	38	60+
Selected patterns/lines of evolution	Increasing Ideality	12	100+
	Building bi- and poly-systems	16	
	Segmentation	4	
	Developing substance structure	4	
	Dynamization	5	
	Increasing controllability	10	10+
	Universalization	4	6+
	Matching/mismatching	4	

[2] *More detail list is out of scope of this paper.*
[3] *These Operators are linked to the direct ones allowing the user to follow the chains for further detalization of possible solution.*
[4] *Altogether 94 parameters/special purposes, including utilization of various effects*

Altogether about 400 Operators have been created (some are not included in the count above, for example over 60 direct and associated Operators for resolving contradictions). Apparently, this number can be effectively utilized once stored in professional full scope software[5]. Another structure was suggested for a simplified software or "mental" use.

Using contradiction as a structure for Operators

The following is a well-known TRIZ statement: if one has a difficult problem, one has faced a contradiction. A typical contradiction in most cases could be graphically described on Fig. 1[6]:

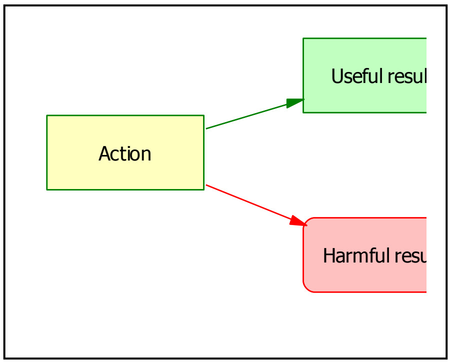

Fig.1. Graphical depiction of contradiction

This graphical depiction of a contradiction is quite convenient because it can be utilized for both types of contradictions known in TRIZ: technical and physical:

- Technical contradiction: An action creates an improvement (useful result) but also causes deterioration (harmful result).
- Physical contradiction: An action should be provided to achieve useful result and not provided to avoid harmful result.

Traditionally, classical TRIZ provides two knowledge-based tools to address the above: a set of several Innovation Principles (from the list of 40) and Separation Principles (4 to 7). However, vast experience of numerous TRIZ practitioners has shown that no matter how desirable it could be, not every contradiction can be resolved, especially when the given system is on its maturity stage and resources for further development within the existing paradigm are practically exhausted [14]. At the same time, it doesn't mean that the situation cannot be improved. Based on the graphical model shown above, the following typical directions for solutions could be identified:

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[5] *Innovation WorkBench® software. See more at www.ideationtriz.com*
[6] *Suggested by Alla Zusman in late 1980s. To a certain extent, the underlined idea was similar to the concept of Key element suggested by Boris Goldovskiy in 1970s.*

1. Find a way to eliminate, reduce or prevent Harmful result under conditions of the given Action.
2. Find an alternative way to obtain Useful result that doesn't require the given Action (meaning, the associated Harmful result doesn't take place).
3. Find an alternative way to the given Action that provides the Useful result and doesn't cause the Harmful result.
4. Resolve the contradiction: the given Action should be provided to produce Useful result and shouldn't be provided to avoid Harmful result.

From the list above, three groups of Operators could be identified: Elimination, Alternatives and Resolution.

For each group, a set of Operators is suggested as in Table 3.

Table 3 Simplified set of Operators

Elimination	Alternatives	Resolution
• Remove/modify the source of harm • Modify harmful effect • Counteract harmful effect • Protect the subject of harm • Increase the resistance to harm • Eliminate the effect of the harm • Convert harm into benefit • Exclude the subject of harm	• Modify existing way • Mobilize internal resources • Increase effectiveness of the action • Change the principle of Operation • Find additional benefits	• In space • In time • Between the parts and the whole • Based on different conditions

This structure and the limited number of Operators make it easier to memorize and thus to become an element of TRIZ way of thinking in addition to a number of universal Operators and the main TRIZ concepts like Ideality, Contradictions, Resources, System Approach and Patterns/Lines of evolution.

The first extensive knowledge base and new process was developed for Inventive Problem Solving (IPS) [15].

Complete Innovation Platform

IPS is only one of the existing innovation needs. To address all needs and develop a complete innovation and problem solving system suitable for computerization the following steps have been taken:

1. Identifying all needs related to problem solving and innovation and development of a comprehensive set of applications that will address these needs.

2. Development of computer-aided processes for each application.

This approach resulted in development of the following applications and corresponding knowledge – based tools and supported by the family of TRIZ-based software (TRIZSoft®) [16]:

Table 4 Complete Innovation Platform and corresponding knowledge- based tools

Application name	Short description	Knowledge-based tools
Inventive Problem Solving (IPS)	Solving difficult problems and improvements in technical and non-technical areas.	• System of Operators • Innovation Guide (collection of physical, chemical and other effects • Collection of Illustrations
Anticipatory Failure Determination (AFD)	Pro-active process for analyzing, predicting and eliminating failures in systems, products, and processes.	AFD checklists: • Ways to produce harm • Operators for failure prevention/ elimination
Directed Evolution® (DE)	Predicting next generations of products, services and technologies via inventing and developing a comprehensive set of scenarios describing future generations of a system.	• Patterns and lines of evolution (12 patterns and over 500 lines) • Bank of evolutionary alternatives (futuristic concepts for various industries).
Control (Management) of Intellectual Property (CIP)	Evaluation and Enhancement of Intellectual Property (IP) related to proprietary technologies, inventions, patents and patent portfolios	IP checklists: • Invention evaluation (over 35 parameters) • Invention enhancement

Conclusions

1. To facilitate TRIZ dissemination abound the world, computer support becomes an essential productivity tool.
2. Historical attempts to develop software tools were mostly converting various TRIZ tools into electronic format and offering limited value as they still required substantial TRIZ education for effective use.
3. New approach to computerization undertaken by the authors has resulted in restructuring existing and development of new analytical and knowledge-based tools embedded into various professional software packages. Simplified tools could be utilized mentally and/or utilizes via abridged software tools.

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A Semantic-interactive Model and Application in the field of Computer-Aided Inventive Problem Solving

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Abstract

Most Computer-Aided Innovation (CAI) software has integrated various innovative tools in the process of solving inventive problems. However, most designers, particularly new hands, are frustrated about which tool they should choose to finish the design work. To solve problems, this paper has analyzed the application of various innovative tools, and has proposed a semantic-interactive model for solving inventive problems in the computer-aided innovative design process .This model consists of four phases: problem description, problem analysis, problem solution, and solution formation. System recommends different tools in each phase. The type of problem is basically determined during the interactive dialogue between the system and designer. Based on the types of problems, each phase recommends innovative tools for a corresponding problem, that the user can choose from to complete the construction of problem models and obtain the final solution by assessing the solution. Our project team has completed the software system based on the this model. The proposed software system although still at a prototype. At last the operation process of the system was demonstrated by an example to verify its integrity and feasibility.

Keywords: CAI, Interactive, Inventive problem , Semantic , Innovative tools.

1. Introduction

The emergence of computer-aided innovation software system helps designers to develop new products and to correctly analyze and solve problems in the technical domain. Computer-Aided Innovation (CAI) was developed more than ten years ago and has enjoyed striking growth since then. Currently, a lot of institutions, both home and abroad, are engaged in the study of CAI systems. Furthermore, quite a few software systems based on CAI have been developed, such as Goldfire by Invention Machine, CREAX Innovator Suite by CREAXNV-Mlk, Pro/Innovator by IWINT, and InventionTool3.0, InventionTool-net, InventionKnowledgeCloud developed by Hebei University of Technology. Most of these kinds of software cover a wide range of applications.

Most of the software systems integrate a variety of auxiliary innovative tools in the process of invention problem solving. Such auxiliary tools include problem analysis tools such as Root-cause analysis, Resource analysis,etc, and problem solving tools such as 40 Inventive Principles, Effect, Standard solutions, etc. The presence of such a large variety of tools makes most of the designers, especially beginners, confused in the case of choosing the right tool for their innovative design process. (S. Ahmed, 2004)(S. Ahmed,2007)Since the designers sometimes fail to grasp the characteristics of the problems correctly, they do not know which auxiliary tool would be most suitable for solving the particular problem. This paper analyzes various problem solving tools, and presents a semantic-interactive problem solving model to help designers to solve inventive problem.

2. Semantic-interactive problem solving process model

▪2.1 Innovative tools introduction

TRIZ is a problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature designers who try to solve the invention problem, are required to get familiar with and master the different aspects of TRIZ theory. The following detailed analysis sums up the main characteristics and applicable situations of part of innovative TRIZ tools.

(1) Root-cause analysis

When faced with a technical issue that involves many factors, the designers often do not know how to deal with it. The key of the analysis is to rationalize the causes of the issue, mining internal and external resources of system and to find the most effective solution to the scheme. Root-cause analysis provides a powerful method for the exploration of the cause of the problem.

(2) Ideality analysis

Idealized solution is the one where in the beginning of problem solving, the designer lays down various objective constraints, defines the problem in terms of an ideal solution, and makes clear the direction and position of the ideal solution. This method avoids the disadvantages of lacking goals in the traditional innovative design approach and enhances the efficiency of innovative design. In general, the tool is often used for determining the initial solution target and physical contradiction.

(3) Component analysis

With the help of component analysis tool, designers analyze technical systems and build functional models to understand the system. With analysis we can identify significances in the current system and define the existing problem in it. The tool effectively reveals and solves the existing function problems and their corresponding component problems in the technical system, thus paving the way for further enhancement and improvement of those functions.

(4) SuField analysis

SuField analysis is an important tool for problem description and analysis in the theory of TRIZ. It is a type of function model to establish contact with existing systems or to tackle new technical problems. According to the problem described by the model of SuField, we can find general and standard solutions corresponding to TRIZ theory. It is applicable to solve problems of function improvement.

(5)Nine-windows analysis

Nine-windows analysis tool takes into consideration not only the current scenario and the explored problem, but also their position and roles in the aspect of hierarchy and time. We can view the explored problem as a set of interrelated issues, and can acquire a more comprehensive understanding about it.

(6) Functional analysis

This tool analyses the system from the perspective of system abstraction, including the status of execution or completion of its function. There exist many schemes that perform the mapping from function to structure. Through optimizing and screening this mapping, we can draw the best solution. The function analysis tool is mostly used for problems dealing with function solving. (Gao C,2006)

(7) Contradiction matrix

When using the contradiction matrix to solve problems, we must first determine the technical contradiction pertaining to specific problems, and then describe the two parameters used by the standard technical contradiction. After the contradiction matrix is computed, the inventive principles may then be finalized. The advantages of this approach are that it has a simple form, is easy to use, and can provide a fair amount of contradiction resolution. But we must confirm the system contradiction using 39 engineering parameters to describe the contradiction. So taking advantage of the contradiction matrix solution method is appropriately suitable for the problem to facilitate technical contradiction with 39 engineering parameters described above.

(8) Separation Principles

The core idea of solving the physical contradiction is to realize the separation of the two sides of contradiction. Typically there are four forms of separation principle: Spatial separation, Time separation, Separation based on conditions, and Global and local separation. However, a prerequisite for applying separation theory to a system is that the physical contradiction has been identified. Therefore this method is suitable only for the problem of clear physical contradiction.

(9) 76 Standard Solutions

76 Standard Solutions is powerful tool for solving SuField model, a model that describes the problem model of a system. Considering SuField as the problem model and Standard solutions as the intermediate tool, a solution model can be obtained that can be considered the standard result to the system. Using this method, one can analyze the problem structurally. While different new concepts can be analyzed easily with this system, the flip side is that the designers need to have a strong engineering background of related issues. Generally it applies to solving the problems of new concepts generated by the existing design scheme.

(10) Effect

Effect is a knowledge-based tool in TRIZ. The relevance between the effect and product can be used for determining the theoretical solution to the product design. As a tool for problem solving, Effect has been applied in various fields. However, it also requires that the users have a sound background of knowledge and are generally acquainted with the process of solving the problem.

2.2Model summary

Using qualitative analysis and garnering a comprehension of the innovation question is a valuable method to improve the efficiency of solving the inventive problem. The alternative approach is to choose the corresponding TRIZ theory for solving the problem. Problem expression forms are diverse, and therefore the methods of solving the problem are also varied. And the most important factor is to distinguish the problem properties of technical systems and the root causes of problems. According to the parameter properties of problem, structure and resource attribute, the problem model of TRIZ question can be divided into four forms: technical contradiction, physical contradiction, SuField and knowledge enable problem.

The process of solving a problem can be divided into four stages based on ARIZ algorithm (ALTSHULLER G，1999): problem description, problem analysis, problem solving and solution formation. At each stage, different innovative tools are recommended for the user. In the process of interaction between the system and designer, at first the type of the problem is determined, then the corresponding tools are recommended to the user for analyzing the problem and to complete the structure of the problem model. In the next step, the concept program can be obtained by using the corresponding tools based on the different problem models, and then the plan can be finalized after a comprehensive review. Figure1 shows the structure of the model.

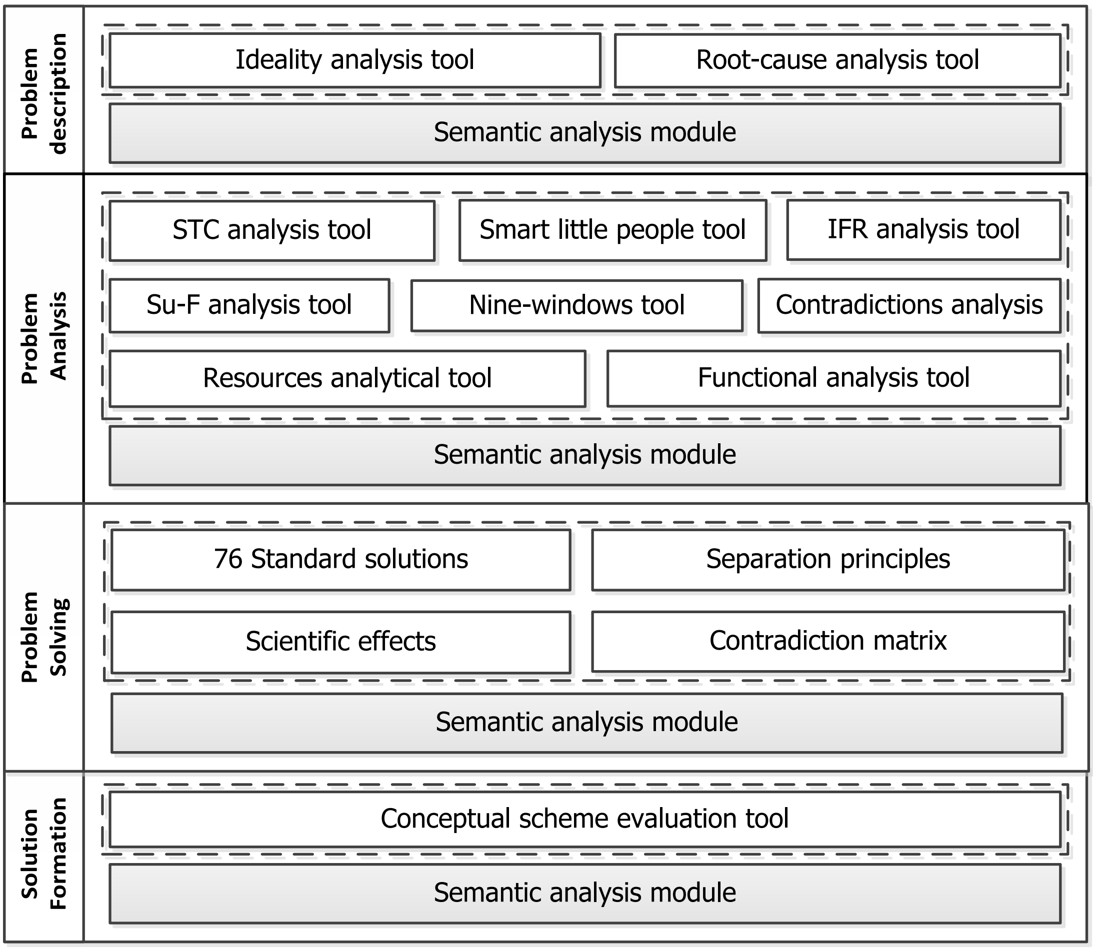

Figure 1. semantic-interactive problem solving model.

(1) Problem description

Inventive problem solving is developing the process toward determining "cause of the problem" and "direction to solve the problem". Therefore, the following steps should be performed:

a. Analyze problem situation and describe the main problem.

b. Describe the ideal goal of solving the problem

c.Identify the core problem

System recommended designers use causal analysis tools, the use of which is to find the root of the problem, i.e. to help designers to find the true problems hidden behind the surface problem. Through the analysis of the core problem, it can be divided into three types: function improving type, the system development imbalancing (parameter modified) type, function solving type. By interacting with the system, designers can determine the type of the problem. If the problem blongs to function improving type, the system will lead the designer to use the component analysis tool or functional analysis tool. If the problem belongs to system development imbalancing or parameter modified type, system will lead the designer to the contradiction module. On the other hand, If the problem belongs to function solving type, system will lead designer to function analysis tool. If designer is still not clear about the problem, system will lead him into problem analysis phase.

(2)Problem analysis

The main goal of problem analysis phase is to convert the initial state of a fuzzy problem into a clear standard model of the problem through the use of problem analysis tools.

a. System analysis

Designers analyze the system components using fishbone diagram tool. Then they use component analysis tool to analyze the technical system and set up function model to understand the system. And through this analysis, they try to find out the shortcomings of the current system, and define the problem functions existing in the system. The system will then lead the designer to the appropriate tools suitable for the problem

b. SuField analysis

If the problem belongs to function improving type, designers can also use the component analysis tool to analyze the technical system. The component analysis tool detects the harmful or defective features of the system, and takes them into account while building the SuField model. Then it steps into the problem solving stage, using 76 standard solutions to improve its function. If a suitable solution is not obtained, system boot is applied for contradiction analysis.3) Functional analysis

The designer can use functional analysis tool when the problem belongs to the function solving type. On the basis of the technical requirements for the target, the designer analyses system, subsystems and components from the perspective of completing functions. In the process the designer carefully researches every function if necessary, to see whether contradiction occurs in any function, and then determines the types of contradiction. If there is no contradiction, then we can proceed to get the specific design requirements; otherwise if there is contradiction, the system leads to the contradiction analysis section.

c. Contradiction analysis

If the problem belongs to system development imbalancing or parameter modified type, system will lead into contradiction analysis. In this phase, the following steps are performed:

i. Technology contradiction description: Designer can describe the technology contradiction of TC1, TC2 from two aspects (positive and negative) and then using SuField analysis tools can set up graphic models of contradiction of TC1 and TC2 respectively. Then he may select the contradiction that is more important to the main function of the system.

Designers describe the contradiction according to the technical contradiction description format and determine the improved characteristics and degradation characteristics, and then map them to 39 engineering parameters. It will forward the contradiction to the problem solving phase retrieval tools, to obtain the corresponding principles and example, and also the concept scheme. If designer is not satisfied with concept scheme, he can directly enter the next step.

ii. Use STC tools to sharpen contradiction. Strengthen the contradiction by setting system parameter to limit state.

iii. Assuming that the introduction of X resources can solve the contradiction, state the functions of the resources.

iv. Turn to the SuField analysis tool for searching standard solutions.

v. Define contradiction zones and time.

vi. Use nine-windows tool to define the available resources.

vii. Using the idealized analysis tool to define the ideal solution, describe the physical contradiction.

viii. Try to use the SuField analysis tools to solve physical contradiction.

ix. Using the method of little-man tools or available resources, develop analytical tools to

(3) Problem solving

The phase target of solving problems is forming a preliminary concept scheme. Aiming at the former formation model, we should use appropriate tools to solve the problem. Separation principle solves physical contradiction, invention principle solves technology contradiction and 76 standard solutions solves the material-field model. Knowledge enable problem can search for the effect of library. Then, the concept of the problem solution is obtained. If the concept scheme is not satisfactory, the problem can be described and analyzed again. Otherwise, the stage for forming the solution is entered.

(4)Solution formation

The goal of this step is forming the final solution. Designers use scheme evaluation tools to manage and filter the conceptual scheme, to delete an unreasonable solution, to choose a way of evaluating scheme, and in the end select the most suitable conceptual scheme and final solution. There are three default standards for evaluating the scheme: with minimum resources, minimum time and minimum cost. The user can define the evaluation standard according to the actual need. This step requires the user to input the proportion of time, resources and cost, and the system outputs the final plan ordering according to the ratio. If the end evaluated solutions is feasible, you can select generate text report and fill all documents of the entire solution process and compile detailed content of the solution. At the same time, you can add solution to private or shared knowledge base to improve the mobility and reusability of knowledge. Otherwise, if the plan is not feasible, you can reiterate the whole process or withdraw the process altogether.

2.3 Semantic analysis module

Natural language understanding is an important part in man-machine dialogue system, its task is to analyse users' colloquial input, and understand the purpose of the user and extract the key information. In this paper, the concept of semantic framework is applied to solve the problem of natural language understanding.

Since it is difficult to directly describe the problems, it is done through a series of questions in each tool. Each of these tools is a semantic framework that is used to integrate the many parameters that need to be filled in. Figure2 shows the instance to explain.

Following are some example questions:

a. What is the main feature of the system?[*PF*]

b. What are the system components?[*COM*]

c. What are harmful functions?[*HF*]

d. What are the components associated with the harmful functions?[*HC*]

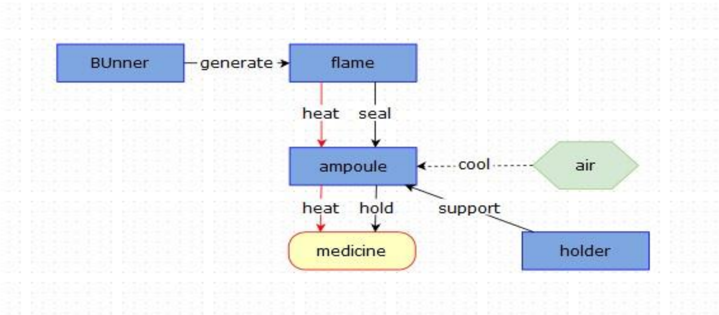

Figure 2.Components analysis diagram.

The above questions are related to component analysis tool, the tool that is used to answer questions and draw the component function diagram. First designers answer the questions that are put forward by the system, and draw functional diagram of problem function component Then the system extracts parameters from the structured description provided by designers, or directly obtain the parameters from image analysis in the tool, such as [*COM*], [*HF*], etc. In the last step, the tool gets results through initial semantic understanding of the parameters. An example of such a result is: harmful effect is "heat", exists in heating process of the ampoule on drug.

3. Engineering Applications

Let us look at an example of using the system in a real-life engineering scenario. At the early stage of the development and utilization, most of the forest biomass raw materials need to be crushed for further processing and handling. For this a grinder needs to be designed, whose grinding particle size is below 1 mm, and productivity is above 1 t/h. After inquiry and investigation, it is found that there is no grinder products that can meet the requirements above. The existing hammer grinder usually consists of the body, motor, the rotor hammer mill, hammer and screen mesh., Using high speed rotating hammer knife in the crushing room to blow and cut the materials, it discharges qualified granularity of materials through the screen mesh. The main problems with this structure are: grinding particle size is too large (most are above 10 mm), productivity is low, and hammers wear out quickly with short service life. So its design needs to be improved. (Fu M,2010)

3.1 Problem Description

a. Main problem: effectiveness of grinding materials is poor.

b. Ideal goal: under the premise that the complexity of the system should not be increased, the material can be crushed to the qualified granularity (1mm).

c. Core issues: The core issue obtained by using the root-cause analysis tools is that materials formed circulation which hindered speed of hammer. Simultaneously, due to centrifugal force, large particles of the material are close to the screen mesh, causing the low granular materials to screen down as time passes. Figure 3 is the root-cause analysis diagram.

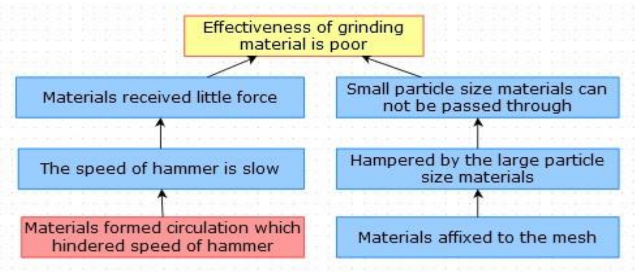

Figure 3 .Root-cause analysis diagram.

3.2 Problem analysis

a.System Analysis

Name of the system: Grinder.

Function of the system: Crushing material.

Components of the system are materials, hammers, screen mesh and crushing chamber. Use component analysis tools to create component function diagram. As can be seen, the harmful effects are between the materials and the hammers, and the materials and the screen mesh. Then by interacting with the designer, the problem is determined as an issue of function improvement. Therefore the system recommends using the SuField analysis tool. Figure 4 is a diagram of components analysis.

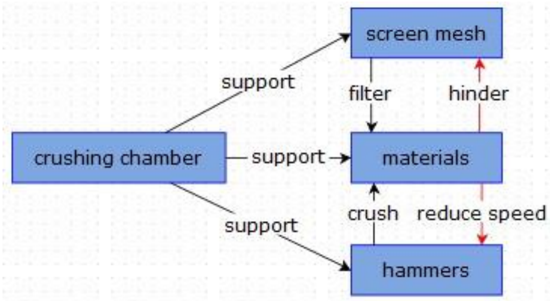

Figure 4 .Component analysis diagram

b. SuField Analysis

By establishing the material - field model, shown in Figure 5, the deficiency of the force from hammer S1 to the material S2 can be seen, and three conceptual proposals can be obtained by applying the second type of standard - "reinforcements of material - field model" in the standard system. Designers are not particularly satisfied with these three proposals, so the system recommends the designer to use the contradiction analysis tool.

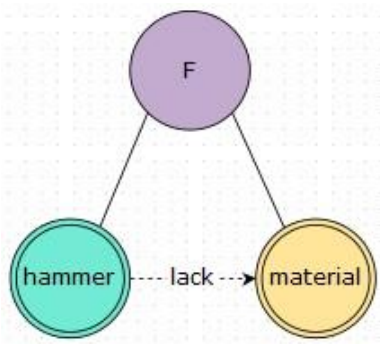

Figure 5 .SuField analysis diagram

c. Contradiction Analysis

i. Technical contradiction description:

TC1: If the tool is arranged in high density, the material can be crushed to very small particles, but the system complexity will be increased.

TC2: If the tool is arranged in low density, the crushed material is not qualified, but the manufacture process is easy and costs less.

Determine the main technical contradiction. Select the technical contradiction which is closely linked to the main function of technological systems to resolve the problem. The main purpose of this system is that the material can be crushed into a desired granularity, therefore the technical contradiction *TC1* is selected.

ii. Intensification of the contradiction: pointing out the limitations of the component's function. Tool array density is very small (only one tool), but capable to crush material very fine.

iii. An element *X* must be found that can maintain high density of tool array, and is capable to crush material very fine (idealized analysis).

iv. Describe the time and region of the contradiction:

1. Determine the operating areas: The contact point between the tool and material. Generally, the operating area is defined as the place where the contradiction in the problem model arises. General operating area is defined as the place where the contradiction arises.

2. Determine the operating time: Operating time includes the time of the occurrence of the contradiction (machine running, crushing job), and the time before the occurence of the contradiction (pretreated material, feeding time).

3. Determine the SuField resources of the technical system, the external environment and the target object. The resource list is shown below in Table 1.

Table 1. List of available resource.

Available resources	Material resources	Field Resources
Tools	Hammer	Mechanical field
System Components	Materials 、Rotor	Mechanical field
Specific Environment	Wind 、Air 、Heat	Thermal field 、Wind field
Super System	Grinding Chamber	

v. Mobilization and use of the SuField resource SFR: Establish a "villain" model. The left part of Figure 6 below shows the villain model of the current system. Because of the high speed of the circulation layer, the material is posted on the screen wall, the hammers chase after the material, resulting in insufficient effective crushing. The right part of figure 6 shows improved villain model of the system, each material is surrounded by the hammer villains, the effective crushing is improved.

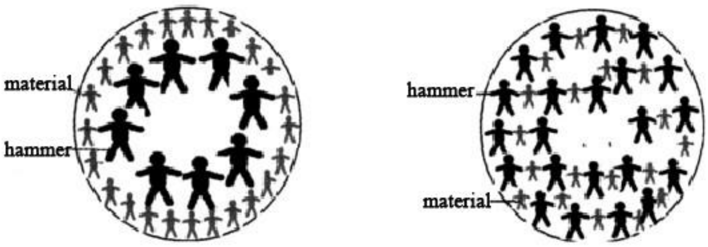

Figure 6 .Smart little people analysis diagram

3.3 Problem solving

We finally retrieve three solutions based on the Substance-field model that are formed from the step just described.

a. According to the 15th standard solution, in Figure 7, the useful function F1 is not so powerful, so another field ought to be added to enforce F1. Now follow the 1st conception solution: use the wind power to transport, accelerating the speed of qualified materials through the sifter.

Figure 7

b. According to the 17th standard solution, in Figure 8, enhance the dispersion of the substance achieving tool-function. Now follow the 2nd concept solution: make the granulating-chamber full of cutters in order to install the cutter in the bottom of the screen.

Figure 8

c. According to the 21st standard solution, in Figure 9, transform uniform physical spatial structure into the nonuniform physical spatial structure, conceive the 3rd conception solution: using granulating-chamber of irregular shape such as elliptical shape, or using granulating-chamber in water-drop shape instead of in circular shape, destroy the material layer, and enhance the effectiveness of crackdown.

Figure 9

3.4 Solution formation

Using the analysis of the system, and making a synthesis of the three solutions that were generated, we can finally come up with a solution to the problem:

The double screen's hole size is made smaller, solving the problem of larger particles going through in the screen single layer structure.

Wind is used to convey qualified materials, which increases the relative velocity of material and cutters, thus enhancing the effectiveness of crackdown to materials. In the bottom of the inside screen install the cutter that has assistant effect in cutting. it is the existent of cutters in the bottom that destroys the high-speed circulation layer of material.

Material between two layers can be acquired in regular intervals, and can be sent back to the granulating chamber for repeated crushing. This structure of double screen can also be used to produce products with two different size requirements.

4. Conclusion

Based on the analysis of the way various innovative tools are applied, this paper proposes the semantic interactive computer aided inventive problem solving process model. The model includes four stages: problem description, problem analysis, problem solving, and solution formation. Each stage recommends different innovative tools to the designer. Due to the complexity of practical problems, it is impossible to make a totally correct description of the problem. Designers can use this model iteratively to achieve in-depth analysis and to transform the problem definition gradually, until the ultimate solution of the problem is found.

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Research on Construction and Reasoning of Semantic Web for Topic-based Scientific Effect Knowledge

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Abstract

This article has studied the meaning of scientific effect knowledge through the application of this knowledge in innovative design, and proposes an organization method of topic-based scientific effect knowledge by introducing the topic concept and combining the function expression method of natural language and function ontology. In this paper, we extract and classify the concepts and the relations between them according to the topic, and construct a semantic web of scientific effect knowledge based on ontology. The innovation of our approach is to elevate these concept property to the semantic level based on ontology, and associates all original single-chained and semi-structured knowledge to form a bidirectional associated multi-level knowledge web. On this basis, we construct the semantic inference rules necessary for reasoning to realize the extension and screening of function and flow, and then to diverge and converge the solution space of effect. In the end, using an example demonstrates that the structure and method can realize cross-field semantic retrieval and various relationships between knowledge based on different topics, and realize the sharing and reuse of scientific effect knowledge.

Keywords: ontology, scientific effect knowledge, semantic inference rules, semantic web, topic-based

1. Introduction

The effect is a knowledge-based tool of Theory of Inventive Problem Solving (TRIZ) (Altshuller G.S, 1999), which assists the design of innovative products. The main source of the effect knowledge of TRIZ is patents. However, innovation typically draws from effect knowledge belonging to different fields and professions, which makes its use and mastery by designers challenging. Therefore, there is an urgent need to facilitate more effective search to help designers better leverage existing scientific effect knowledge to realize product innovation.

There has been a lot of research, foreign and domestic, aimed at the topic of effect knowledge organization and retrieval for product innovation. The alternative approach is based on function ontology and TRIZ theory. This approach is most widely used forms the bases of today's computer aided innovation (CAI) systems. Researchers at the Sichuan University of China have explored a coreference index knowledge retrieval model, which has resulted in a great improvement in Chinese knowledge retrieval, but this model lacks breadth of applicability and is effective only on a specific form of effect knowledge retrieval and association. The most well-known CAI systems include Goldfire (developed by Invention Machine), CREAX Innovator Suite (developed by CREAXNV-Mlk), Pro/Innovator (developed by IWINT), and InventionTool3.0, InventionTool-net and InventionKnowledgeCloud (IKC) all developed by our researchers of Hebei University of Technology). Goldfire and CREAX are both exclusively in English. Pro/Innovator supports function retrieval, keywords retrieval, and extended query in Chinese and English, but the ability of Chinese extended query is weak. IKC is a cloud services platform of computer-aided innovative design used to solve the technical problems oriented toward the innovative engineer, which can achieve a certain semantic extended query and association.

According to the deficiency of effect knowledge organization and semantic extension in the innovative design field, this paper studies the meaning of scientific effect knowledge and proposes an organization method of topic-based scientific effect knowledge by combining the function expression method of natural language and function ontology. This paper introduces a novel topic concept and aims to construct a topic-based semantic web based on ontology to associate all scientific effect knowledge. On this basis, we construct the semantic inference rules necessary for reasoning to realize the extension and screening of function and flow, and then to diverge and converge the solution space of effect.

2. An organization method of topic-based scientific effect knowledge

Scientific effect knowledge contains scientific effects and instances of effect. Scientific effects are formed on the basis of the correlation between the technical functions of patented product coming from the analysis of patents and the scientific principles used to implement the technical function. The effect describes the relations between input flow, output flow, and the controls parameters used to realize the corresponding function. Instances of effect are project examples that realized some function extracted from the patents or specific application examples of scientific effects in some field.

In current CAI design field there are two ways to express function information based on function ontology: The first method is the expression of the verb-object phrase of "verb + noun", where the verb is taken as an operation and the noun is a flow. The second approach is to express function information in terms of change in material flow, energy flow and signal flow that occurs between input and output.

The presence of function is based on the flow, each flow has certain property, and different flow has different property. This article further differentiates noun into object noun and parameter noun, which also includes compound noun combined by object and parameter noun by combining the grammar structure of natural language. Parameter noun is used to describe the property of object noun. The function is then expressed by the combination of verb, object noun or parameter noun in this ontology. Function is redefined as a binary group model. Function and noun are expressed as Equation (1), (2), and (3). *F*, *V*, *N*, *ON* and *PN* represent function, verb, noun, object noun and parameter noun, *pON* and *oPN* represent parameter object compound noun and object parameter compound noun. *ON* and *pON* belong to object noun, *PN* and *oPN* belong to parameter noun. There are four function expressions. For example, produce water, change temperature, increase the temperature of water, and produce red gas.

$$F=(V, N) \tag{1}$$

$$N=[ON/pON/PN/oPN] \tag{2}$$

$$F==[(V, ON)/(V, PN)/(V, oPN)/(V, pON)] \tag{3}$$

There has been using the three-tier structure focused on scientific effect from function to effects to instances in the field of innovative design. The popular three-tiered structure currently used in CAI can only realize single chain link between effect knowledge nodes. But in reality the relations of effect, instance, and function are many-to-many relationships. And there is also other specific relations among them, flow and parameters. This paper proposes a topic-based organization method by introducing the topic concept to organize the scientific effect knowledge. The topic itself has a certain semantic meaning. And there are a variety of semantic relationships between topics. Function, flow and parameter are regarded as different topics, and they reflect the scientific effect knowledge from different aspects. This method can associate all original single-chained and semi-structured knowledge and form a bidirectional associated multi-level knowledge web. Scientific effect knowledge semantic web is constructed by analyzing and studying the meaning of each topic and the semantic relationships between them.

3. The Construction and Reasoning of scientific effect knowledge semantic web

Ontology is a kind of integration tool oriented application and domain knowledge; it is a collection of concepts and relationships between concepts in a certain field. The relationship reflects the constraints and links between the concepts. The description of scientific effect knowledge and relationships can be standardized and formalized by ontology. In here we extract and classify the concepts and relations between knowledge according to the topic to construct the semantic web of scientific effect knowledge based on ontology. We choose the protégé to construct ontology，and construct semantic inference rules to reasoning based on Jena to realize all kinds of extension and connection of knowledge.

▪3.1 The extraction and classification of ontology concepts based on the topic

The category and hierarchy of concepts are organized by extracting and classifying the concepts of scientific effect knowledge based on topic, analyzing and researching the meaning and composition of function, flow, parameter and relations between them and effect knowledge.

The first class is the scientific effect, which constitutes the effect ontology tree; the second class is the instances of effect, which constitutes the instance ontology tree; the third class is the topic class, divided into the subclass of verb and noun according to the part of speech. The verb class constitutes the operation ontology tree used to describe the verb of function. Noun class is used to describe the noun of function, parameters, flow and flow property of effects and instances, and is further subdivided into object noun and parameter noun. The noun class has four forms, as in Equation (1). The class of object noun and parameter noun constitute the object ontology tree and the parameter ontology tree.

Figure 1 shows the concept classification tree of scientific effect knowledge. I, E and T represent the classes of instance, scientific effect and topic.

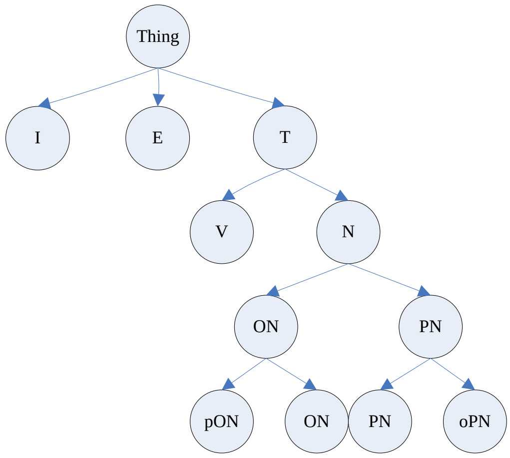

Figure 1. The concept classification tree of scientific effect knowledge.

Figure 2 shows the structure of scientific effect knowledge ontology.

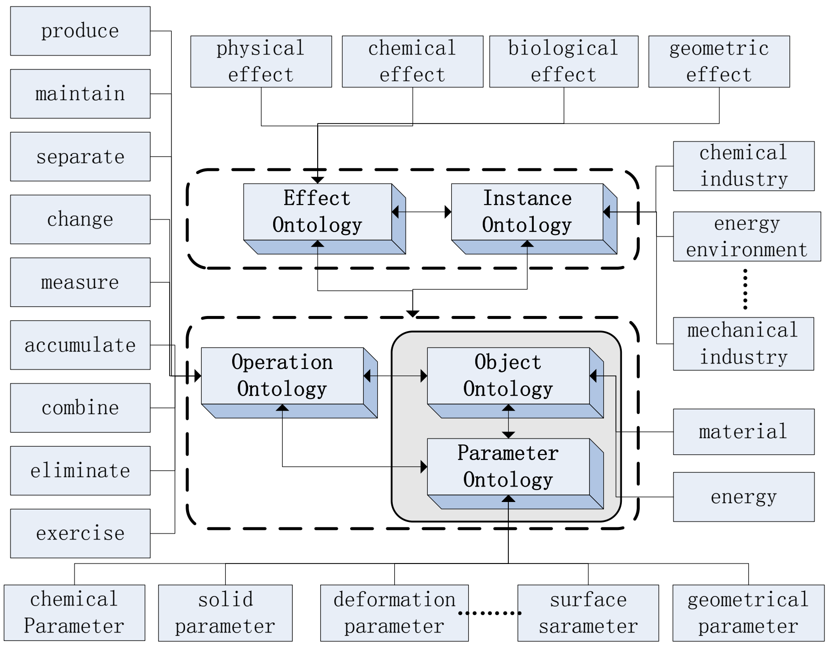

Figure 2. The structure of scientific effect knowledge ontology.

▪3.2 The extraction of relationships between concepts and definition of property based on topic

The relationships between concepts are defined as bidirectional relationship in order to realize the forward and reverse link between knowledge. The properties of each concept and the relations between them are analyzed starting from the concept itself. And the relationships should be refined step by step according to the hierarchy and structure of concepts. The combination of multiple concepts together through specific semantic relations can constitute different topics. The bidirectional association between any two concepts is established by transforming the semantic relations of effect, instance, function, flow and parameter into the relationships of effect, instance, operation verb, object noun and parameter noun.

(1) The relations between the class of effect and topic contain relationship of effect and object noun, relationship of effect and parameter noun and relationship of effect and verb, represented by EOR, EPR, EVR.

(2) The relations between the class of instance and topic contain relationship of instance and object noun, relationship of instance and parameter noun and relationship of instance and verb, represented by IOR, IPR, IVR.

(3) The relations between the class of instance and effect contain relationship of instance and instance, relationship of effect and instance and relationship of effect and effect, represented by IIR, EIR, EER.

(4) The relations of topic class contain relationship of verb and verb, relationship of noun and noun, relationship of verb and object noun, relationship of verb and parameter noun and relationship of object noun and parameter noun, represented by VVR, NNR, VOR, VPR, OPR.

Figure 3 illustrates the ontology concept relation model of scientific effect knowledge. Relationships between the concepts are shown in Figure.

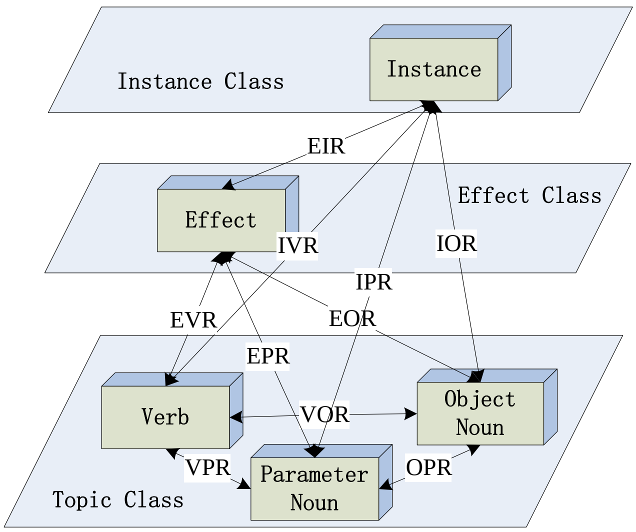

Figure 3. The ontology concept relation model of scientific effect knowledge.

The extraction of relationships between concepts depends on the semantic relationship of the data in the knowledge base, such as attribute relationship, part and overall relationship and peculiar relationship of knowledge. The relations of V, ON, and

PN are extracted from the function description of effect and instances, such as VOR and VPR extracted from function, and OPR extracted from noun phrase. The relationships of concepts can be reflexive, symmetric, and transitive. Some of them are properties that the concept has itself, namely direct relationships, others are indirect relationships inferred by direct relationships. These relationships should be refined to define the object properties in the ontology, and to determine the domain and range of these properties. For example, the two object properties of "*object_property*" and "*paramerter_object*" are defined according to OPR, represent the relationships of "parameter of object noun" and "object described by parameter noun", which can realize the relevance between ON and PN. There are multiple bidirectional relationships between effect and noun, such as the relationships of input flow, output flow, function noun and parameter of effect. The two object properties of "*effect_inputflow*" and "*inputflow_effect*" are defined according the input flow of effect, represent the two reciprocal relationships of "input flow of effect" and "effect that noun regard as input flow associated", which can realize the forward and reverse relevance between effect and flow. The two object properties of "*verb_noun*" and "*noun_verb*" are defined according to VNR, represent the two reciprocal relationships of "noun that verb matched" and "verb that noun matched", which can realize the automatic matching between verb and noun.

The bidirectional association knowledge semantic web relates all concepts to each other. It is the base of inference rules. The divergent thinking produced by the forward and reverse reasoning of concepts can inspire the product innovation. The correlation between multiple concepts can effectively divergent and convergent the solution space, and improve the efficiency of solving.

We propose a new method to find the semantic relationship between concepts and relationships that tie them through the concept nodes to structure undirected complete graph. The number of edges of the undirected complete graph of n nodes is expressed as Equation (4), each edge can be refined into multiple directional relationships. The unstructured knowledge will be structured to construct a bidirectional association semantic web. Figure 4 illustrates the scientific effect knowledge undirected complete graph. Each edge in the graph represents some semantic relationships.

$$Kn=[n(n-1)]/2 \tag{4}$$

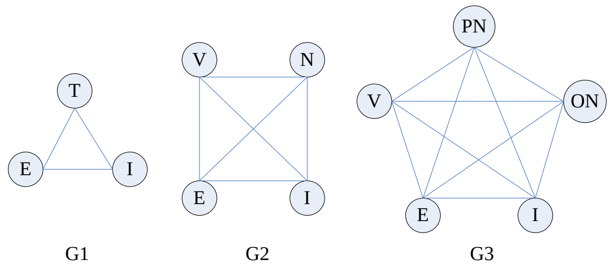

Figure 4. The Scientific effect knowledge undirected complete graph.

▪3.3 Semantic reasoning based on the rules

We customize two kinds of inference rules based on the concepts and object properties: one is function and flow extension inference rules, the other is the correlated effect inference rules. (*EKB* is the abbreviation of ontology namespace).

(1) Noun flow extension inference rules are as follows(x, y, u, v and p represent variable):

rule1: (?x EKB:object_property ?p) (?y EKB:object_property ?p)->(?x EKB:ex_noun ?y)
rule2: (?x EKB:object_property ?u) (?u EKB:father ?p)
(?y EKB:object_property ?v) (?v EKB:father ?p) ->(?x EKB:ex_noun ?y)
rule3: (?x EKB:object_property ?p) (?p EKB:property_object ?y)->(?x EKB:ex_noun ?y)
rule4: (?x EKB:parameter_object ?y)->(?x EKB:ex_noun ?y)
rule5: (?x EKB:parameter_object ?p) (?p EKB:object_parameter ?y)->(?x EKB:ex_noun ?y)
rule6: (?x EKB:parameter_object ?u) (?u EKB:father ?p)
(?y EKB:parameter_object ?v) (?v EKB:father ?p)->(?x EKB:ex_noun ?y)
rule7: (?p EKB:function_verb ?y) (?p EKB:function_noun ?x)
->(?x EKB:noun_verb ?y)

The extended and matched collections of verb and noun are geted from the reasoning rules. It has realized the extension and screening of function, and then diverge the solution space of effect based on rules and logical reasoning. The two kinds of extended function are expressed as Equation (5) and (6). The final extended collection of function is expressed as Equation (7). V and N are the extended collections of verb and noun, vi is an element of V, nj is an element of N. Ni is the collection of matched noun of vi, Vj is the collection of matched verb of ni.

$$Fi=vi\times(Ni\cap N),\ ni\in(Ni\cap N),\ vi\in V,\ Fi=(vi,\ ni) \tag{5}$$

$$Fj=(Vj\cap V)\times nj,\ vj\in(Vj\cap V),\ nj\in N,\ Fj=(vj,\ nj) \tag{6}$$

$F = Fi \cup Fj$
(7)

(2) The correlated effect inference rules are as follows:

rule1: (?e1 EKB:effect_outputflow ?f) (?f EKB: inputflow_effect ?e2)
->(?e1 EKB: backward_related_effect ?e2)
rule2: (?e1 EKB:effect_inputflow ?f) (?f EKB: outputflow_effect ?e2)
->(?e1 EKB: forward_related_effect ?e2)
rule3: (?e1 EKB:effectoutput_flow ?f1) (?f1 EKB: inputflow_effect ?e3)
(?e2 EKB:effectoutput_flow ?f2) (?f2 EKB: inputflow_effect ?e3)
->(?e1 EKB:parallel_related_effect ?e2)
rule4: (?e1 EKB:effect_inputflow ?f1) (?f1 EKB: outputflow_effect ?e3)
(?e2 EKB:effect_inputflow ?f2) (?f2 EKB: outputflow_effect ?e3)
->(?e1 EKB:parallel_related_effect ?e2)
rule5: (?e1 EKB:effect_outputflow ?f) (?f EKB:controlflow_effect ?e2)
->(?e1 EKB: control_related_effect ?e2)

The forward and reverse inference rules are builded based on the intput flow, output flow and control flow of effect.Among them, *rule3* and *rule4* can reason out the parallel effects; *rule2* and *rule4* are reverse inference rules; *rule1*, *rule3* and *rule5* are forward inference rules.

Figure 5 summarizes the correlated effect inference rules. *e1*, *e2* and *e3* represent effect; *f*, *f1*, and *f2* represent flow.

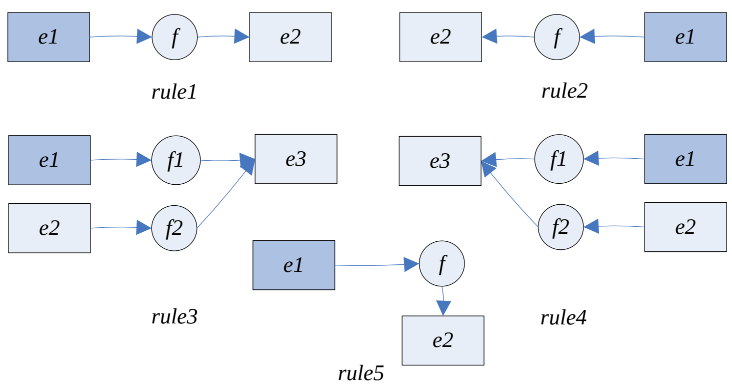

Figure 5. The correlated effect inference rules.

4. Application example

To better illustrate the system proposed in this paper, we consider the toy example in light bulb manufacturing. Suppose there is a quality problem at a light bulb manufacturing plant, possibly due to internal pressure of the bulb and the gas inside the bulb are in adequate. In order to solve this problem, the topic-based scientific effect knowledge laid out in this paper can directly search the effect that the noun regarded as flow or parameter correlated starting from gas, internal pressure or gas pressure. This method extends the original single function search approach and diverges the effect solution space through different topics. At the same time it can convergent the solution space effectively and find an exactly matched effect by getting the multiple topics together.

The function of detecting gas has corresponding effects, such as corona discharge, light scattering, and light absorption. The control parameter of gas pressure can be associated with these different effects. Let us choose corona discharge as an indicator of internal pressure of light bulb. At the same time, we can know the control effect of corona discharge effect reasoned out according to the correlated effect inference rules is overflowing effect and so on.

Figure 6 is the result of correlated effects. *cp*, *fn* and *fv* represent the relationships of control parameter, function noun and function verb of the effect. *op* and *vn* represent the collocation relationships of object noun and parameter noun, verb and noun. Figure 7 is the result of control effect. *fi*, *fo* and *fc* represent the relationships of input flow, output flow and control flow of the effect.

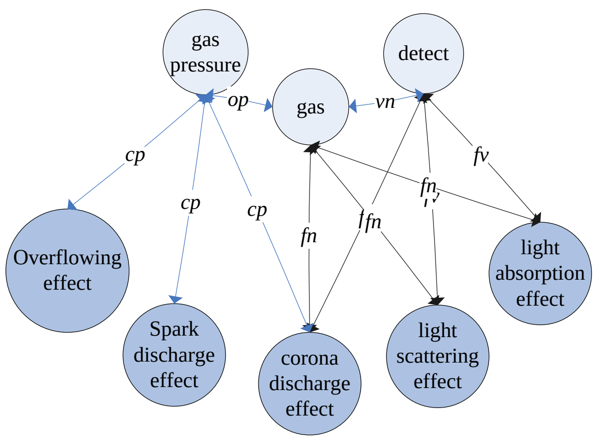

Figure 6. The result of correlated effects.

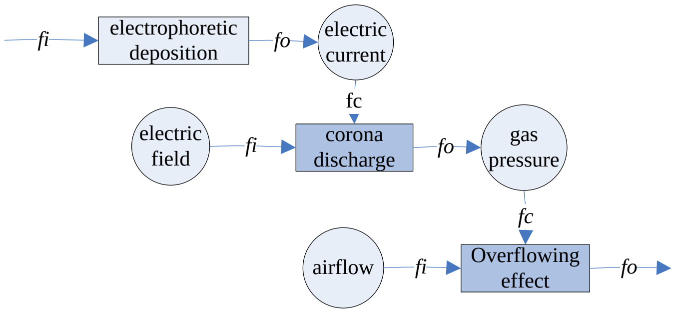

Figure 7. The result of control effect.

5. Conclusion

The organization method of topic-based scientific effect knowledge proposed is a kind of new train of thought. This paper extends the properties of a given concept and the relationships that exist between concepts. The innovation of our approach is to elevate these concept properties to the semantic level based on ontology, and by associating all original single-chained and semi-structured knowledge to construct a bidirectional associated multi-level semantic web of topic-based scientific effect knowledge. This structure extends the search based on function and can searches solution space through different topics to find the exactly matched effects and instances. The associated effects or instances of the determined effect can be reasoned by forward and reverse reasoning based on flow or parameter. At last it truly achieves the sharing and reuse of the effect knowledge.

The scientific effect knowledge ontology is the basis of semantic reasoning. The pros and cons of its design have a great influence on semantic retrieval and knowledge expansion. Further work is needed to optimize the knowledge structure this paper constructed and research the topic-based scientific effect knowledge retrieval strategy to make better use of ontology in semantic retrieval and extension.

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An Image Authentication Scheme for High Dynamic Range Images

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Abstract

Upon the images with high dynamic range (HDR) have drawn more and more attentions in academia and industry, as our best knowledge, the existing researches of digital watermarking for HDR images focus on robustness to guarantee copyright protection. In this paper, a tailor-made image authentication for HDR images with RGBE format is proposed to not only detect but also precisely locate any modification in the protected images. The experimental results show that the proposed scheme achieves high detection accuracy while preserving acceptable visual quality after embedding.

Keywords: high dynamic range image, image authentication, RGBE image format

1. Introduction

In the past decades, digital image is represented with size of from 8 to 12 bits for each color channel of RGB format to meet consumer electronics such as monitor or projector. Recently, high dynamic range (HDR) imaging formats ([a]Ward, 1991, Larson, 1998, Industrial Light & Magic) have already been developed, in which more accuracy than traditional images is achieved by enabling the darkest area as shadow and brightest area as sunlight in HDR images simultaneously. The raw format of HDR imaging is 32-bits for each color channel R, G, B and, thus, totally 96-bits. Due to the size of raw HDR format is comparatively large, some HDR formats with fewer bits such as *RGBE* ([a]Ward, 1991), *LogLuv* (Larson, 1998), or *OpenEXR* (Industrial Light & Magic) are defined instead.

Upon the HDR images signal the dawn of spectacular new imaging and have garnered more and more attentions in academia and industry, the security, such as confidentiality and authentication, of HDR images become crucial. In particular, with the advances of networking technologies, digital image is shared widely and rapidly via the public Internet in people's daily life. This implies the risks of eavesdropping, plagiarizing and maliciously modifying transmitted HDR images.

The abovementioned three risks can be addressed by HDR image encryption (Yan et al., 2013, Lin et al., 2013), HDR robust watermarking ([a]Guerrini et al., 2008, [b]Guerrini et al., 2011, Naguarammal and Meyyappan, 2012, Wu, 2012, Rattanacharuchinda and Amornraksa, 2012, Solachidis et al., 2013, Autrusseau and Goudia, 2013, Zhu et al., 2014), and image authentication (or called fragile watermarking), respectively. Unfortunately, as our best knowledge, there is no research to guarantee the integrity of HDR images in the literature.

In this paper, we proposed a tailor-made HDR image authentication scheme to achieve the following features.
1) RGBE format: The proposed scheme aims at solving the problem of integrity of RGBE images.
2) Transparency: The visual quality of protected images is so high that the protected one is visually equivalent to the original.
3) Integrity: The scheme is sensitive to tamper on the protected HDR images.
4) Localization: The detection can locate any parts that were illegally modified or counterfeited.
Furthermore, taking HDR image formats and the visual quality into accounts, this scheme embeds different amount of bits into different color channels. The experimental results show that the proposed scheme satisfied the above-mentioned requirements.

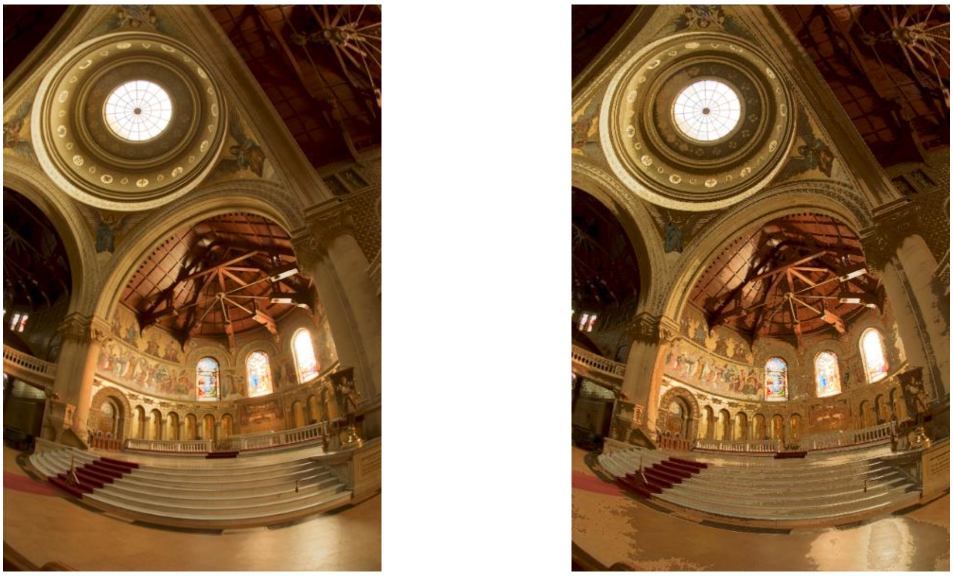
2. Related work

Comparing to the other HDR image formats, RGBE format draws much attention. Each pixel with RGBE format is constructed by four color channels, including three color channels and one exponent channel. Each channel uses 8-bit integer to represent one pixel. Assume parameters, r, g and b represent three color channels of uncompressed HDR image format, and R, G, B and E represent the three color channels and one exponent channel of RGBE image format. The transformation between (r, g, b) and $(\mathrm{R}, \mathrm{G}, \mathrm{B}, \mathrm{E})$ is defined as Equation (1) and Equation (2) (Yu et al., 2011).

$$E = \lceil \log_2[\max(r,g,b)] + 128 \rceil \quad (1)$$

$$C = \left\lfloor \frac{256 \times c}{2^{E-128}} \right\rfloor, C \in \{R,G,B\}, c \in \{r,g,b\} \quad (2)$$

Even the slightest modification of exponent channel E may cause obviously visible distortion, as shown in Figure 1, in which Figure (b) is the version of modifying by replacing 1-th LSB of E with a random bit. Due to the above observation, the proposed scheme should keep the value of E unchanged to guarantee the visual quality of protected images.



(a) (b)

Figure 1. The experimental results of modifying the channel E by modifying HDR image by replacing 1-th LSB with a random bit (a) original HDR image (b) altered HDR image.

3. Proposed authentication scheme

The proposed image authentication scheme consisting of two parts: embedding phase and authenticating phase. The former describes the method how to compute and embed the authentication bits to HDR images to form the protected ones while the latter explains the operations how to detect and locate the tampered area in the test HDR images.

▪3.1 Embedding phase

There are three steps aiming at dividing HDR images, computing authentication bits and embedding authentication bits.

Step 1: The original HDR image with size of $M \times N$ is divided into $\left\lfloor \frac{M}{2} \right\rfloor \times \left\lfloor \frac{N}{2} \right\rfloor$ overlapping blocks and each block size is 3×3, as shown in Figure 2. The center pixel of each block is used as the embedded pixel. Note that the resolution of 3×3 block size is acceptable to locate the tampered area.

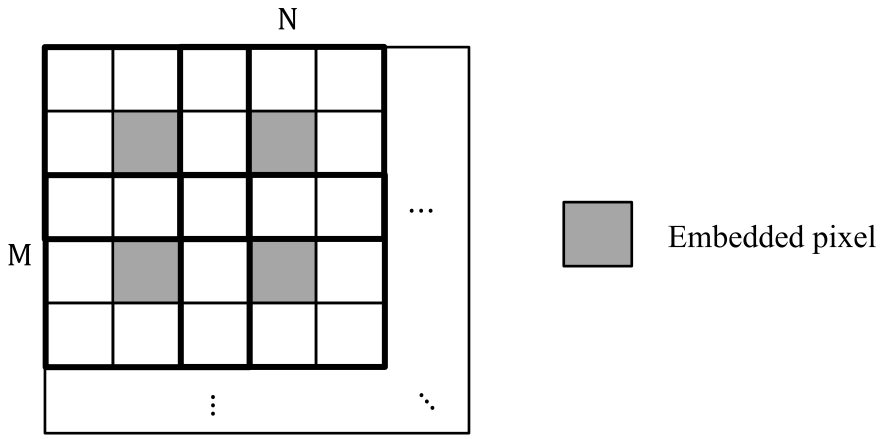


Figure 2. The overlapped 3×3 block and the gray pixels are the embedded pixels.

Step 2: The information of each block will be used to compute four authentication bits and embedded in the center pixel. As mentioned in Section 2, this scheme takes into account the RGBE image formats so the exponent channel E is not used to embed the authentication bits. The other three color channels, R, G and B, are embedded authentication bits with 1, 1 and 2 bits, respectively. Because the modification of B can avoid severe color distortion in HDR images (Rattanacharuchinda and Amornraksa, 2012), the proposed scheme uses 2 bits of B to embed. The other unused 284 bits, $(8 \times 9 - 1) + (8 \times 9 - 1) + (8 \times 9 - 2) + (8 \times 9)$, in each 3×3 block are the input data of a cryptographic hash function $H(\cdot)$. For example, SHA-512 (Gutierrez et al., 2008) is a common one way function that computes the bit stream with any length as input into a 1024 bits stream as output. Assume that the $M \times N$ HDR image which is divided into 3×3 blocks in Step 1 with a unique ID, $image_{ID}$, and $P^i_{r,c}$ is a pixel in i-th block, where $P \in \{R, G, B, E\}$, $1 \leq r \leq 9$ represents the nine pixels in each block and $1 \leq c \leq 8$ represents the eight bits in each color channel, as shown in Figure 3(a). With user's secret key key_{secret}, there are 1024-bit output is obtained by Equation (3).

$$b_1 b_2 \dots b_{1024} = H(R^i_{r,c}||G^i_{r,c}||B^i_{r,c}||E^i_{r,c}||i||image_{ID}||M||N||key_{secret}) \quad (3)$$

The authentication bits A_1, A_2, A_3 and A_4 are computed by the bit stream. The bit stream is folded into shorter stream with four bits, by Equation (4):

$$A_1A_2A_3A_4 = b_1b_2b_3b_4 \oplus b_5b_6b_7b_8 \oplus \cdots \oplus b_{1021}b_{1022}b_{1023}b_{1024} \quad (4)$$

Step 3: Finally, the four authentication bits replace the LSB of red, green and blue channels, as shown in Figure 3(b). After reconstructing those blocks, the protected HDR image is obtained.

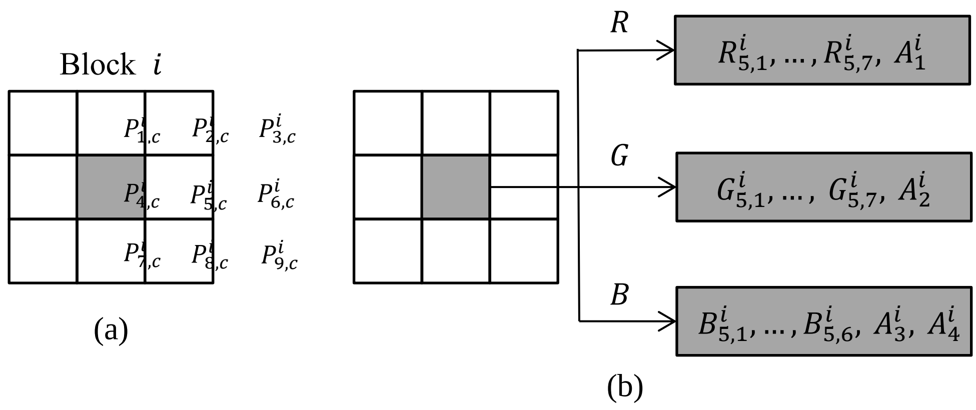


Figure 3. (a) The block is the *i*-th block and (b) the embedded three color channels of *i*-th block's center pixel.

▪3.2 Authenticating phase

The authenticating phase has three steps: dividing HDR images, extracting embedded authentication bits and computing newly authentication bits, finally comparing two kinds of authentication bits and locating the tampered blocks.

When the receiver wants to verify the received HDR image, the first and the second steps are the same as the ones in the embedding phase.

Step 3: Extract the embedded authentication bits from the LSB of red, green and blue color channels. If the extracted authentication bits are identical to those in Step 2, the block is valid; otherwise the block is located as a potential tampered area.

4. Experimental results

There are several test HDR images including “DaniBelgium”, “DaniCathedral”, “DaniSynagogue”, “Rend07”, “SpheronNapaValley”, “SpheronNice” and

"SpheronSiggraph2001" ([b]Ward). The original HDR image Figure 4(a) and the protected HDR image Figure 4(b) are indistinguishable by human eyes. The PSNR values between the tone mapped versions are listed in Table 1 and the values of PSNR are higher than 56 dB. In such a way, the experimental results show that the embedding process doesn't produce significant distortion.

(a)

(b)

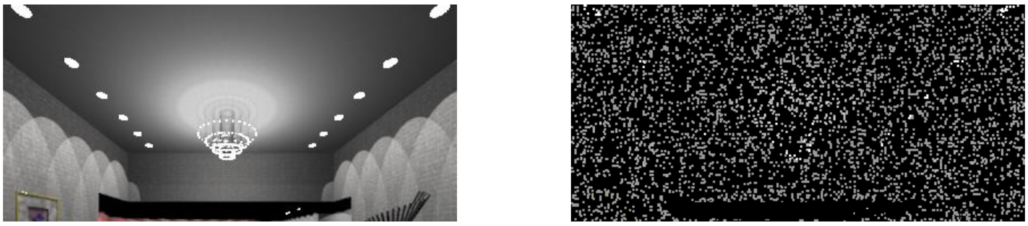
Figure 4. (a) The original HDR image and (b) the protected HDR image.

Table 1. The visual quality.

Image name	PSNR (dB)
DaniBelgium	59.337
DaniCathedral	58.2397
DaniSynagogue	56.0005
Rend07	59.795
SpheronNapaValley	57.8881
SpheronNice	58.6988
SpheronSiggraph2001	59.6138

▪Experiment 1: Image cropping

To evaluate the validity of this proposed image authentication scheme, the first is to crop the protected HDR image into a smaller one (the Figure 5(a)). Figure 5(b) is the located HDR image with black blocks. Because the pixel's information $P_{r,c}^{i}$, block ID i, image size (M, N), image ID $image_{ID}$, secret key key_{secret} are taken into account, the change of image size will cause the cropped HDR image fails to the verification.

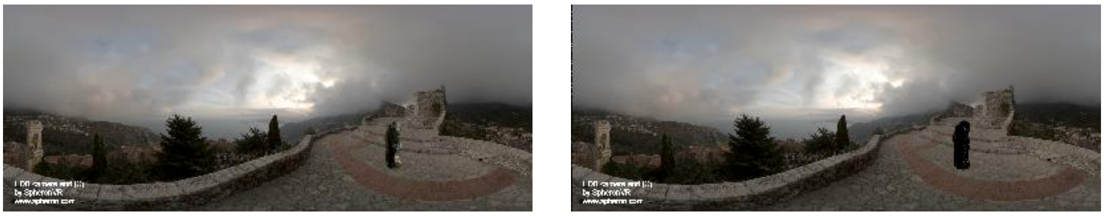


(a) (b)

Figure 5. (a) The cropped HDR image and (b) the tampered part detected.

▪Experiment 2: Content modification by coping and pasting from the other image

The second experiment is to modify the content of protected HDR images. Figure 6(a) demonstrates that the modified HDR image is pasted a person and Figure 6(b) shows the located HDR image with black blocks. The experimental result shows the modified area is located.



(a) (b)

Figure 6. (a) The modified HDR image and (b) the tampered part detected.

▪Experiment 3: Content modification by coping and pasting from the same HDR image

Figure 7(a) is the result by coping and pasting the portrait on the wall. The experimental result Figure 7(b) shows the modified area is detected from the protected image, is located.

(a) (b)

Figure 7. (a) The modified HDR image and (b) the tampered part detected.

5. Conclusion

In this paper, a modification-sensitive image authentication scheme for HDR image is presented. As the experimental results demonstrate, the four requirements including: 1) RGBE format, 2) transparency, 3) integrity and 4) localization are satisfied. It is worthwhile to note that the proposed scheme is the first attempt to propose the tailor-made HDR image authentication scheme.

Acknowledgment

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An authenticated Concealed Data Aggregation Scheme Based on Secret Sharing for Smart Grid

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Abstract

Smart grid, new electricity technology, is envisioned by numerous stakeholders as the next-generation approach of electricity delivery. Data aggregation in smart grid is adopted to consolidate the power consumption data which is encrypted along the routing path. Only the central node (e.g. the utility company) can decrypt the data, so that the electricity consumption data can keep confidential. However, smart grid also faces some security challenges such as message modification attacks and message injection attacks. To deal with these challenges, an authentication mechanism needs to be adopted. In this paper, an authenticated concealed data aggregation scheme based on secret sharing is proposed. This scheme forms a new CDA scheme which can achieve data confidentiality and data integrity during the transmission between consumers and utility company.

Keywords: authentication, concealed data aggregation, secret sharing, smart grid

1. Introduction

Recently, a new electricity distribution system called “smart grid” has become a popular issue which is expected to be the next generation of power system (Fadlullah et al., 2011, Fouda et al., 2011, Liang et al., 2011). Two reasons the need to turn the traditional power grid into smart grid: 1) the traditional power grid is aging and outdated to satisfy future demand; and 2) the demands include efficient power usage, transmitting data in real-time and supervisory control. Thus, smart grid is aimed at providing more stable, reliable and efficient power distribution and consumption.

One of the significant features of smart grid is the replacement of mechanical meters with digital meters, called "smart meter". A smart meter is featured by digital panel and capable of collecting electricity consumption information and transmitting it to utility company in the period time for monitoring and billing purposes. Consumers can also check the current electricity usage in real time to adjust appliance usage from peak time to nonpeak time at will. In addition, smart grid is also featured by wide area monitoring and control, renewable energy generation, Internet-like communication network, etc.

It is worth mentioning that smart grid enables not only consumers to send real-time electricity usage but also the control center to give back a response of pricing information. However, compared to traditional mechanical meters, smart meters connected to the public networks are potentially vulnerable to more attacks. The frequency of smart meter reading transmission is speculated that it might be as every few (1-5) minutes. The increasing communication frequency will also increase the risk of data vulnerability (Quinn, 2009).

Considering message transmitted between smart meters and utility company, either meter reading data or pricing information, it is important to guarantee confidentiality and integrity by aggregated encryption and authentication.

Concealed data aggregation (CDA) of smart-grid data (Sanders, 2010) enables the possibility that the utility company has an efficient way to analyze power usage, and further manage data. In such a way, it is welcome to protect the data by encryption before aggregation and prevent the adversaries from obtaining security-sensitive information. Lu et al.'s scheme (2012) uses a superincreasing sequence to structure multi-dimensional data while adopting homomorphic Paillier cryptosystem to encrypt the structured data. Fan et al. (2014) proposed a privacy-enhanced data aggregation scheme against internal attackers in smart grid in which blinding factors are used to create blinded data to prevent the internal attacks from knowing the individual electricity consumption of the others. Unfortunately, the above-mentioned schemes (Lu et al., 2012, Fan et al., 2014) introducing public-key operations, such as encryption and signature also bring high computation overhead due to high communication frequency.

Although Hong et al. (2009) introduce the concept of secret sharing (Shamir, 1979), which is well-defined to lower the computation overhead, into aggregation. Unhappily, it does not provide authentication for integrity of concealed data. In this paper, inspired from Hong et al.'s scheme, an authenticated concealed data aggregation (ACDA) scheme based on secret sharing for smart grid is proposed. This work forms a new CDA scheme with ability of verifying the integrity of concealed data while aggregating. Compare to Lu et al. (2012) and Fan et al. (2014)'s schemes, the computation overhead is lower by only two lightweight polynomials are used to generate the secret key and the encrypt data for smart meter to achieve both data confidentiality and integrity.

2. Background

▪2.1 Concealed Data Aggregation

The CDA scheme is based on a tree-like structure. It adopts the end-to-end encryption between the leaf nodes and the root node, and enables aggregation nodes (i.e. non-leaf nodes) to apply aggregation function over the ciphertext directly. The leaf node i encrypts its data m_i to obtain ciphertext d_i which is transmitted to an aggregation node. Then the aggregation node integrates all data received by a function $f(.)$ and sends the result y to the root node, where $y = f(d_1, d_2, \dots, d_i, \dots, d_n)$. Finally, the root node aggregates all y to disclosure the intended information.

▪2.2 Secret Sharing

To share a secret numerical value a_0 into n pieces, Shamir defined a polynomial $f(x) = a_{c-1}x^{c-1} + a_{c-2}x^{c-2} \dots + a_1x^1 + a_0$, in which c was the threshold pre-determined, where the constant term a_0 was the secret value, and all other coefficients $a_i\ (i = 1, 2, \dots, c-1)$ were random numbers chosen for data-protection use. The n generated pieces are $(1, f(1)), (2, f(2)), \dots, (n, f(n))$ where $n \geq c$. Any c or more of n pieces are collected, Lagrange's interpolation is used to evaluate all coefficients, especially, the coefficient a_0 of the polynomial $f(x)$.

3. The Authenticated Concealed Data Aggregation Scheme

The ACDA scheme consists of four phases: initialization, data concealment, authenticated concealed data aggregation, and concealed data disclosure.

1) Initialization phase

The utility company *UC* should do the following operations.

Step 1.1 Choose *P* as a large prime, where *P* must be larger than the possible sum of all electricity consumption data.

Step 1.2 Generate a cyclic group $\mathbb{G}$ with order q and generator g where q is a large prime. Then, UC generates $\ell + 1$ distinct random secrets $r_j \in \mathbb{G}$ for $j = 0, 1, \ldots, \ell$ and assigns random secrets r_j to the smart meters $(SM_1, \ldots, SM_\ell)$ and local gateway GW by the way below. UC arranges smart meters SM_i $(i = 1, 2, \ldots, \ell)$ with ranks $(1, 2, \ldots, \ell)$ at random. The smart meter $SM_i$with ID_i at rank k obtains the secrets (r_k, r_{k+1}) and GW obtains the secrets (r_1, r_0). Note that $r_{\ell+1} = r_0$.

Step 1.3 Choose random coefficients $a_i \in \mathbb{Z}_P$ to form a polynomial $f(x)$, called the secret key generating function. Let $f(x) = a_c x^c + a_{c-1} x^{c-1} + a_{c-2} x^{c-2} + \cdots a_1 x^1 + a_0$ and keep a_i secret. The value of security parameter c depends on the amount how many nodes can be compromised in a neighborhood area under the assumption that the attacker can only compromise a small number of nodes.

Step 1.4 Use the polynomial to generate the secret key for smart meter SM_i with its identity ID_i such that $k_i = f(ID_i) \bmod P$. Assume each SM_i obtains its k_i in a secure channel.

2) Data concealment phase

Each smart meter SM_i should perform the following operations to protect the consumption data m_i with confidentiality and integrity.

Step 2.1 Construct a secret polynomial $g_i(x) = 2\alpha_i x + m_i \bmod P$, where $\alpha_i = k_i - m_i$.

Step2.2 Compute

(1) $d_i = g_i(1) = 2\alpha_i + m_i = 2k_i - m_i \; mod \; P$ for confidentiality,

(2) $\bar{d}_i = d_i + r_k^{H(T)} - r_{k+1}^{H(T)}$, where T is timestamp and H(.) is a cryptographic hash function and

(3) Verifier $\sigma_i = g^{ID_i + d_i}$ for authentication.

Step 2.3 Send the tuple $(ID_i, \bar{d}_i, \sigma_i)$ to the GW in the corresponding area.

3) Authenticated concealed data aggregation phase

This phase assumes that each gateway, says GW_t, receives the tuples $(ID_i, \bar{d}_i, \sigma_i)$, for $i = 1, 2, \dots, \ell$, from smart meters. GW_t should perform the following operations to aggregate the received data.

Step 3.1 Compute the tuple $(u_{t,0}, u_{t,1}, u_{t,2}, \dots, u_{t,c}, \sigma_t)$, where $u_{t,0} = \ell$, $u_{t,j} = \sum_{i=1}^{\ell} ID_i^j \ mod\ P$ for $j = 1, 2, \dots, c$ and $\sigma_t = \prod_{i=1}^{\ell} \sigma_i$.

Step 3.2 Compute $\sum_{i=1}^{\ell} \hat{d}_\iota = \sum_{i=1}^{\ell}(d_i + r_k^{H_1(T)} - r_{k+1}^{H_1(T)})$ $= \sum_{i=1}^{\ell} d_i + \left(r_1^{H_1(T)} - r_2^{H_1(T)} + r_2^{H_1(T)} - r_3^{H_1(T)} +, \dots, + r_\ell^{H_1(T)} - r_0^{H_1(T)}\right) = \sum_{i=1}^{\ell} d_i + \left(r_1^{H_1(T)} - r_0^{H_1(T)}\right)$, and the aggregated encrypted data $\omega_t = \sum_{i=1}^{\ell} d_i = \sum_{i=1}^{\ell} \hat{d}_\iota - (r_1^{H_1(T)} - r_0^{H_1(T)})$ with the random secrets (r_1, r_0).

Step 3.3 Check if the equation $\sigma_t ?= g^{u_{t,1}} \cdot g^{w_t}$. If holds, perform the next step; otherwise, terminate the rest operations.

Step 3.4 Send the tuple $(u_{t,0}, u_{t,1}, u_{t,2}, \dots, u_{t,c}, \omega_t, \sigma_t)$ to UC.

4) Concealed data disclosure phase

UC collects the γ tuples of data sent from GW_t, $t = 1, 2, \dots, \gamma$. Let the tuple be $(u_{t,0}, u_{t,1}, u_{t,2}, \dots, u_{t,c}, \omega_t, \sigma_t)$ for $t = 1, 2, \dots, \gamma$. Then UC should disclosure the sum of all consumption data by doing the following operations.

Step 4.1 Compute $u_i = \sum_{t=1}^{\gamma} u_{t,i} \ mod\ P$, $i = 0, 1, \dots, c$.

Step 4.2 Compute W such that $W = \sum_{t=1}^{\gamma} \omega_t \ mod\ P$.

Step 4.3 Compute $\sigma = \prod_{t=1}^{\gamma} \sigma_t$, and verify $\sigma ?= g^{u_1} \cdot g^W$, if not hold, terminate the phase.

Step 4.4 Compute K such that $K = \sum_{i=0}^{c} a_i u_i \ mod\ P$.

Step 4.5 Compute SUM such that $SUM = 2\mathrm{K} - \mathrm{W}\ mod\ P$

Note that SUM is the sum of all consumption data.

4. Discussions

This section describes the result how confidentiality and authentication are achieved.

1) Confidentiality with aggregation: The transmitted data between UC and SM_i is always sent in a form of ciphertext. If adversary A tries to deduce the information, he/she faces the data in an encrypted form without the secret key, A has no feasible way to disclosure the information. Besides, since the secret key generating coefficient a_i is only known by UC, anyone including adversary A can't recover the key K to disclosure the concealed data. Hence, the data confidentiality is guaranteed.

2) Authentication with verifier: The transmitted data between the UC and SM_i is sent along with a verifier σ_i to ensure the data integrity. If adversary A modifies the data, he/she faces the verifier σ_i and the data $\bar{d}_i$ without the secret (r_1, r_0), A has no feasible way to forge a data which can make the equation $\sigma_t = g^{u_{t,1}} \cdot g^{w_t}$ hold after aggregating. As a result, the adversary A's malicious behaviors in the smart grid communications can be detected. Hence, the data integrity is guaranteed.

5. Conclusions

This paper presents an end-to-end ACDA scheme for securing communication over smart grid, in which electricity consumption data is encrypted and authenticated along the routing path. The utility company is the only one can decrypt and recover the total electricity consumption data while the gateways and the utility company can verify the integrity. The present scheme does achieve both high security and efficiency.

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Healthcare Phone Watch by Guider Technology Co. Ltd. to Promote ICloud-based Telecare

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Abstract

This paper is a case study, it describe how Guider Technology Co. Ltd. In response to the increasing number of elderly persons living alone and rising homecare needs, has introduced a state-of-the-art healthcare phone watch featuring functions of mobile phone positioning and icloud-based health measurement and healthcare interaction service model to help homebound elderly persons live safe through icloud-based telecare services. In view of its good motivation of R&D, this device perform functions of telecare and first-aid services
necessary for the ever-increasing demand for long-term care market, not only increasing life quality for seniors and persons with disabilities but also giving caregivers who have undertook the long-term homecare services a chance of catching their breath.

The healthcare phone watch designed specifically for senior residents and persons with disabilities by Guider Technology is the world's first platform focusing on home security of senior residents and ones with disabilities that integrates health management with interactive medical services and icloud-based interaction services. This watch features integration services composed of phone-based position sensing watch (intelligent terminal)+icloud-based prompt interaction services(elderly LOHAS)+smart phone App(family members can know well the important messages any time)

Keywords: healthcare phone watch，icloud-based health measurement，telecare and first-aid services

Introduction

This study starts with stories of Taiwan's aging families to delve into issues of how to deal with issues of care for the elderly and those with disabilities. In many families having both husband and wife working, the married couples hope to find adult daycare centers where their elderly family members can receive care services during their working days. Despite the fact that Ministry of Health and Welfare has established community concern centers nationwide in Taiwan, many of these centers lack facilities available for daycare services. Many families hope to send the elderly and those with disabilities to care centers but would receive strong reactions against their decision from the cared-for, thinking that their family members intend to abandon them.

Taiwan's population aging and long-term care need

Since 1993, population of people above 65 (the elderly) constitutes 7.1% of the total population in Taiwan that ushers in an aging society; elderly population will reach 2,343, 000 in 2007 that constitutes 10.2% of the total population, meaning that one out of every 10 persons is the elderly. Percentage of Taiwan's aging population has been increasing by year from 10.2% in 2007 to 11.2% in 2012, and is expected to reach 22.5% in 2028 (one out of every 5 persons is the elderly) and 37.5% in 2056, and it is estimated that aging of population will speed up in the future. According to estimate of demographic transitions (natural change) by Council for Economic Planning and Development of Executive Yuan, with international demographic transitions excluded, natural population growth will turn into population decline after curves of crude birth rate and crude death rate intersect in 2017. Population pyramid of Taiwan will be upside down in 2060 that give rise to a heavy burden for the aging society.

According to the latest statistics by Ministry of the Interior on Jan.18, 2014, Taiwan's population aging index has been in sharp rise. The number of persons above 65 has reached 2,690,000 in the end of 2013 that constitute 11.5% of the total population, and the aging index is 80.5%, meaning an increase of 33.9% in nearly 10 years. Since 1993 when Taiwan entered the aging society, percentage of persons above 65 has continued to rise. Though the aging index in 2013 is lower than that of Canada, European countries and Japan, the index is still higher than that of US, New Zealand, Australia and other Asian countries. According to Ministry of the Interior, percentage of elderly population is higher in agricultural counties, with Chiayi County having the highest percentage in 137.3% and Hsinchu City having the lowest one in 53.7%. Northern Taiwan and central Taiwan have the lower aging index in 73% and 79% respectively, and eastern Taiwan and Kinmen and Matsu islands, the outlying islands, have the highest aging index in 98% and 96% respectively. In term of category of county and city, Chiayi County has the highest aging index, followed by Penghu County and Yunlin County, while Hsinchu City has the lowest aging index, followed by Taoyuan County and Taichung City. The rapid increase of aging population has greatly affected the structure of family in Taiwan, work and life style and consumption pattern that further needs sound medical care service system（Kane

& Kane,1987） and multiple aging economic security systems to create healthy, friendly, safe and active aging environment.（Daniels,2008）

As of end of Oct in 2013, 206,376 foreign caregivers which constitute 43.15% of a total of foreign laborers have arrived in Taiwan to be brought to families and care institutions to take care of their employers' relatives with severe disabilities. According to regulations by Council of Labor Affairs, one of being cared for will be eligible to hire foreign caregivers when the degree of disability scores below 35 on Barthel index. Barthel index measures a person's ability to perform ten daily personal care items, including feeding, mobility, bathing, toilet use, etc. A person who receives a full score of 100 is capable of caring for himself; according to the existing provisions, a person who needs 24-hour care and scores below 35 on the Barthel Index (means total dependency) is eligible to hire a foreign live-in caregiver; a patient who is able to feed himself scores 60. In comparison to other countries, most of families of the elderly persons or persons with disabilities in Taiwan have hired foreign caregivers who don't speak Chinese nor have medical care expertise to take care of their relatives with severe disabilities. For the sake of saving care expenses and in view of wages paid to foreign caregivers to be half of that of domestic caregivers, most families of persons who need care prefer to hire foreign caregivers.

Besides, most elderly and people with disabilities in Taiwan are content with the existing living environment by showing no willingness to live concentration camp-like group life. Though Formosa Group has constructed a large-scale Chang Gung Health and Culture Village in Linkou offering the elderly good living and caring environment, it's still not a lure for the elderly and persons with disabilities as admission rate is still low that can be attributed to paying a sum of one million New Taiwan dollars as a sum of deposit before moving into the caring community, thus giving rise to financial burden for family members. Long-term care specialists and scholars suggest downscaling operations of caring institution can increase capacity of small and middle caring institutions established in local communities. Long-term care insurance should be implemented early to encourage homecare of the elderly and persons with disabilities, （Nightingale,1991）and this measure has been listed as the primary task in the administrative plan by Ministry of Health and Welfare.

The population of elderly persons living alone in Taiwan has been gradually increasing that saw a unique phenomenon in many families: one son or daughter never wants to get married, and even gives up his/her job for work-at-home jobs (SOHO) to accompany their parents or their relatives with disabilities. There are a number of small apartment-based caring institutions of varying quality in communities that poor living environment, abuse fire or flood have emerged, as even the insufficient medical staffing has given rise to the condition that no one came to rescue flood-soaked senior residents and ones with disabilities.

It is estimated that over 34,000,000 Americans which constitute 15% of the total population rely on cloud-based telecare mode to take care of their elderly parents who live in areas within a one hour distance from their children. What they are concerned about is the quality of icloud-based telecare mode.（Ogata,2001；Suzuki,2004；Thom,2001）

In Taiwan, only National Taiwan University Hospital has established Tele-health Center offering its members the 24-hour cloud-based telecare services. It is according to the icloud-based telecare project made by the Exective Yuan（Spiro,1993；Sullivan,1986）Currently, it's still in the activity promotion phase offering 2-week free trial that leaves room for business expansion.

In response to the increasing number of elderly persons living alone and rising homecare needs, Guider Technology Co. Ltd. has introduced a state-of-the-art healthcare phone watch featuring functions of mobile phone positioning and cloud-based health measurement and healthcare interaction service model to help homebound elderly persons live safe through cloud-based telecare services. In view of its good motivation of R&D, this device perform functions of telecare and first-aid services necessary for the ever-increasing demand for long-term care market, not only increasing life quality for seniors and persons with disabilities but also giving caregivers who have undertook the long-term homecare services a chance of catching their breath.（Wasserman,1993）

Background of Case Manufacturer

Founded in 2007, Guider's R&D team consists of specialists from IBM Taiwan. What Guider Technology has done is motivated with human concern at heart, and the company is committed to integrating active RFID/ Sensor/ RF by developing devices applied to medical healthcare and individual security and security monitoring industry. Headquartered in Taipei City, Guider Technology has established R&D beachheads in Tainan and Kaohsiung. Guider has also invested in ParaLucent International Co. Ltd., Taiwan Digital Co. Ltd. and ARAVision Incorporated, and has also built strategic alliance and long-term goal of development plan with Inventec group for cloud-based application, and the purpose lies in obtaining related technology to be integrated into solutions.

Guider has also transferred its key technologies developed in Medical Hub / OSGi of Industrial Technology Research Institute to secure that its solutions with the framework of trends is competitive internationally and meets practical market needs. In early years, Guider Technology mainly specialized in the development of RFID technology including campus e-cartoon and school affairs. Guider went on to develop a business group specializing in campus energy-saving control and air-con control. The first generation of RFID with identification technology is RFID healthcare phone watch featuring general fall detection and calling-for-help functions that can only be used at home. After having been engaged in a process of market integration, Guider has found that this product shows no significant beneficial results if it can only be used indoors or outdoors. Guider went on to begin software and hardware design and production by combining household and outdoor products, i.e. improving the original healthcare phone watch and cell-phone to strengthen its dialing and SOS functions including end-use equipment, such as blood pressure and blood glucose meters, to send information to cloud-based platform through data collection method and then the fixed Internet of CPCIP, sending information of blood pressure and blood glucose information to cell phone through Bluetooth before being sent to network platform through SIM, and then add RFID homecare positioning service and the outdoor call-for-help function that makes it the only server in the world integrating measurement and call-for-help function with strategy to show concern.（Watson,2008）

Characteristics of the Case Product

The healthcare phone watch designed specifically for senior residents and persons with disabilities by Guider Technology is the world’s first platform focusing on home security of senior residents and ones with disabilities that integrates health management with interactive medical services and cloud-based interaction services. This state-of-the-art watch features integration services composed of phone-based position sensing watch (intelligent terminal)+cloud-based prompt interaction services(elderly LOHAS)+smart phone App(family members can know well the important messages any time)!

Guider’s healthcare phone watch equipped with emergency call, GPS base station positioning, reminder of abnormal temperature, possible fall detection, reminding patients to take medicine and booking outpatient appointments, Bluetooth single-key physiological measurement and upload, peed dial keys set up for the user’s adult children, touch screen, and daily water-proof performance. LOHAS Cloud offers information of prompt call-for-help and fall position warning, abnormal temperature message, physiological measuring data, taking medicine and booking outpatient appointment. It also offers medical health service unit synchronous database and advanced services. Smartphone apps allow users know well their aged parents’ security, dynamic position, physiological measurement information, safe and health conditions any time and advanced medical health interaction services.（http://www.guidertech.com.）

Product Case Sharing - Guider Technology The Retired Professor Chien-Han Chang of National Taiwan University Saved by Guider iCloud-based Healthcare Phone Watch

Once as one of oral examination committee members for President Ying-jeou Ma who took Level A of the Special Examination in early years, the retired Professor Chien-Han Chang from National Taiwan University got lost on Nov. 3, 2013 when going for a stroll. A large umber of police and firemen searched the Four Beast Mountain in Taipei City and finally found Chang who has suffered from bruising on hands and feet in a 10-meter deep narrow valley, at nightfall on Nov. 6. He was fine after being rushed to hospital. According to judgment by Police and firemen, 85-year-old Chang survived with rainwater and it's really a miracle that he could survive when police and fireman reached for a rescue.

Taipei City Fire Department indicated that a human can probably live for about 3 days without any water and foods. Chang might slip and all to the deep narrow valley when rain was involved, but was fortunate enough to avoid the strong northeasterly wind in evening; despite the lack of prepared foods to appease his hunger, he drank rainwater to sustain his life. He was able to cry for help in a weak voice when police and firemen found him, while he could climb the narrow valley under ambulance men's support.

Having arrived in Taiwan with the Chinese Nationalist (Kuomintang) government which retreated to Taiwan in 1949, Professor Chang is a martial law expert who once was the Chairman with the Department of Politics and Dean of College of Law at National Taiwan University. Chang was one of oral examination committee members for President Ying-jeou Ma who took Level A of the Special Examination in early years. Chang has retired from National Taiwan University for 17 years and is a mentor for a number of politicians. His research interests include constitution and administrative law.

GPS Positioning Watch to Locate Missing People

After retirement from NTU, Professor Chang has lived an unworldly life by always taking a stroll and participating in mountain-climbing activity. On Nov. 3, he was on his way to the Four Mountain for a hiking but didn't return home that evening. His family members reported the case to Taipei City Police Department Xinyi Precinct next day and offered police Chang's GPS watch to send text message that showed he was in the area of Four Beast Mountain. Despite the fact that this watch is equipped with functions of easy answering phone calls and monitoring body temperature, no one was available that might be attributed to poor message in mountain area.

Despite a massive searched the mountain by police and firemen, position detection of the healthcare phone watch is within a range of 2-km radius. Police and firemen kept searching for culverts, groves and valleys for three days in a futile attempt. Chang's anxious family members sought internet assistance on Nov. 6 through NTU. Police and firemen originally planned to call for rescue crews temporarily suspended search efforts at nightfall, but message of Chang's watch position re-appeared that the rescue crews decided to continue the search with flashlights.

At 17:09 in the vicinity of the trailhead in Lane 650, Songshan Rd., police and firemen finally heard a cry for help in a weak voice from the valley, and shone their flashlights down it and found someone keep waving hands. The ambulance men went down the valley by a rope for observation and inspection and confirmed the man trapped in the valley was Professor Chien-Han Chang who had missed for three days. Chang has suffered from bruising on hands and feet but is in a state of consciousness and has kept saying that he has a wolf in his belly.

Chang was rushed for the hospital and was in fine condition. According to of Yao-Chen Wang, Deputy Commander of Second Corps of Taipei City Fire Department, Chang's GPS watch is equipped with the function of monitoring body temperature. On Nov. 5, his body temperature was 2 degrees higher than that on Nov. 4, showing no signs of hypothermia. Rescue workers judged that he survived by rainwater, and he could climb on the wall independently under the ambulance men's support that proves him a vigorous and healthy elderly. After being rescued, Professor Chang's family members visited to Guider Technology to show their appreciation for President Hsu and all colleagues, expressing that this state-of-the-art homecare phone watch designed for senior residents and residents with the disabilities by Guider Technology has saved Professor Chang's life.

Business administration theory applied in this case

Theory of business administration applied in this case:

1. e-business operation mode The models include at least B2C and B2B e-commerce models. Guider can directly sell this healthcare phone watch to customers, but must offer customers the first-aid care platform built by the company. Most of Guider's healthcare phone watches are sold through some large telecommunication providers commissioned by Guider, working with mobile number and Bluetooth wireless transmission of blood pressure and blood glucose meter. Through healthcare phone watch, these telecommunication systems will be connected to Guider's first-aid service platform that effectively implements intelligence care services.

2. Customer relationship management

Integrate intelligence care businesses, cloud-based medical health security system, automated physiological measurement and interaction health management platform, use more accurate and prompt methods to response related manufacturers and customers, and offer customers the custom-made services to increase the service quality and customer satisfaction and loyalty to achieve the goal of intelligence care business performance.

3. Technology Acceptance Model (TAM)

Put forward by Davis in 1989, TAM universally explains the decisive factors for end-user's degree of acceptance to information technology by using theory to verify and explain most of behaviors to use technology. Its theoretical foundation is to understand the influence of external factors on the user's internal beliefs, attitude and intention, and these internal factors further affect technology use conditions (Davis, Bagozzi, & Warsaw, 1989). According to studies, Davis thinks the main beliefs influencing attitude are Perceived Usefulness (PU) and Perceived Ease of Use (PEU). PU and PEU will affect a user's attitude to use technology that further affects their behavior intention to use, while behavioral intention further affects behavior to use, thus analyzing users' willingness to use information technology based on the user's PU and PEU of technology.

This healthcare phone watch designed specifically for senior residents and persons with disabilities by Guider Technology is the world's first platform focusing on home security of senior residents and ones with disabilities that integrates health management with interactive medical services and cloud-based interaction services, generally called as individual-based telemedicine care model. Through wired or wireless network, the RFID-based phone combines psychological monitor by sending physiological information, such as blood pressure and blood glucose, to patients' adult children who will know well their elderly parents' security, dynamic position and physiological measurement information through smartphone APP any time. With the development of wireless communication technology in the diffusion of wireless Internet access and the characteristic that telemedicine services not limited by place, there are several telemedicine care models that facilities applied and services offered also differ; only one new technology product which will earn favor from consumers who show willingness to use and feel satisfied with the results of use can be considered one successful system. Therefore, this paper uses Technology Acceptance Model (TAM) which is frequently used in information management as the theoretical foundation to delve into key factors influencing consumers or users' intention to use telemedicine.

(1) Radio Frequency Identification (RFID)

RFID which is acronym for Radio Frequency Identification is not an emerging technology but a technology already applied to radar in 1940's during WWII to identify data of friend or foe and transmit data of flying vehicle height, while the first RFID tag did not appeared until 1970s. In comparison with traditional bar-code system, RFID has the advantages of reading/writing data, large data volume, simultaneously reading multiple data, having no need to aim at object, being solid and not be easily counterfeited. Notwithstanding, the factors of volume or price makes the RFID's scope of main application in high price of commodities. Currently, R&D technology and inexpensive price have made RFID become popular with all walks of life.

As one method to identify specific articles through radio waves, RFID can be either active or passive. The typical RFID system is composed of three parts, including reader, tag and application system. Tag is inlaid with one microchip and the reader sends electromagnetic message. By antenna, tag receives electromagnetic messages transmitted by the reader by turning a part into energy needed for operation and sending the stored information. After read by the reader, the information will be sent to the rear end of application system for subsequent processing.

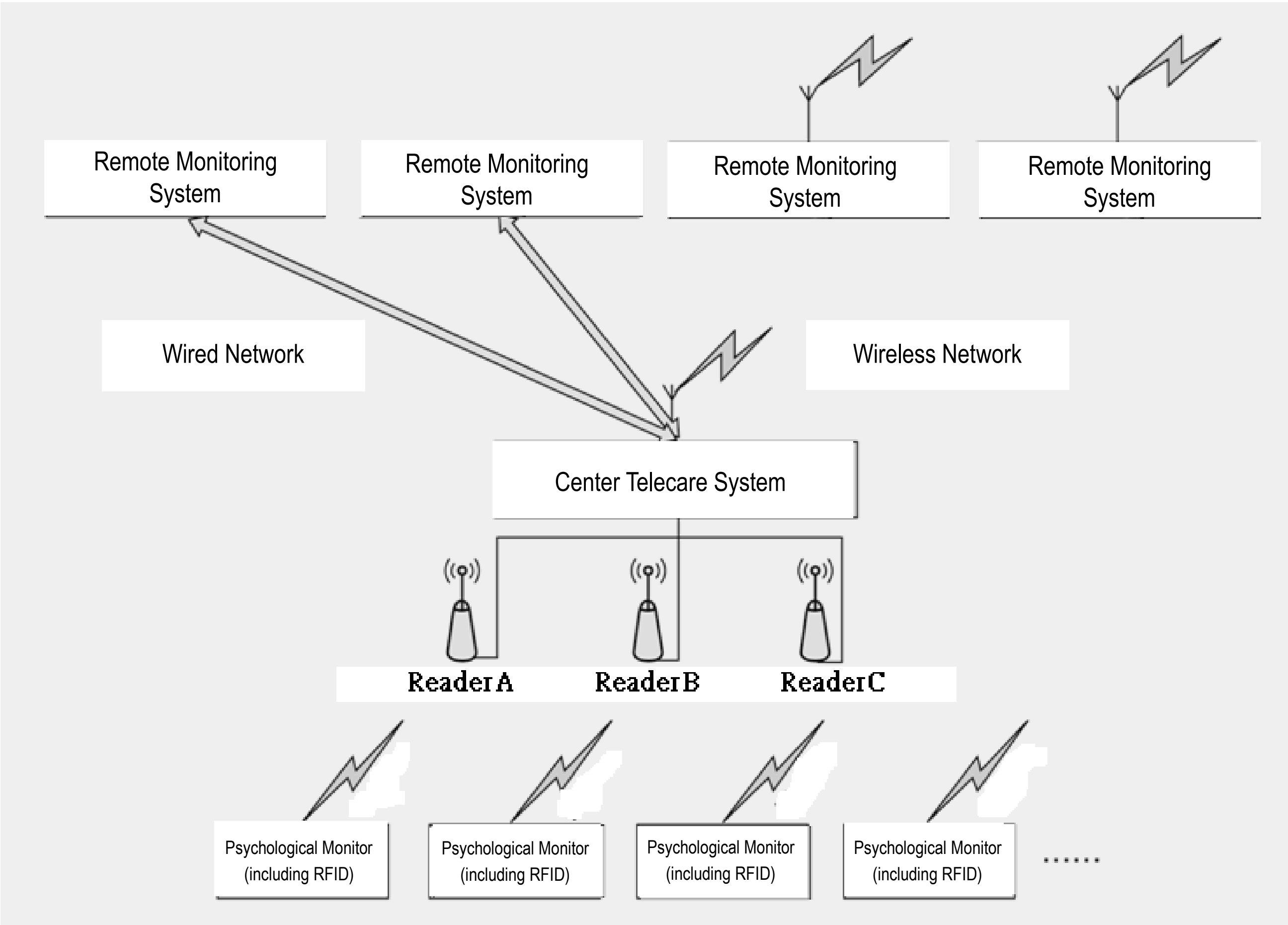
In summary, RFID gets physical world connected to information world to offer information through the object inlaid with chip and sensor; its unparalleled, identifiable status allows people to know well things happening all around them any time and can respond to each need timely; with its functions of identification and positioning, aside from being applied to access control system, warning, logistics, tracking, monitoring and logistic procedure optimization, the combination of RFID with WLAN can produce a powerful function of message exchange, and its wide applications can cover management of people, time, place and thing.

(2) A study of application of RFID on medical example

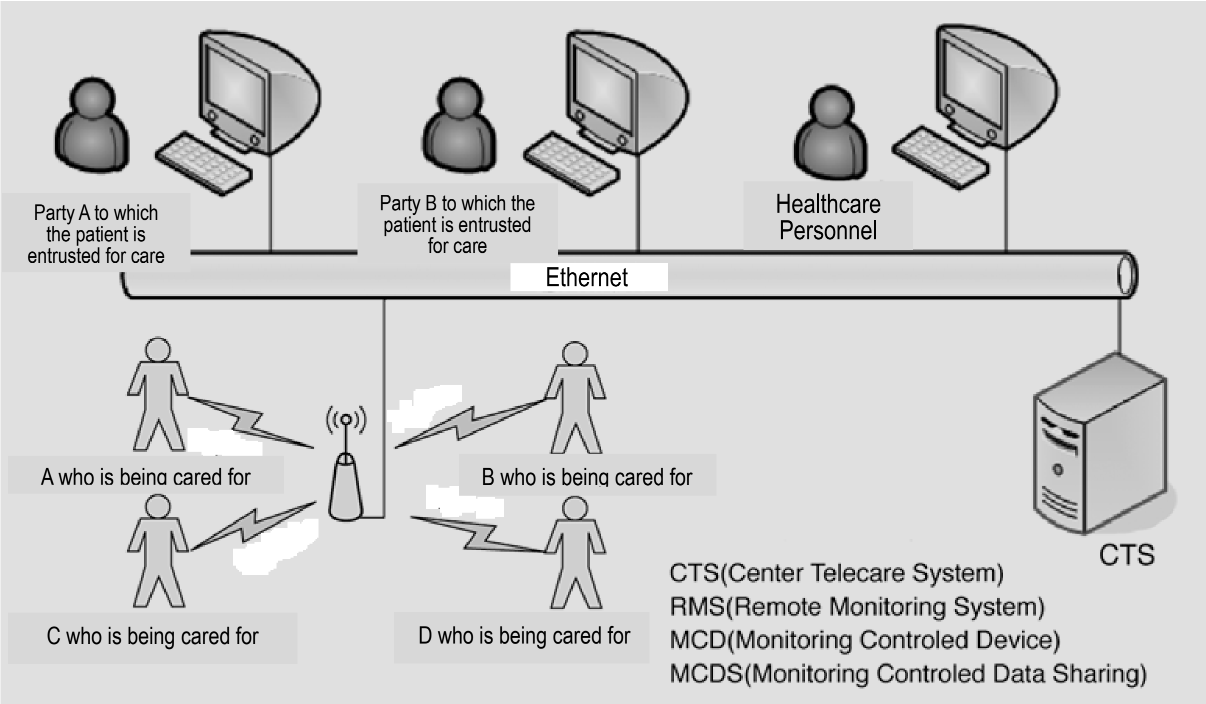
RFID technology has been widely used in many industries, such as information technology, logistics and retail sale industry, etc. In Taiwan, however, RFID was first used by medical institutions. Taipei Medical University Hospital, Show Chwan Memorial Hospital, Koo Foundation Sun Yat-Sen Cancer Center, Tri-Service General Hospital, Kaohsiung Veterans General Hospital, Ton Yen General Hospital and Chang Gung Memorial Hospital have made huge investment in introducing RFID to confirm patients' status and ways to use medicine and blood preparations through functions of identification and positioning for effectively implementing vector control and monitoring epidemic situation (such as control of nosocomial infection of SARS), zoning and quarantine control, and avoiding wrong injections administered, wrong meds given to patients and wrong blood transfusion. Some hospitals have applied RFID to intra-hospital and inter-hospital cooperation on telemedicine and senior care, to be working with the hospital's round-the-clock monitoring system and Internet and transmitting data of physiological conditions through RFID to the information system of medical station which can instantly learn if physiological conditions of the aged patients with chronicle diseases are abnormal before adopting appropriate medical treatments. Hospitals can even use smart computer for prompt information transmission by RFID to work in with patients' past medical records to compute valuable reference data to make doctors make comprehensive evaluations of patients' causes of diseases.

(3) Telemedicine system framework

Reader of RFID directly uploads information measured by physiological monitor to center monitoring telemedicine system through wired and wireless networks or gets information transmitted directly to the system, as indicated in the figure below:

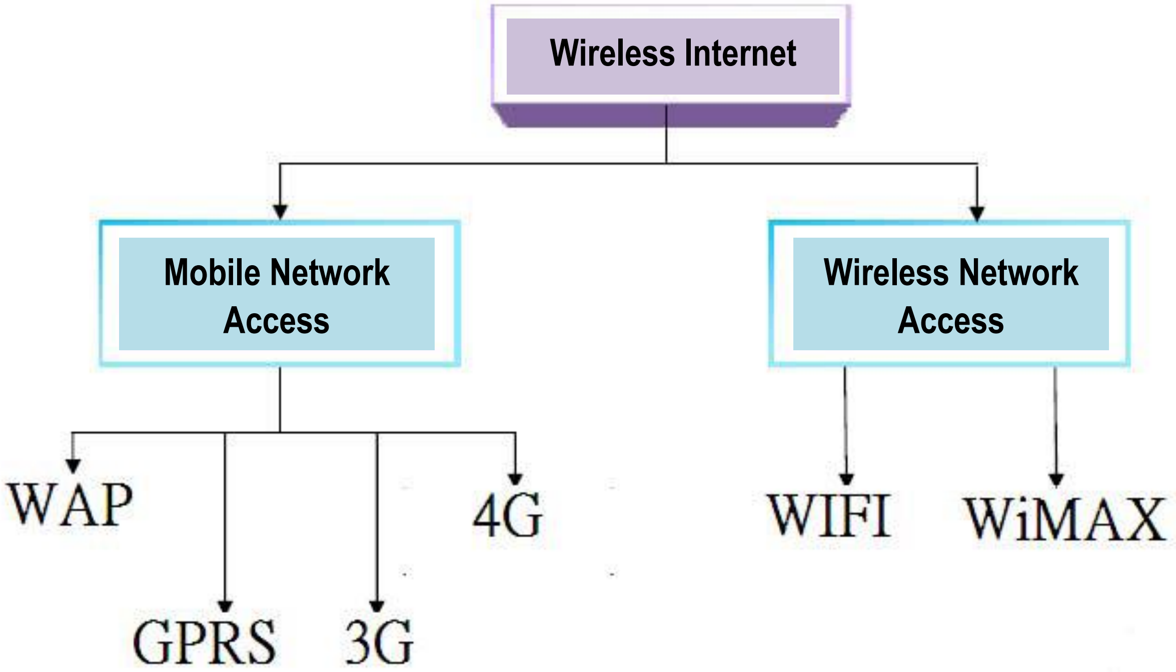


After being read by the Reader, monitoring information for one of being cared will be transmitted by internet to be recorded in server for processing before being presented to the party to which the patient is entrusted for care for monitoring. The controlled device is one set of physiological monitor which is programmed and has a RFID chip. Each remote monitoring system stores information to Center Telecare System through LAN, Internet and wireless network.



(4) Ways to make Internet connections

Ways of using wireless Internet access to make Internet connections include mobile Internet access, such as WAP(Wireless Application Protocol), GPRS(General Packet Radio Service) and 3G and 4G, and wireless Internet access, such as WIFI and WiMAX, as indicated in figure given below:



(5) The possibly derived business models
(5.1) Care center-based telemedicine care model
(5.2) Community-based telemedicine care model
(5.3) Individual-based telemedicine care model

(6) Technology Acceptance Model (TAM)

In studies delving into the end-user's behavior to use new information technology and system, Technology Acceptance Model (TAM) developed by Davis in 1989 is the most widely-used theoretical model. Much evidence-base research in the past has corroborated that TAM is one simple and effective theoretical model predicting the end-user's behavior to use, and it also has a high explanatory power on the end-user's behavior and intention to use a new information technology and system (about 40%).

Applicable Issues of this Case

1. What are the market needs for "cloud-computing based healthcare" in a population aging environment?

Telemedicine is the use of information and telecommunication technologies exchanged from one side to another to provide clinical health care at distance. Telemedicine combines computer, telecommunication technology and expertise of medical staff to make doctors hold video conference and carry out distance diagnosis that offers comprehensive medical care to residents in remote and outlying areas as well as opportunities of offering teaching and training to doctors and nursing staff.

ICloud-based system for healthcare is a concern-centered technology system, mainly providing children, parents and senior residents ，offer different ages of residents the all-round health management services to secure the health of your family members.

According to Okamoto Yutaka, a leading Japanese neurosurgeon: hypertension, diabetes, hyperlipidemia, hypercholesterolenlia, obesity, gout, constipation, gastric ulcer, headache, Muscular pain in lumbar, allergy, insomnia, and autonomous nerve dysfunction, etc., which constitute 90% of diseases among out-patient services. Can you image that patients can be treated by not necessarily taking medicines? He indicates that a “smart” patient has a higher probability of being cured than that of a “good” patient in the doctor’s mind.

As what indicated in the preceding paragraph, the current cloud-based healthcare allows the users’ adult children, seniors and the elderly carry out their health management autonomously by using assisted medical devices to record and upload data of their health conditions to database that will be directly managed by professional medical team for disease improvement.

For current conditions of the existing hospitals, insufficient manpower usually leads to the establishment of one room in some public areas and care stations with several devices offered (such as blood pressure meter, blood oxygen meter) that allow patients to measure their health status by themselves, and seek assistance from medical staff for any problem emerged, while it usually produces one sheet of data after the measurement that gives no systematic management and automated care mechanism to the measurer. The condition of limited manpower only make hospitals wait patients passively or the patients will receive first aid and treatment procedure after having an accident that makes preventive and management mechanism can hardly be carried. The final result turns out a treatment-centered and care-assisted model.

ICloud-based healthcare security applications:

Understand your own health	The health measurement information station measures the user’s weight, body fat, height, blood pressure and vital capacity to be uploaded to database for statistical results.
Detailed health change chart	Upload the user’s individual health conditions to database through health measurement station before interpreting statistical results on chart of changes in health conditions.

Professional medical team	Professional medical team analyzes the necessity of improvement for the user's life style through the chart of changes in individual health conditions uploaded by health measurement station.
Individual prescription	By means of chart of changes in health conditions, professional medical team issues health improvement prescription based on the user's individual health conditions through health status change chart.

The population of elderly persons living alone in Taiwan has been gradually increasing that saw a unique phenomenon in many families: one son or daughter never wants to get married, and even gives up his/her job for work-at-home jobs (SOHO) to accompany their parents or their relatives with disabilities. There are a number of small apartment-based caring institutions of varying quality in communities that poor living environment, abuse fire or flood have emerged, as even the insufficient medical staffing has given rise to the condition that no one came to rescue flood-soaked senior residents and ones with disabilities.

It is estimated that over 34,000,000 Americans which constitute 15% of the total population rely on cloud-based telecare mode to take care of their elderly parents who live in areas within a one hour distance from their children. What they are concerned about is the quality of cloud-based telecare mode. In Taiwan, only National Taiwan University Hospital has established Telehealth Center offering its members the 24-hour cloud-based telecare services. Currently, it's still in the activity promotion phase offering 2-week free trial that leaves room for business expansion.

2. What kind of intelligence electronic technology do elderly population and persons with disabilities need? What factors shall be emphasized and considered for its R&D and design?

As users of care-based intelligence electronic technology are seniors or elderly population and persons with disabilities, operations of such care product shall never be too complex but quick and easy operation. This product has four functions. The first function features 24-hours emergency SOS: the user just presses the emergency button when any accident occurs, and the message will be immediately sent to emergency rescue center or the user's family members; fall detection is the second function features: the device will be automatically connected to the user's family members when a fall accident occurs, and the device directly connect to the emergency rescue center if there is no response from family members; care service is the third function: through the cooperation with hospitals and care centers, a user can use intelligence electronic technology to receive medication consultation from the hospital as well as meal services based on his needs, and the care center can use intelligence electronic technology to remind the user of taking medicine and returning to the clinic for a check-up; the fourth function features the integration of information about the user's blood pressure, blood oxygen and blood glucose meter. Through the linked blood pressure, blood oxygen and blood glucose meter, the data measured by the user will be automatically uploaded to internet platform that allows care centers or family members to understand the user's physical conditions any time.

3. What kind of e-business operation model can Guider's healthcare phone watch adopt?

The models include at least B2C and B2B e-commerce models. Guider can directly sell the healthcare phone watch to customers, but must offer customers the first-aid care platform built by the company. Most of Guider's healthcare phone watches are sold through some big telecommunication providers commissioned by Guider, to be working with mobile number and Bluetooth wireless transmission of blood pressure and blood glucose meter. Through healthcare phone watch, these telecommunication systems will be connected to Guider's first-aid service platform to effectively implement intelligence care services.

4. How do smart electronic products increase customer relationships?

Integrate intelligence care business, cloud-based medical health security system, automated psychological measurement and interaction health management platform for more accurate and prompt methods in giving response to related manufacturers and customers, thus offering customers the custom-made services that increases customer service quality and customer satisfaction and loyalty to achieve the goal of intelligence care business performance.

5. How is the TAM for Guider's healthcare phone watch?

Put forward by Davis in 1989, TAM universally explains the decisive factors for an end-user's degree of acceptance to information technology, using theory to verify and explain most of behaviors to use technology. Its theoretical foundation is to understand the influence of external factors on the user's internal beliefs, attitude and intention, and these internal factors further affect technology use conditions (Davis, Bagozzi, & Warsaw, 1989). According to studies, Davis thinks the main beliefs influencing attitude are Perceived Usefulness (PU) and Perceived Ease of Use (PEU). PU and PEU will affect a user's attitude to use technology, further affecting their behavior intention to use, while behavioral intention further affects behavior to use, and analyze users' willingness to use information technology based on the user's PU and PEU on technology. This healthcare phone watch designed specifically for senior residents and persons with disabilities by Guider Technology is the world's first platform focusing on home security of senior residents and ones with disabilities that integrates health management with interactive medical services and cloud-based interaction services, generally called as individual-based telemedicine care model. Through wired or wireless network, the RFID-based phone combines psychological monitor by sending physiological information, such as blood pressure and blood glucose, to the users' adult children who will know well their elderly parents' security, dynamic position and physiological measurement information through smartphone APP any time. With the development of wireless communication technology in the diffusion of wireless Internet access and the characteristic that telemedicine services not limited by place, there are several telemedicine care models that facilities applied and services offered also differ; only one new technology product which will earn favor from consumers who show willingness to use and feel satisfied with the results of use can be considered one successful system. Therefore, this paper uses Technology Acceptance Model (TAM) which is frequently used in information management as the theoretical foundation to delve into key factors influencing consumers or users' intention to use telemedicine.

6. How can the Guider's healthcare phone watch increases customer satisfaction?

The healthcare phone watch designed specifically for senior residents and persons with disabilities by Guider Technology is the world's first platform focusing on home security of senior residents and ones with disabilities that integrates health management with interactive medical services and cloud-based interaction services. This state-of-the-art watch features integration services composed of phone-based position sensing watch (intelligent terminal)+cloud-based prompt interaction services(elderly LOHAS)+smart phone App(family members can know well the important messages any time)! This healthcare phone watch features great functions of emergency call, GPS base station positioning, reminder of abnormal temperature, possible fall detection, informing the patients of taking medicine and return to a clinic for a check-up, Bluetooth single-key psychological measurement and upload, speed dial keys set up for the user's adult children, touch screen, and water-proof performance. LOHAS Cloud offers information of prompt calling-or-help and fall position warning, abnormal temperature message, physiological measuring data, taking medicine and return to the clinic for a check-up, and it also offers medical service units the synchronous database and advanced services. Smartphone app allows patients' adult children to know well their elderly parents' security, dynamic position, psychological measuring information, security and health conditions any time and advanced medical health interaction services.

Interview and questionnaire survey results have indicated the correct current design concept and development direction for Guider's healthcare phone watch; in view of low birthrate and ageing society in Taiwan, there's room for development based on the following aspects to increase customer satisfaction:

1. Easy operation: Most of seniors and persons with disabilities lack certain understanding of
intelligence electronic technology products, and operations of these products shall be simplified to achieve the goal of self-operation independently.

2. Multiple custom-made products: seniors and people with disabilities have different needs for functions of intelligence electronic technology products due to different physical environments in which they live. For example, users who live in groups to receive care services, including health measuring services by medical staff, offered by medical units need GPS satellite positioning system function to prevent them from getting lost when they are out. If we can design custom-made easy functions for individual seniors and persons with disabilities to meet their special needs and get the price of such product down, this product will become more competitive in the market.

7. How can telecare center and healthcare phone watch build a role of complementing each 5 **other?**

Telecare center and healthcare phone watch complement each other; only when telecare centers show willingness to offer care services for seniors and persons with disabilities wearing healthcare phone watch can these centers achieve the ultimate goal of cloud care. Guider is cooperating with Taipei Medical University (TMU) in cloud-based care, while TMU-Wan Fang Hospital thinks that Guider's healthcare phone watch is a little complex in its operations that is not suitable for cloud-based care platform. Both sides need to enhance their communication to reach consensus on cooperation that will offer Guider a stage of development for its products designed by its R&D team after years of efforts.

8. How will graduates with degrees in computer science and information systems

develop their career in cloud-based care related intelligent electronic industry?

Cloud-based healthcare related smart electronic industry is going to become an important emerging industry in Taiwan which has already entered the aging society that will meet needs of seniors and persons with disabilities. Therefore, there are plentiful job opportunities offered by pioneering manufacturing and service industry awaiting for graduates with degrees in computer science and information systems to launch their career.

9. What is the market niche for GPS healthcare phone watch of Guider Technology? How to increase the market competitiveness?

As the subjects using the healthcare phone watch are seniors, operations of this watch shall never be too complex but easy and quick. This healthcare phone watch has four main functions. The first function features 24-hour emergency rescue: the user presses the emergency button when an accident occurs that connects the watch to emergency rescue center or the user's family members immediately; fall detection is the second function: when fall accident occurs, healthcare phone watch will automatically make contact with the user's family members; if there is no response from family members, the watch will be directly connected to emergency rescue center; the third function features care services as the user can use healthcare phone watch to receive medication consultation service from the hospital and enjoy meal services based on his needs through cooperation with the hospital, while the care center can remind the user of time to take medicine and return to the clinic for a check-up through healthcare phone watch; the fourth function is the service integrating data of blood pressure, blood oxygen and blood glucose meter; by the linked blood pressure, blood oxygen and blood glucose meter, healthcare phone watch will automatically upload users' measuring data to Internet platform, making healthcare centers or family members understand users' health conditions any time through internet platform.

Development for healthcare phone watch differs domestically and abroad, and Taiwan's higher medical level leads to people's higher willingness to accept this product. With regard to the similar practices in Spain and France, such promotion is launched by local governments, and there is no such kind of product in the market with its functionality same to that of Guider's healthcare phone watch. Though there are mobile phone watches available in the market, most of these products are fashion-centered, while design for Guider's healthcare phone watch is motivated with innovative services. In recent years, a growing awareness of healthcare, domestically and abroad, has seen an increasing degree of acceptance for healthcare phone watch has been increased. Guider's future business strategies and goal focuses on international market as the network by selling hardware first and linking it with each care service, gradually turned into the value-added service platform which uses B-B-C framework for market diffusion:

1. In the respect of telecommunication system, we have worked with Chunghwa Telecom, Taiwan Mobile and Far Eastone Telecommunications served as cloud-based management of senior residents in using healthcare smartphone.

2. We have worked with hospitals affiliated with TMU to build a patient-physician based care model to be served as cloud-based telecare management on healthcare smartphone APP for seniors.

3. We will work with more manufacturers in the future to design more smartphone applications of seniors' healthcare.

10. Why Guider cannot get the price of its healthcare phone watch down? How will Guider Technology deal with the fact that many seniors and persons with disabilities cannot afford such a high price?

Due to its high price, most of consumers cast some doubts when preparing to purchase healthcare phone watch. Notwithstanding, innovative services offered by this healthcare phone watch make many consumers accept this product. We plan to further work with other industries in the nature future to increase the value of healthcare phone watch which will be promoted through alliance power

Summary

Telemedicine is the use of information and telecommunication technologies exchanged from oneside to another to provide clinical health care at distance. Telemedicine combines computer,
telecommunication technology and expertise of medical staff to make doctors hold video conference and carry out distance diagnosis that offers comprehensive medical care to residents in remote and outlying areas as well as opportunities of offering teaching and training to doctors and nursing staff.

Healthcare Phone Watch by Guider Technology Co. try to build iCloud-based system for healthcare，**it** is a concern-centered technology system, mainly providing children, parents and senior residents， offer different ages of residents the all-round health management services to secure the health of family members.

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The Bags that Package Themselves

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Abstract

In the first application of TRIZ within the S. C. Johnson Corporation, a challenge for TRIZ application was the reduction in labor cost, handling costs, and sterilization costs related to a new approach to transitioning Saran™ Wrap from a conventionally rolled film product, similar to many other plastic wraps, into a more consumer friendly form, which is best described as a “hair net” bag, which could be stretched over a bowl or container without concerns about the film tearing prior to its use. This paper describes the TRIZ approach to this problem and the new product (Saran Bowl Covers™) developed from the use of basic TRIZ principles.

Keywords: Ideal Final Result, resources

Saran Wrap™ is a well-established consumer product brought to market by Dow Chemical many decades ago. It is distinct from most other plastic food wraps based on polyethylene. Polyethylene has acceptable barrier to moisture, but poor resistance to oxygen transfer. This limits its ability to protect certain fruits and vegetables whose spoilage is accelerated by oxygen.

Saran™ is a unique polymer, being a copolymer of vinyl chloride and vinylidene chloride. Its chemical and polymer composition provides a significant barrier to oxygen transfer. It is also an inherently more expensive polymer to manufacture since its raw materials are derivatives of the polyethylene used in the less expensive polymers. It also has a significant drawback compared to polyethylene in its much lower longitudinal tear strength, meaning that as the film is pulled from the roll, it has a much greater tendency to split and tear. Since the film is clear, the user has difficulty identifying where the film has torn. Attempts were made over the years to provide a marking mechanism on the roll to assist the consumer, but many consumers simply reverted back to their use of the less expensive, but lower barrier polyethylene films.

When Dow went through a restructuring in the early 1990's it sold off its consumer product brands to S.C. Johnson, a well-respected and well known consumer products company. S.C. Johnson, when inheriting the Saran Wrap product, recognized the potential in changing the form of the final product sold to the consumer. It considered the possibility of taking the basic polymer film (still supplied by Dow Chemical) and manufacturing an expandable, stretchable "hair net" bag. This bag, while more difficult to manufacture, would eliminate entirely the "split and tear issue", and allow a user to stretch the bag over a variety of container sizes. It is illustrated here:

The process envisioned to manufacture this product was to export the raw film to a third party source overseas which would shape it into a banded hair bag, assemble ten of these into a package by wrapping them in a rubber band, and then shipping large cargo containers of these bags to S.C. Johnson's primary plant in Racine, WI (USA) where these steps would be performed:

1. Unwrap the bags by removing the rubber band

2. Grabbing the unwrapped bags and manually stuffing them into something resembling a cottage cheese container, and finally putting a lid on the entire assembly.

3. Appropriate sterilization of the bags due to being touched by human operators.

A number of issues developed in the implementation of this process:

1. The labor difficulty in putting a rubber band (double banded) around a set of bags which naturally are trying to expand

2. The packaging density and overseas shipment time back to the US resulted in severe compression of the assembled bag packages.

3. When it was attempted to remover the rubber band, the bags had a natural tendency to expand rapidly "fly away" from the operator trying to recover them and stuff them into the final container.

4. Human factors and ergonomic issues were an indirect result of this process.

Improving this process was the first major project to be attacked with TRIZ after a general site-wide general training session.

A team of S.C. Johnson personnel were assembled to utilize TRIZ principles to attack this problem. After a brief review of the general training received, the group started with a discussion of the most basic of TRIZ principles, the Ideal Final Result or IFR. Most TRIZ professionals would recognize that it is necessary to see the use of the word(s) itself, themselves, or something similar in such a statement. It is also necessary in making this statement that HOW this will be achieved is not a consideration at this stage. After some coaching and discussion, the concept of "the bags package themselves" was an agreed upon IFR.

The second stage of our algorithm says that we should look for available, preferably low cost and already existing, resources. When one looks at this system, we can list the following:

1. Bags

2. Rubber bands

3. Human resource (I.e labor)

4. Packaging and material movement machinery

5. Physical and potentially modifiable properties of the bags, their polymers, the rubber bands and their polymers

It is also possible to look at this problem from the standpoint of the TRIZ principle of making a system more "ideal" by trimming an expensive or trouble causing component. In this case it is the rubber band, which requires a large amount of labor to put on and later take off.

Regardless of which approach is taken, using the resources we already have (the bags) or eliminating (trimming) the annoying rubber band, the group came up with the concept of simply packing 9 of these bags into the tenth bag, eliminating the need for a rubber band, any expensive rigid final package, producing the product shown here:

The "9 bags into the tenth bag" product would still be produced overseas but with far less labor cost and upon arrival in the US, the entire process of moving the bag assemblies into a final display package could be automated significantly. This product could be displayed on a hanging rod on a store "wall", minimizing shelf space and packaging costs. Since it also minimized the need for human operators, the costs for sterilization were significantly reduced.

This project demonstrated the powerful impact of the most basic of TRIZ tools: The Ideal Final Result and the identification and use of readily available resources to dramatically reshape a product and process redesign.

▪References

(None)

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Systematic Innovation for Computing

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Abstract

There have been a variety of applications of TRIZ and Systematic Innovation (SI) techniques to the disciplines of computing and software development. When these computing system analyses are directed specifically towards a system's computing hardware it is a somewhat straight forward endeavor of standard TRIZ and systematic innovation employed for electro-mechanical/thermal systems. However, the application of TRIZ and systematic innovation to only the software sub-component of a computing system is not only problematic but also fundamentally misguided in its rationale. As stated, software is simply a single component, or multiple components, in a larger system which most likely serves as a control system for some even greater physical system. Granted the software component is unique in that it has virtual characteristics, but the software/coding is a component none the less. One of the fundamentals of TRIZ is that it helps to identify and resolve contradictory requirements between system components. TRIZ is not effective when applied to individual components or when visibility to the larger system is not available to shed light on the functional requirements of the components.

Unfortunately many of the attempts to apply TRIZ and systematic innovation to software have been met with less than desirable results. The lackluster outcomes are a consequence of two misunderstandings: 1.) that the non-tangible software is a functional tool in and of itself and 2.) that it is sensible to improve the design/functionality of a single component operating within a larger system by analyzing that component as if it were a standalone entity. Attempting to improve a piece of coding by analyzing it in and of itself is analogous to attempting to improve a musical score without any thought or attention to the musical instruments (at the micro level), or the orchestra (at the macro level), that the music has been written for. While syntax changes may very well result in some improvements in the software/code operation or effectiveness (an optimization attempt), the gains over the functionality of the basic code (assumed to be already operational) will be limited. In fact, the only way to effectively improve a piece of coding, as far as its ability to substantially improve its affect as to the operation of the system to which it is assigned, is to understand the interface and interaction of the coding within the overall system. Only then can meaningful changes be made to the coding based on understanding the needs of the larger system. This analysis can never be accomplished based solely on the examination of the software itself.

The paper will describes a systems engineering approach to analyzing and improving computing systems which sometimes requires coding changes and which sometime can be improved by changes to other portions of the overall control system.

Keywords: Software, Computing, Innovation, Systems Engineering, Control Systems

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1. Introduction

According to the Gartner Worldwide IT Spending Forecast "...worldwide dollar-valued IT spending will grow 3.2% in 2014..., reaching $3.8 trillion as the world economy gradually recovers."[1] This level of spending signifies that IT is seen as a crucial component in most every commercial and government operation worldwide. It is no wonder that businesses are looking for ways to innovate in the software development space. As a result of the pressure to improve coding development and effectiveness many have attempted to apply TRIZ and Systematic Innovation techniques to the discipline of programming, usually with lackluster results. The primary reason for the less than desirable affect of TRIZ/systematic innovation on the world of syntax is the shortsighted focus of looking only at the software. In fact, most everyone who has ever asked me about the application of TRIZ to software only wants to analyze, and therefore "fix," the coding itself. However, a piece of coding is without exception but a single component, or several components, within a much larger and more complex engineering system. Further, the computing system the coding operates within most often fundamentally serves the purpose of being a control system within an again larger engineering system. Why is it then that so many have concentrated only on the coding when trying to improve their programming? Isn't that very much like an automotive engineer, who wants to improve the operation of the cam shaft, only analyzing the cam shaft (one of the devices that controls and orchestrates the engine) and ignoring all other system components while doing so? This appears to be a technique limited to marginal affect.

Because of the poor results of previous software innovation attempts a more fruitful method for software innovation has been developed. The technique is the best way to gain innovative insight when working to improve an engineering system that includes a computer based control sub-system. The methodology, also known as SI for Computing, combines modifications of several traditional TRIZ and systematic innovation techniques in a process that provides enhanced insight towards the goal of innovating computer based engineering system. The following materials will discuss SI for Computing's: Capabilities Maturity Model Integration (CMMI) process inspiration, utilization of systems engineering analysis as the basis for the method and finally additional features that allow for its effective usage in a variety of scenarios.

It should be noted that a glossary for "words of art" utilized within this paper is included just prior to the references.

2. Capabilities Maturity Model Integration (CMMI)

The Capabilities Maturity Model Integration (CMMI) process improvement methodology demonstrated that poor software is not a development issue but rather a system analysis and integration issue. "CMMI was developed by a group of experts from industry, government, and the Software Engineering Institute at Carnegie Mellon University. CMMI models provide guidance for developing or improving processes that meet the business goals of an organization. A CMMI model may also be used as a framework for appraising the process maturity of the organization."[2]

CMMI was originally designed for the support of software engineering processes but has since been expanded for general product and service development, among other applications. According to the Software Engineering Institute (SEI, 2008), CMMI helps "integrate traditionally separate organizational functions, set process improvement goals and priorities, provide guidance for quality processes, and provide a point of reference for appraising current processes."[3] As can be seen in "Figure 1 - Characteristics of the CMMI Levels" organization's processes are rated on five levels of maturity. The higher maturity ranking an organization's processes receive the more effective and robust software those processes are capable of developing.

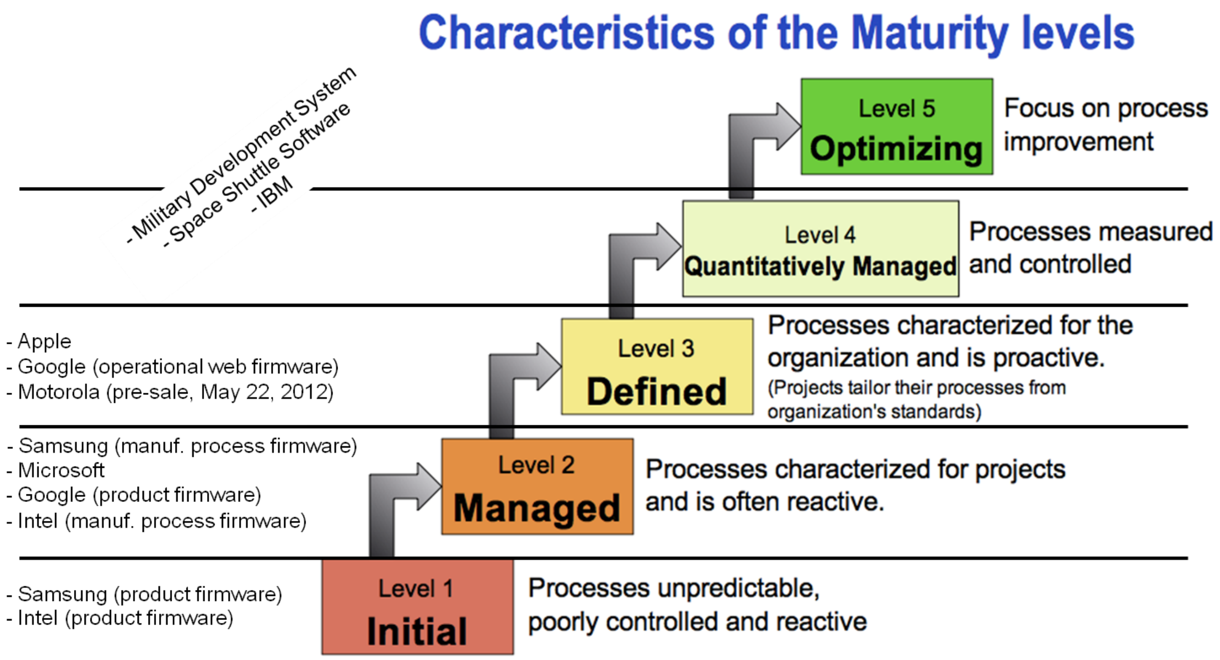

Figure 1 - Characteristics of the CMMI Levels [4]

Organizations whose processes are ranked at the lower levels (one and two) mistakenly believe that their software developers need more skills and that they will then write better and more effective coding. However, in fact there is probably little to no difference in the ability of the programmers within those CMMI level one and two organizations than those employed by the organizations in the upper echelon levels of the CMMI. So then why do the programmers working within organizations with processes ranked at CMMI levels three, four and five consistently produce high quality software? The answer is surprisingly simple. Among other attributes, higher level CMMI organizations utilize elevated degrees of organizational coordination, customer input, feedback and understand, and control their projects from a full systems level approach (in so far as both the software development process and the engineering system the software is being developed for). It sounds obvious but the extent to which programmers interface with the end customer, and better understand the entire system they are coding for, the more robust and effective coding they write. However, organizations with processes ranked at CMMI levels one and two most often throw programming chores to their software developers treating their task as a necessary evil in finishing a larger project. Referring again to "Figure 1" it can be seen that both Intel and Samsung Electronics are believed to be ranked at CMMI levels one and two. When you step back and consider that both Intel and Samsung Electronics' primary business is hardware design and manufacturing it seems more likley that they would treat firmware for those products as a task rather than a product in and of itself. Contrary to that approach, organizations whose processes are ranked at the upper CMMI levels treat the software they development as a products and expect it to be orchestrated with their, or their customer's, full engineering systems. It is this last attribute of understanding the software coding requirements form a full systems engineering analysis standpoint that prompted my initial jump into developing the systematic innovation for computing process (SI for Computing).

3. Systems Engineering Analysis

Systems engineering analysis is a process that drives to insure that all pertinent aspects of a system are considered and integrated into a single study. There are many models that can be effectively used within a systems engineering approach but the method that best integrates with TRIZ, and other systematic innovation methodologies, is functional modeling. Functional modeling is a system analysis method which considers functional relationships between a system's components. A graphical representation of a functional model depicts the system's components and connects those components with arrows showing the functional relationships between those components. In other words, it depicts the affect the components have on each other. "Figure 2 - Generic Computer Based Engineering System Functional Model" portrays a simple functional model of a generalized computer based engineering system (*note - no insufficient, excessive or harmful functions are annotated outside of the air and heat components*). The beauty of a graphical functional model is that it focuses the analyst on what is import about an engineering system, namely the functional output of the system and the functions occurring between the system's components that create that functional output. It is through this function mapping that the requirements of an engineering system's computer control systems software can easily be established with little uncertainty.

The goal when functionally modeling a computer based engineering system should not be myopically focused on improving the software but rather on improving the system in general. Sometimes the system improvement pursuit does point towards the need for a modification of the control software/firmware. However, in other cases the system issues can be addressed at other locations within the engineering system. Just as with an engineering analysis of an electro-mechanical/thermal system the problem solver should never begin an analysis with a preconceived notion of which system component, or interaction, needs to be improved.

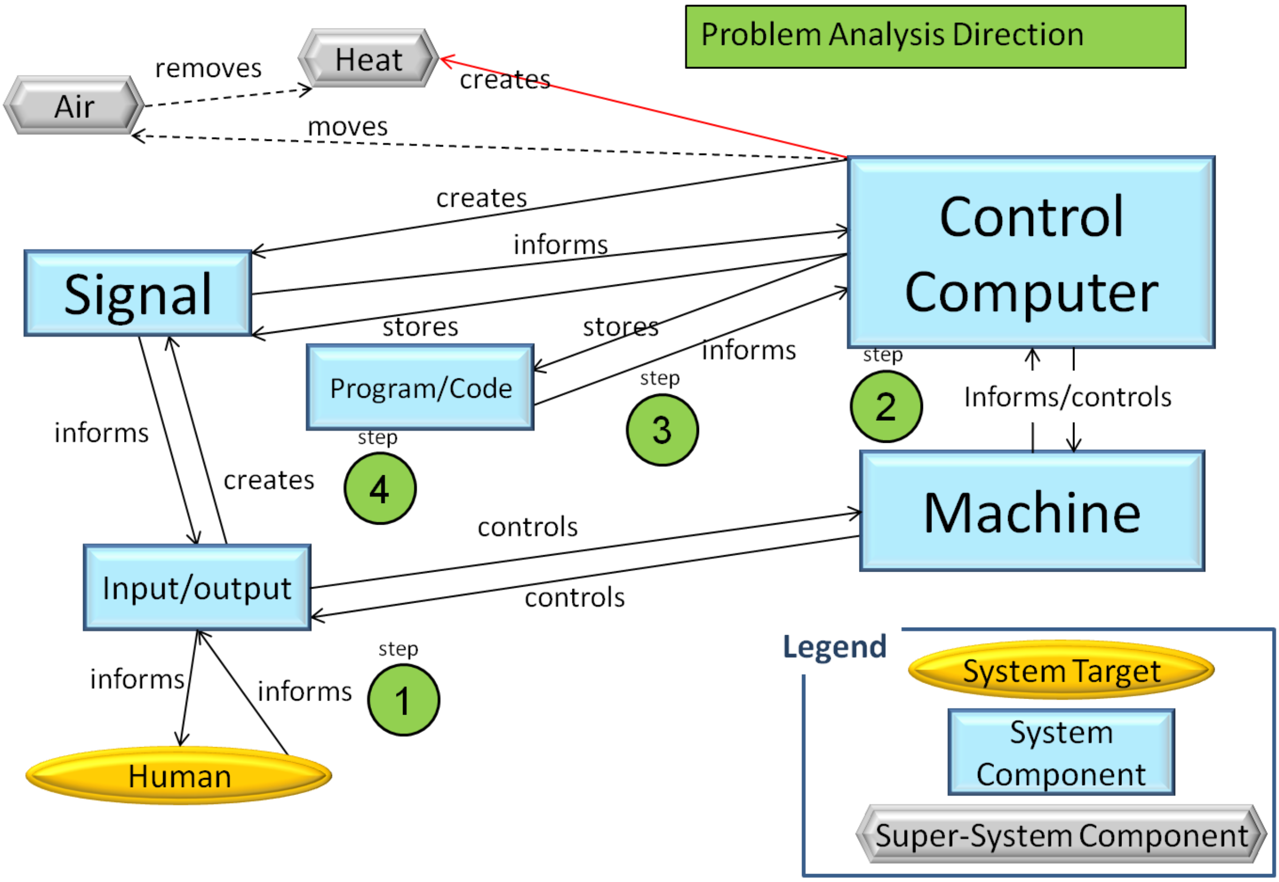

Figure 2 - Generic Computer Based Engineer System Functional Model

Pre-determining an improvement focus usually results in significantly limiting the improvement opportunities and therefore the overall results. In fact the first place an analyst should focus on is the basic function of the system. What is the basic function? The basic function of a system is a "useful function that acts directly upon the product of the functional model, also very likely to be the main function of the engineering system."[5] The reason it is best to start the analysis with this interaction is that the basic (or main) function is the most important function of the engineering system as this is where the systems functionality (or affect) is delivered. For example, a programmable thermostat has the job of measuring air temperature, deciding if the air temperature is within a pre-set range and then sending an on or off signal to the furnace. It is the function of signal *informs* furnace that is most important to the successful operation of the engineering system called programmable thermostat. If the basic function of signal *informs* furnace is judged to be insufficient then it is necessary to understand why. It should not automatically be assumed that the programmable thermostat's firmware is the problem. What if the signal wire from the thermostat to the furnace is of a smaller gauge than necessary, resulting in a high electrical resistance, in-turn not allowing the signal to reach the furnace consistently? In this scenario a simple signal wire upgrade might very well fix the problem. However, assuming wire gauge was not the problem then it would be necessary to continue working the analysis back through the system eventually arriving at the thermostats firmware. If the issue is found prior to reaching the firmware then the problem could be addressed elsewhere. For instance, maybe the system controller is not effectively exchanging data with the system's memory. In this case a hardware fix may be in order. The point is that while software changes may indeed fix issues occurring at other points in the system the software/firmware should never be focused on solely as the target of the analysis. With this in mind any computer based engineering system analysis should always start from the basic function and work its way back towards the software while asking the question - where is the principal issue in the system and where is the best location within the system to address that issue? More specifically:

1.) What is the relationship between the machine and the super-system (shown as a human in "Figure 2") and where can it be improved?
2.) What is the relationship between the machine and the control computer and where can it be improved?
3.) What is the relationship between the control computer and the software/firmware and where can it be improved?
4.) What is the relationship within the software/firmware itself and can it be improved?

"Figure 3 - Computer Based Engineering System Analysis Flow" illustrates the above with an analysis direction and focus that could be utilized when analyzing a computer based engineering system and refers directly to the numbered steps in "Figure 2."

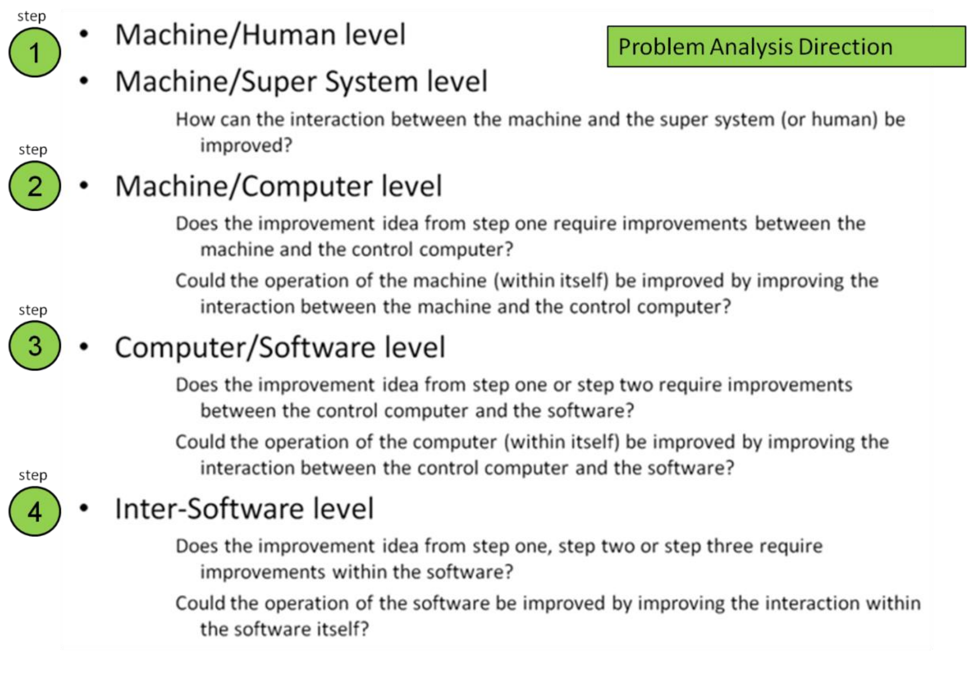

Figure 3 - Computer Based Engineering System Analysis Flow

Now that we have discussed the basics of functionally modeling a computer based engineering system there are a few more details that are important to the effective application of the functional model to this type of analysis. First is the delineation between the control system, the embedded/computing system and the coding. Second is the comprehension of the importance of identifying and understanding the interface and interactions between the physical world components and the control system in so far as establishing the software/firmware operational requirements. And finally, the modeling of the coding itself.

It is important to understand the boundaries, interactions and relationships between three hierarchically concentric, yet distinct, system levels within the computer based engineering system. Referring to "Figure 4 - Computer Based Engineering System Hierarchy" and starting from the inside and working our way out these sub-systems are: software/firmware, embedded/computing system and the control system. The software/firmware, embedded/computing system and the input/output devices constitute the control system. In relation to the management and operation of the greater engineering system, the most important sub-system (functionally) is the control system. The control system is made up of all the sub-systems that work together to create the function(s) that connect the virtual/digital computing components and sub-systems with the physical/analog "real world" sub-systems (e.g., display, hydraulic valve, relay, etc.). If the control system is designated as the engineering system then its output is of course a basic function and serves to ultimately control the super-system based target. For example, considering a motion activated security light, the control system would include the motion sensor (input device), computing/logic system and the relay (output device) that stops electrical current from reaching the light emitting device (see "Figure 4"). Moving deeper into the system the next functionally important sub-system is the embedded/computing system. This sub-system carries all of the components necessary to analyze input signals, make decisions and send output signals but it does not have the ability to connect to our outside "real" world. It can be seen that the embedded/computing system referred to in "Figure 4" is generically made up of a logic circuit, processor core, input/output device, analog/digital converter, signal, "logic" current, memory and code. The power supply may be considered as part of the embedded/computing system depending on whether or not that designation suits the analysis. Finally, moving even deeper into the system the least functionally important sub-system is the software/firmware. The software/firmware sub-system is actually a combination of the coding itself (a virtual component) and a memory module which serves as the physical location for the virtual software to reside and allows for the coding's interface and interaction with the other physical computing component. The inclusion of both the code and its residence (memory module) within the sub-system called software/firmware is important because the inclusion of the memory module allows for the modeling of the interactions of the coding with other components and the inclusion of the coding allows for the modeling of the system focused affects of the software/firmware. This view point produces sometimes small but often significant realizations about the functioning of the code within the embedded/computing system.

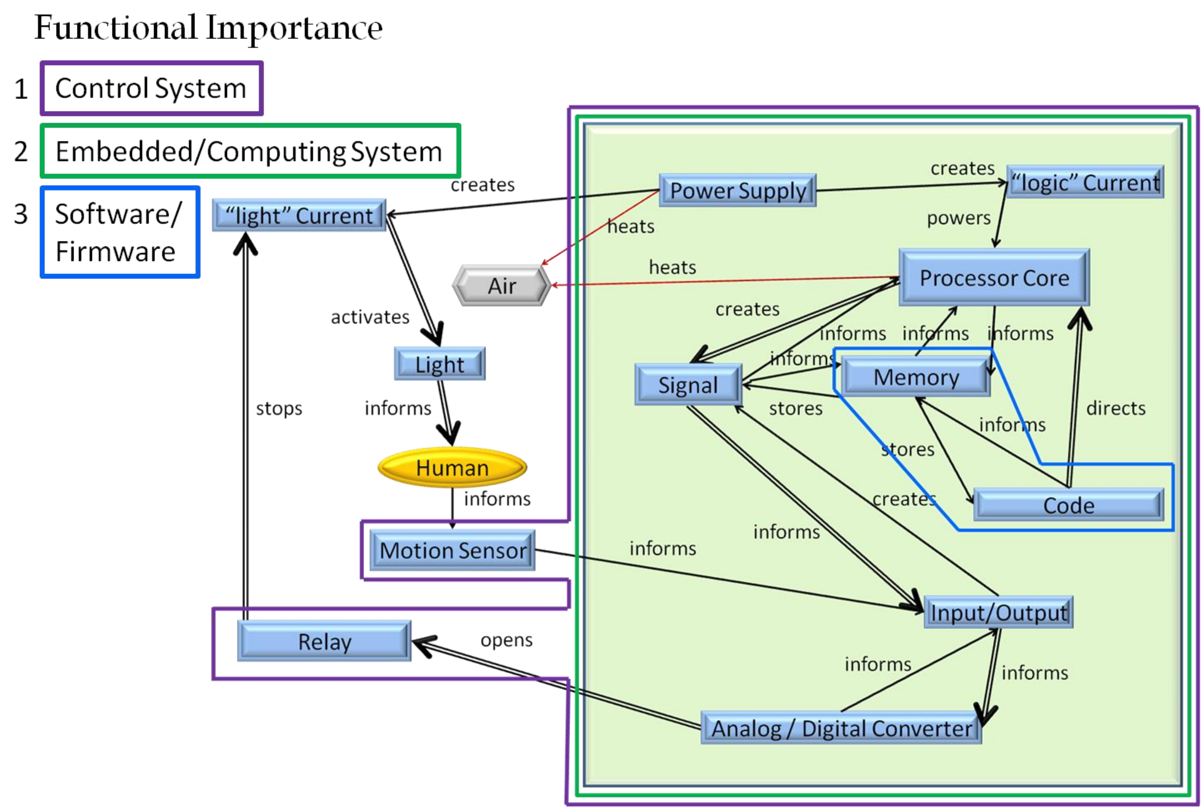

Figure 4 - Computer Based Engineering System Hierarchy

Now that we have defined the three concentrically arranged major sub-systems of the control system it is important to understand their inter-relationships. As we have learned the most important function of any engineering system is its basic function. In the example of the motion activated security light the basic function would be light *informs* human. Now stepping back to the outer most concentric control sub-system the most important function of that control system is the function that directly contributes to the delivery of the basic function. Again referring to the "Figure 4" the function created by the control system and affecting "outside" components is the function of relay *stops* "light" current. Therefore, the function of *stops* "light" current is the basic function of the control system and therefore its most important function of the control system. Furthermore, the auxiliary function of human *informs* sensor is also very important to the effective operation of the motion activated security light because it provides the input signal which triggers the control system. We now know that it is the input to, and output from, the physical/computing intermediary components (e.g., sensors, buttons, switches, relays, monitors, motors, etc.) that ultimately define the operational and performance requirements of the control system. In so far as effectively supporting the basic function of the entire engineering system it is these requirements, and these requirements alone, that the system's software architecture, design and syntax should be designed around.

Assuming that a systems engineering functional analysis indicates that software/firmware changes are in order then it may be necessary to model and examine the existing coding. Due to the immense complexity and sheer quantity of coding existing in most computer based engineering systems this pursuit has proven extremely difficult to most. The difficulties are exacerbated by the practice of attempting to model coding at the command line and syntax level. While it is sometimes possible to gain some limited insight around a focused analysis between a few software commands, the results often provide limited impact and can produce unforeseen complications elsewhere in the coding or greater engineering system. Similar to an example given in the introduction, if we are to improve the functional output of an internal combustion engine we would probably not attempt to do so by modeling the system at the lattice structure level of the engine materials. Analogously, trying to model coding at the command line or syntax level is equally futile. So then how do we model coding? According to Kevin Brune of Google Corp., "software is best functionally modeled at the module level." This is true because it is at the modular level that discrete functional inputs and outputs can be delineated and their interactions with other modules, and of equal importance with other embedded/computing system components, can be analyzed. Once again referring to "Figure 4" it can be seen that the "coding" is represented as a single component within the embedded/computing system. Let us now look at an example of how coding can be functionally represented at the modular level by examining "Figure 5 - Code Module Functional Model." The graphic in "Figure 5" represents a generic anti-lock braking controller with appropriate code modules depicted for such a device. Notice that we now have the ability to see how the various modules interact with each other, and with other components, within the embedded/computing system. Further, we can see how the memory module, part of the "coding" sub-system, interacts with other embedded/computing system components. In other words, it is now possible to analyze the code modules at the same hierarchal level within which the computer/controller components exist. It is now fairly straight forward for a systematic innovation analyst to create technical or physical contradiction models around any problematic relationships identified in the modular level functional model. As modeling at the modular level provides a clear understanding as to which other system components each module interacts with it will then be apparent as to where coding modifications might best be made to support the desired system improvements addressing the individual contradictions. Therefore, this modular level analysis not only points the analyst towards specific sections of code for improvement but also allows for the understanding of how any code changes will affect the greater system. This allows for a much easier evaluation as to how those changes will ultimately affect the overall operational system. This is the desired output of such an analysis because it is system operational improvements we are interested in. The improvements might be driven by coding changes but those coding changes, and the analysis goal, should be focused on improvements to the system, not the coding itself. For the more advanced systematic innovation practitioners it is suggested to apply substance-field (su-field) modeling to a coding module and embedded/computing system component analysis. This recommendation is made because su-fields allows the simultaneous modeling of the interrelationships between all components under analysis while the associated solution modeling Standard Inventive Solutions allow for more advanced solutions concepts to be applied.

4. Two Additional Systematic Innovation for Computing Methodologies

Finally, there is a bit more detail that additionally enhance the ability to analyze computer based engineering systems. Specifically, the further resolution of the action "informs" and a resources analysis framework that is very helpful for innovating within computing systems will be discussed. The advanced resolution of the action "informs" and the computing focused analogy of system resource analysis will improve the insight gained from functionally modeling a computer based engineering system and help with the subsequent solution generation.

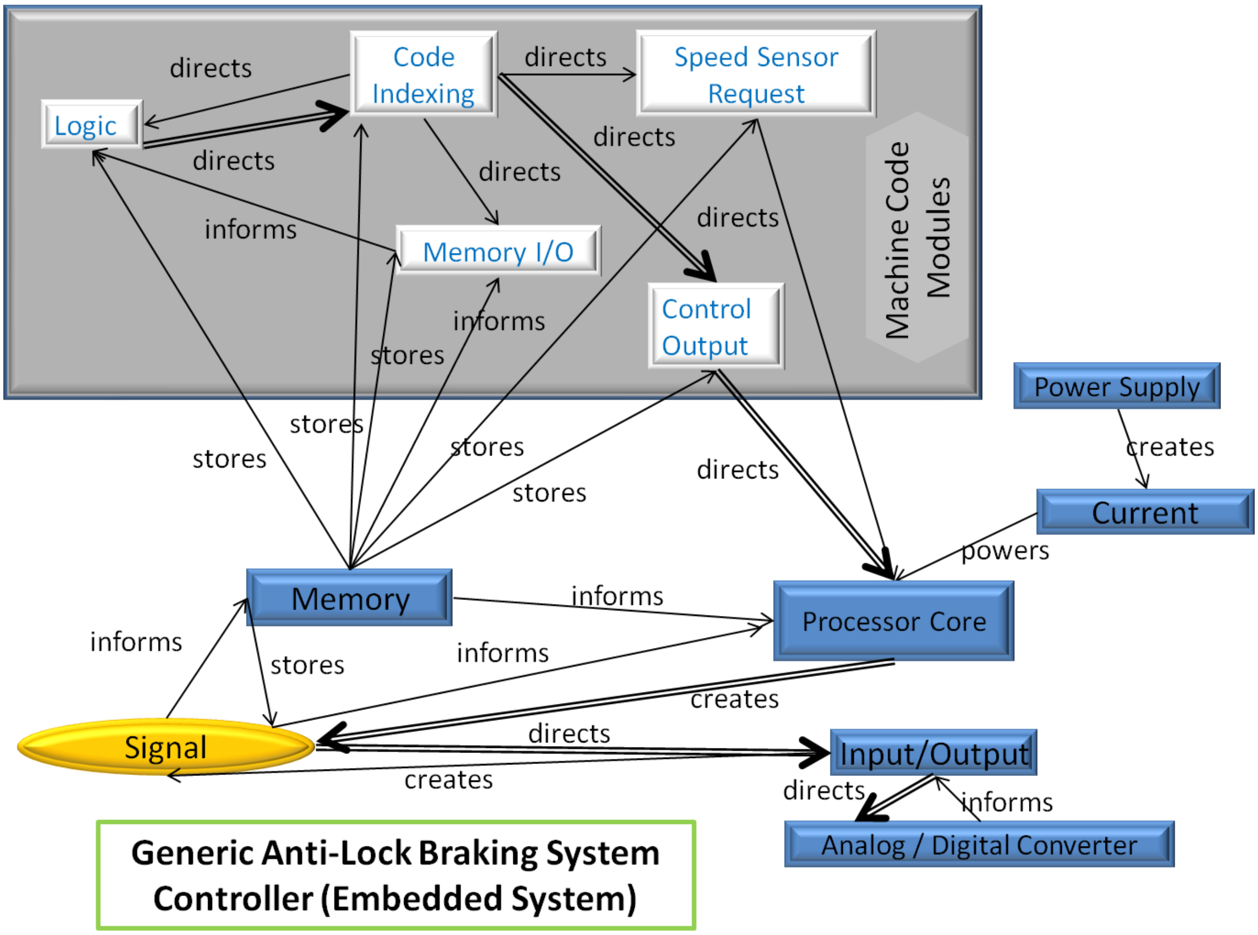

Figure 5 - Code Module Functional Model

The action "informs" is used in electro-mechanical/thermal TRIZ analysis to cover what is actually a fairly wide range of interactions and affects. For the majority of those electro-mechanical/thermal system analyses the action "informs" is sufficiently descriptive to allow for an effective analysis. However, when analyzing computing based systems the action "informs" is much too broad in its meaning and does not sufficiently portray the relationship between the components of interest. Fundamentally, there is a big difference between the action "informs" when it is meant to represent that information is simply available and when it is meant to represent that the function results in a direct control of an effected component. In response the progressive sequence of "informs" functions/actions, which has the goal of providing better modeling tools resulting in improved analysis and insight, has been developed. The progressive sequence pertains to how much control the action "informs" represents. Referring to "Figure 6 - Hierarchy of the

Action Informs,"[6] there are four levels of the action, each increasing the level of system control and therefore their importance to the associated engineering system's basic functionality.

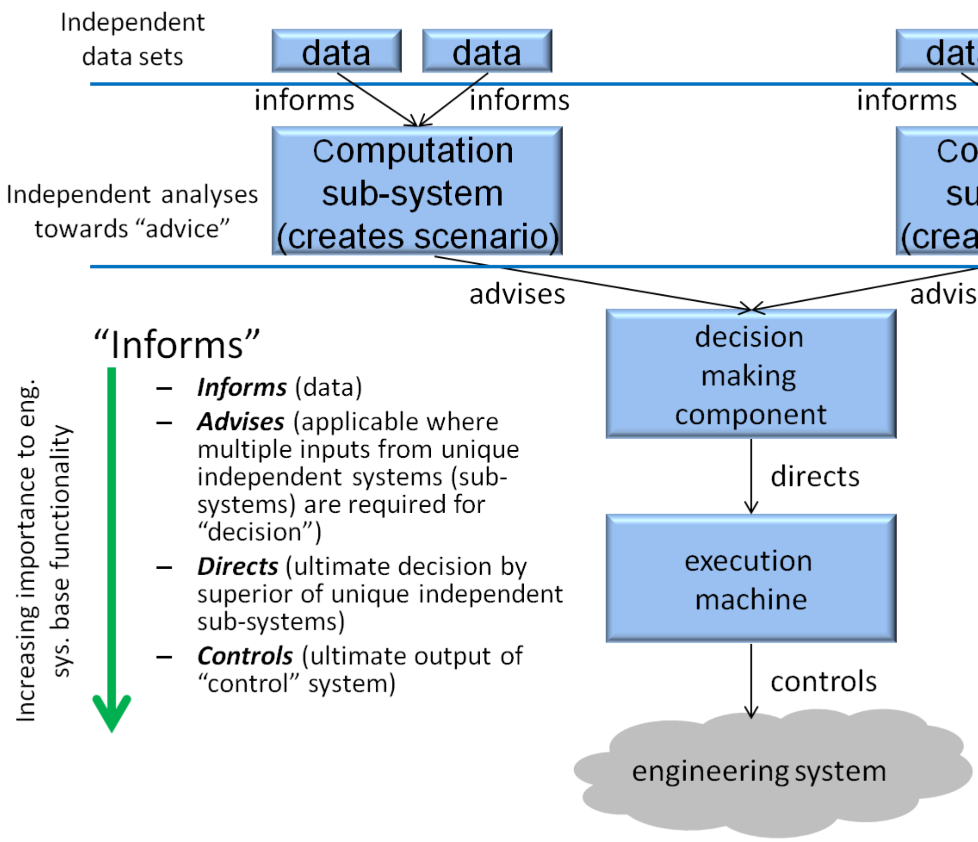

Figure 6 - Hierarchy of the Action Informs

Within this hierarchy, the first, and least important as to the delivery of the basic function, is that of "informs." The action refers to independent data sets and specifically providing those data sets to a component or sub-system that uses that data to create a intermediate step scenario for further analysis. An example of the action "informs" could be the provision of atmospheric environmental data. The next function along the path is that of "advises." "Advises" is the output of a scenario generating sub-system or component that takes multiple independent data sets and in turn combines them into a scenario that will be used in a decision making process by way of a subsequent component or sub-system. An example of the action "advises" could be the output of a scenario generator that takes atmospheric environmental data and makes a tornado advisory recommendation to a subsequent system. Then follows the function of "directs." "Directs" is a function that specifically creates a triggering of a specific action with no additional logic required. This function affects the last component within the embedded/computing system and is therefore still in the data state. An example of the action "directs" is the output of a system which takes multiple "advice" inputs, say from an tornado advisory generator and from a radar analysis, and makes a decision to activate a severe weather alarm. Finally, the last function, and the most important to the basic function of the embedded/computing system, is that of "controls." As implied "controls" is the direct activation of a component, or sub-system, and specifically reaches across the boundary between the embedded/computing system and control system. Therefore the action "controls" is the activation of a devices that directly affects the electro-mechanical/thermal portions of the engineering systems. An example of the action "controls" would be a component that takes the input function of "directs" severe weather alarm and creates a signal that physically activates the alarm system.

Now let's discuss solution generation resource analysis in conjunction with computing systems. A popular method for analyzing resources for an electro-mechanical/thermal system is that represent by the mnemonic MATChEM. MATChEM stands for: mechanical, acoustic, thermal, chemical and electro-magnetic. In other words, when searching for ways to influence an electro-mechanical/thermal system the analyst should consider all of the resources associated with these categories. Therefore an analogous method for computing systems has been developed. Gregory Frenklach, provided some insight regarding the MATChEM resources. He described how each resource in MATChEM represents an interaction at a different level. A slight modification of Gregory's description is as follows:

Mechanical = object interaction
Acoustical = surface interaction
Thermal = lattice/matter interaction
Chemical = molecular interaction
Electromagnetic = electron/spin interaction.

Utilizing the above, an analogous resource list for computing was developed. Referring to "Figure 7 - Resource Analysis for Software and Hardware"[7] it can be seen that there are many ways to look at software and hardware resources and understand at what level their interactions occur. For example, the analogy to a thermal interaction (at the lattice/matter level) would be to consider the code dynamics (or rather the movement/action of the coding relative to itself) in relation to the system's software while clock, speed, or orchestration would be considered relative to the system's hardware. Additional study of "Figure 7" will provide more insight as to how the interactions between and within the software/virtual and hardware aspects of a computing system can be used to help solve challenges residing within that system.

5. Conclusion

The application of TRIZ and systematic innovation to computer based engineering systems can be greatly improved by following a few changes to the methods employed for electro-mechanical/thermal systems analysis. First it should be understood that the system's coding should not be the primary focus of an innovation exercise as there are often other ways to improve computer based engineering systems without any changes to their coding. As far as the analysis process goes the first step is the modification of the handling of the functional modeling of the computer based engineering system. Initially, the delineation between the control system, embedded/computing system and the software/firmware should be well understood and the basic function of, and inputs to, the embedded/computing system should be comprehended. Specifically, it is the basic function of, and inputs to, the embedded/computing system that establishes the operational and performance requirements of the embedded/computing system and therefore the software/firmware. Next, if coding changes are in order then any functional analysis of that coding should be performed at the module level. It is at the module level that coding functionality, and the associated interactions, can best be delineated and judged. Next, a higher resolution of the action "informs" should be employed to better represent the progression from "informs to "controls." Finally, the software and hardware resources should be studied in order to identify the variety of solution generation opportunities available based on interaction improvements.

SI for Engineering		SI for Computing		
Technical		Software/Firmware		Hardware
(MATChEM +)	*Abstraction**	*(SID-LC)*	*Abstraction*	
Mechanical	Object	Software/Firmware Package - design	Design	Operational System
Acoustic	Surface	Interface/Handshaking (w/external systems)	Protocol	Connections/Interconnects/Transmission
Thermal	Lattice/Matter	Code Dynamics (movement/action relative to "itself")	Execution	Clock/Speed/Orchestration
Chemical	Molecular	Language/OS	Instruction	Component/Appliance (micro and macro)
Electro-Magnetic	Electron/Spin	Coding (routines/objects/agents)	Objects	Transistors/Devices
		Bits/Words	Object Code	Electrons/Holes
+				
Nuclear	Atomic			
Biological	*various*	n/a	n/a	Machine/Human Interface

* The Techncial Abstraction column is a modifciation of work by Gregory Frenklach

Figure 7 - Resource Analysis for Software and Hardware

Glossary[8]

- *Auxiliary Functions* – Useful function that acts upon components of the system, usually from within the engineering system.
- *Basic Function (Base Functionality)* – Useful function that acts directly upon the product of the functional model, also very likely to be the main function of the engineering system.
- *Component (System Components)* – A material object (substance, field, or substance-field combination) that constitutes a part of the engineering system or super-system.
- *Engineering System* – A system that has been assigned to perform a function. A set of components that work together to perform a function.
- *Function* – An action performed by one material object (function carrier) to change or maintain a parameter of another material object (object of the function).

- *Function Model* - A model of a function being performed. Performance of the function is measured as sufficient, insufficient or excessive. Function analysis deals with the entity component that is a material object and can be either a substance or a field
- *Function Modeling* – A part of function analysis that builds a function model.
- *Physical Contradictions* – A situation in which two opposite requirements are placed upon a single physical parameter of an object.
- *Standard Inventive Solutions* - a set of 76 typical solutions, in the form of substance-field (su-field) models, to typical problems that are also expressed in the form of su-field models.
- *Su-Field (Substance-Field)* - A model of the problem related to the engineering system, but not of the engineering system itself. Also, the substance and field are clearly differentiated.
- *Su-Field Model* – Symbolic model of a problem or solution formulated in terms of interactions between substances and fields (virtual, real, or improved).
- *Super-system* – A system that includes the engineering system as a component. All systems outside the boundaries of the engineering system. Pertinent super-systems includes those that interact with the engineering system. Understanding the relationship between the engineering system and relevant super-systems is important in understanding system problems and identifying resources that can be used in the ultimate solution.
- *Target* – An object of the main function of the analyzed engineering system.
- *Technical Contradiction* - A situation, in which an attempt to improve one parameter of an engineering system leads to the worsening of another parameter.
- *TRIZ* - The Theory of Inventive Problem Solving,

Reference

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Paper ID: 39

By Systematic Innovation Techniques to Enhance the Quality of Rice Milling

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Abstract

Rice is a key food of humankind, the third largest food crop in the world, behind only corn and wheat. The process of removing the rice husk, the rice skin portion, and the rice germ to make white rice is called rice milling. This study the first used Yixing Rice Milling Company in Taiwan to illustrate the process of fully automated rice milling. There are eight steps in the rice milling process system: testing, drying, refrigeration, hulling, milled rice, rice washing, color sorting, and packaging. Second, using risk assessment theory, the eight steps of the process were evaluated to determine which steps were the most vulnerable to risks. Four key factors in poor milling quality were identified: the hue recognition subsystem, the cold storage structure, ventilation, and the air pressure nozzle subsystem. Finally, the four key factors were improved with systematic innovation (TRIZ) methods. The authors then made recommendations for improving the quality of rice production operations to Yixing Rice Milling Company.

Keywords: automated rice miller; risk assessment theory; related factors; key factors; systematic innovation technique

1. Introduction

Rice is a key food, the third largest crop on earth, behind only corn and wheat.

The process of removing rice husk, the skin portion, germ, and making white rice is called rice milling. This research first used the example of fully automated rice milling performed at Yixing Rice Milling Company in Taiwan. The rice milling process system has eight steps: inspection, drying, refrigeration, hulling, milled rice, rice washing, color sorting, and packaging. Second, using risk assessment theory, the eight steps of the process were evaluated to determine those steps that were most vulnerable to risk. After analyzing these steps, factors that cause poor milling quality were identified. Using these factors, the key factors were revealed. Finally, using a systematic innovation approach, the key factors in poor quality rice milling were addressed to help the rice miller improve rice production operations.

2. Evaluating the rice milling process and determining key factors

▪2.1 Evaluating the rice milling process

In this study, the factory manager, engineers, and workers of Yixing Rice Milling Company were first invited to describe and discuss the eight steps of the rice milling production process. Using two indexes which refer to the degree of severity and the probability of an event occurring, a risk assessment for rice milling production process at the company was performed. Three steps, drying, refrigeration, and color sorting appeared to have the greatest risk. After addressing potential problems, the quality of rice milling should increase.

▪2.2 Identifying vital factors from the three steps of great risk

This study used a Cause-and-Effect Diagram to analyze the three riskiest steps in the rice milling process and identified eight factors that cause poor quality rice milling: (A) refrigerated barrel structure; (B) air conditioner; (C) ventilation; (D) hue recognition subsystem; (E) pressure nozzle subsystem; (F) Moisture testing; (G) Heat temperature; and (H) Rice transporting mechanism, as shown in Figure 1.

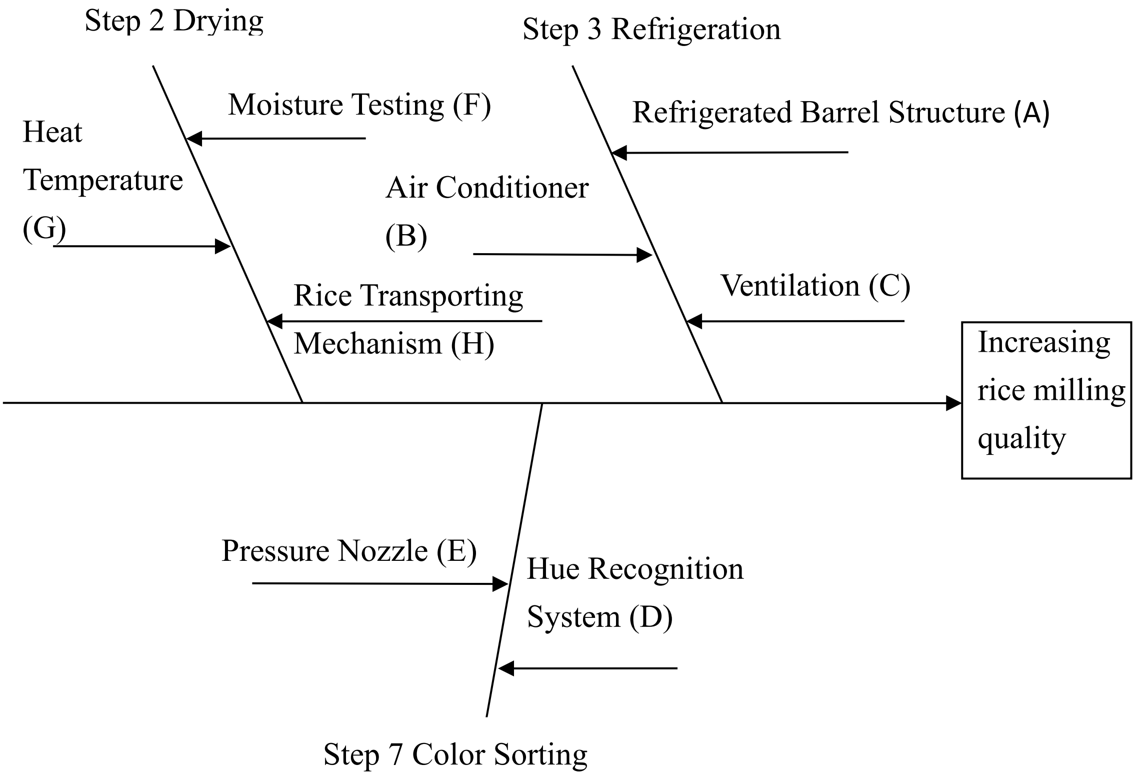

Figure 1.　Analysis of cause-and-effect diagram for enhancing rice milling quality

▪2.3 Determining key factors

Using Quality Function Deployment techniques, The authors determined the key risk factors from among the eight risk factors. From the QFD (Quality Function Deployment) table, we chose the four largest weight values (TWi): (1) hue recognition subsystem (D); (2) cold storage structure (A); (3) ventilation facilities (C); and (4) pressure nozzle subsystems (E). These became the four key factors for improving rice milling quality. The next step was to address the four key factors with a systematic innovation approach.

Determining the key risk factors for enhancing the rice milling process

Weight Definition w_i: Very Strong 4.0; Strong 3.0; General 2.0; Weak 1.0; Unrelated 0.0		Important factors/Vital factors								
		Risk indexes δ_i	A. refrigerated barrel structure	B. air conditioner	C. ventilation	D. hue recognition subsystem	E. pressure nozzle subsystem	F. Moisture testing	G. Heat temperature	H. Rice transporting mechanism
Riskiest steps	Refrigeration	0.53	4	3	4	2	1	0	1	1
	Color sorting	0.50	2	1	1	4	4	0	1	1
	Drying	0.43	1	0	1	2	1	4	4	4
Weight value (TW_i)			3.55	2.09	3.05	3.92	2.96	1.72	2.75	2.75
Key factors			2		3	1	4			

3. Addressing risk factors via a systematic innovative approach

Systematic innovation techniques (TRIZ) are derived from the Russian Theoria Resheneyva Isobretatelskehuh Zadach, translated into English as An Innovative Theory for Solving Problems, which means a new and different theory of solving problems. As long as the procedures of the theory are followed using its practical tools, improvements can be made.

The QFD table analysis showed that quality of the milled rice can be increased by focusing on improving four key factors. Two of the key factors, the hue recognition subsystem (D) and the pressure nozzle subsystem (E), are part of the color sorting step of the rice milling process, which is performed by a color sorting machine (Figure 2). The color sorter is composed of subsystems of component combinations, which makes it suited to functional attribute and causal chain analysis via the systematic innovation techniques (TRIZ). Two other key factors, the cold storage structure (A) and the ventilation pipe (B) are part of the refrigeration step in the rice milling process. They were more suited to analysis by the contradiction matrix of systematic innovation techniques (TRIZ).

Figure2. Color Sorter

▪3.1 Improving the color sorting step

▪3.1.1 The overall process of two subsystem components in a color sorter

A color sorter structure is divided into two parts, the primary choice and the second choice. The color sorter have two subsystems: 1. the hue recognition subsystem (1) the rice flow speed control valve; (2) the illumination lamp; (3) optical lenses and cameras; and (4) the hue decision processor. 2. the pressure nozzle subsystem (1) the nozzle; and (2) compressors. When the grains of rice flow into the color sorting machine, the rice flow speed control valve of the hue recognition subsystem initializes. The grains vibrating in different rice chutes and are sequentially led into a 2/3 position on the left side of the primary groove. When the rice enters the primary groove, the grains of rice fall in a curtain-like waterfall from the groove of the subsystem. The amount of falling rice and the speed are controlled by the rice flow speed control valve. The higher (lower) the control valve setting, the closer (farther) the rice grains of the rice fall plane are, and the faster (slower) the rice flow. At the same time, the rice flow speed control valve controls the rice flowing into the color sorting machine from both the primary and second grooves.

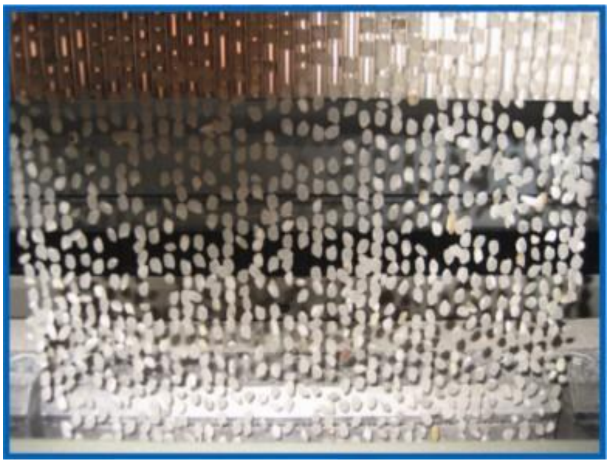

Figure 3. The grains of rice fell down in a curtain-like waterfall manner from the groove of the color sorter

At the moment the light was projected on falling rice waterfall plane by illumination lamp. Simultaneously each row of falling grains is imaged by the camera, and the resultant images sent to the hue decision processor. Based on the images, the hue decision processor identifies the color, transparency, and size of a grain of rice and determines whether the rice is acceptable. If the grains of rice are judged acceptable by the hue recognition subsystem, they fall into the acceptable rice collection area. This process is the primary choice process. If a row of grains is judged to be unacceptable, the pressure nozzle subsystem located at the bottom of the waterfall plane initiates and the nozzle blows the unacceptable rice into a temporary collection area using high-pressure air. When the unacceptable rice is blown out, acceptable rice may be blown into the temporary collection area. Therefore, a second color sorting known as the re-election is necessary.

Re-election begins when a bucket elevator machine sends the grains from the temporary collection area into the re-election groove that is on a 1/3 position of the right side of the groove. Again color sorting is conducted via the hue recognition subsystem and the pressure nozzle subsystem as in the primary choice. If the second choice also rejects the rice, the pressure nozzle subsystem blows them out into the unacceptable rice collection area. The primary choice groove is also used during the re-election process. The former was on the 2/3 of the left side, and the latter was on the 1/3 of the right side of the groove. Therefore, falling primary choice grains occupy in the 2/3 of the left side of the rice waterfall plane, while re-election rice grains fall on in the 1/3 of the right side.

Because of the different colors and translucencies of the rice varieties, before conducting color sorting, the hue decision processor should be adjusted to distinguish the color, transparency and size standard of the grains based on the variety of rice being processed. After the best grain color, transparency, and size standard of each variety of rice grains are determined, the color sorting can be performed. The overall flow diagram for judging the rice quality in the color sorting machine is shown in next Figure.

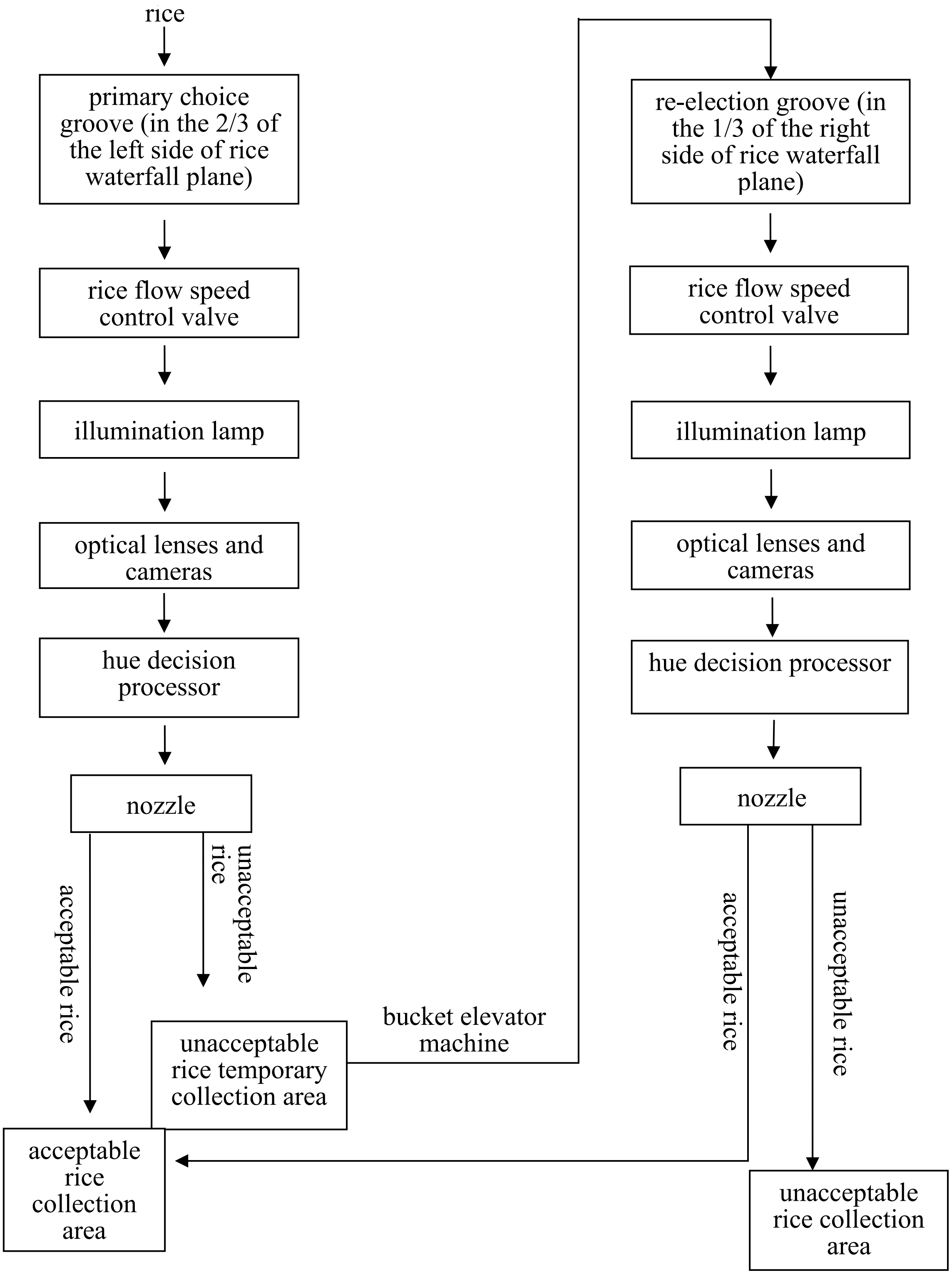

Figure 4. Flow diagram for rice quality evaluation via color sorting machine

▪3.1.2 Causal chain of functional attributes of the components of the color sorter

In this study, the functional attributes of the color sorter's components were plotted into a causal chain of functional attributes in frames, based on the overall sorting process. The functional attribute causal chain was analyzed as shown in next Figure. In the last Figure, where the process contains negative functions, they are marked as with symbols representing insufficient, over-functional, and harmful. Components possessing negative functions are termed "color sorter important functional components" and marked with double borders. Five components, the rice flow speed control valve, illumination lamps, optical lenses and cameras, the hue decision processor, and the nozzles were so marked. The remaining components were termed secondary components and are covered by a single border.

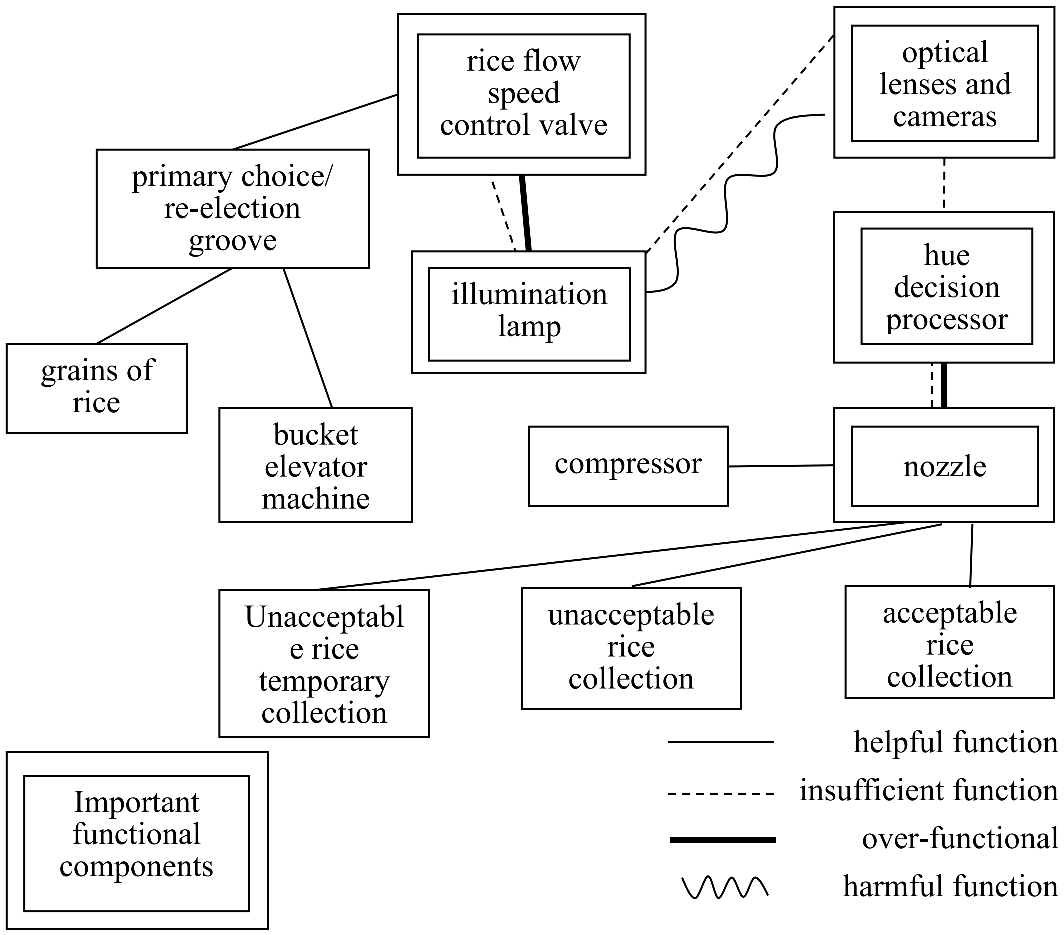

Figure 5. Analysis of functional attributes of the color sorter components

▪3.1.3 FAA-based improvement plan for the color sorter

(1) Rice flow speed control valve

The rice flow speed control valve controls the flow of grains in the primary choice groove and the re-election groove. If the flow of rice is mishandled, the distance between the rice grains in the rice waterfall plane would be wrong, and insufficient/over-function would occur, involving the illumination lamps. Therefore, before the grains of rice enter the primary choice groove, a small portion of rice should be tested to determine the valve opening size to ensure the quality of color sorting.

(2) Illumination lamps

The illumination lamps project light onto the rice waterfall plane. Over time their illumination falls as their lamps wear out. Thus the optical lenses and cameras may not have enough light, producing a frequency spectrum shift. Moreover, the lamps, lenses, and cameras should not be placed too closely to one another. If the distance is too close, interference may occur, resulting in insufficient/harmful function. Our improvement plan involved regular checking and testing of the brightness of illumination lamps to ensure their output was 990 to 1100 lumens as specified.

(3) Optical lenses and cameras

The function of optical lenses and cameras is to image the rice waterfall plane. As the grains of rice fall, they throw off bran fiber. Over time this makes the lenses dirty and causes the hue decision processor to generate false judgments, an insufficient function. The improvement plan involved regularly cleaning the optical lenses to ensure that the camera is functioning properly.

(4) Hue decision processor

The hue decision processor identifies the color, transparency, and size of the rice grains in based on the imagery generated by the imaging system. If it is malfunctioning, it may produce false judgments of the rice color or quality, which in turn may cause the nozzles to function improperly. Our improvement plan was to make appropriate color adjustments for the quality of each batch of rice and test a small portion of rice first to ensure that the processor is functioning properly.

(5) The nozzles

Using high-pressure air produced by the compressor, the nozzle blows grains judged unacceptable by the hue decision processor into the poor rice temporary collection area or the unacceptable rice collection area. If the pressure of the nozzle is too high, acceptable rice around unacceptable rice may also be removed. Conversely, if it is too low, not enough unacceptable rice will be removed from the stream of rice, an over-/insufficient function problem. Our improvement involved checking and testing the nozzle and the compressor to ensure they were at the recommended pressure of 2.6kg/cm^2 to 2.8kg/cm^2.

The improvement plan for the five components was discussed as shown in Figure 6.

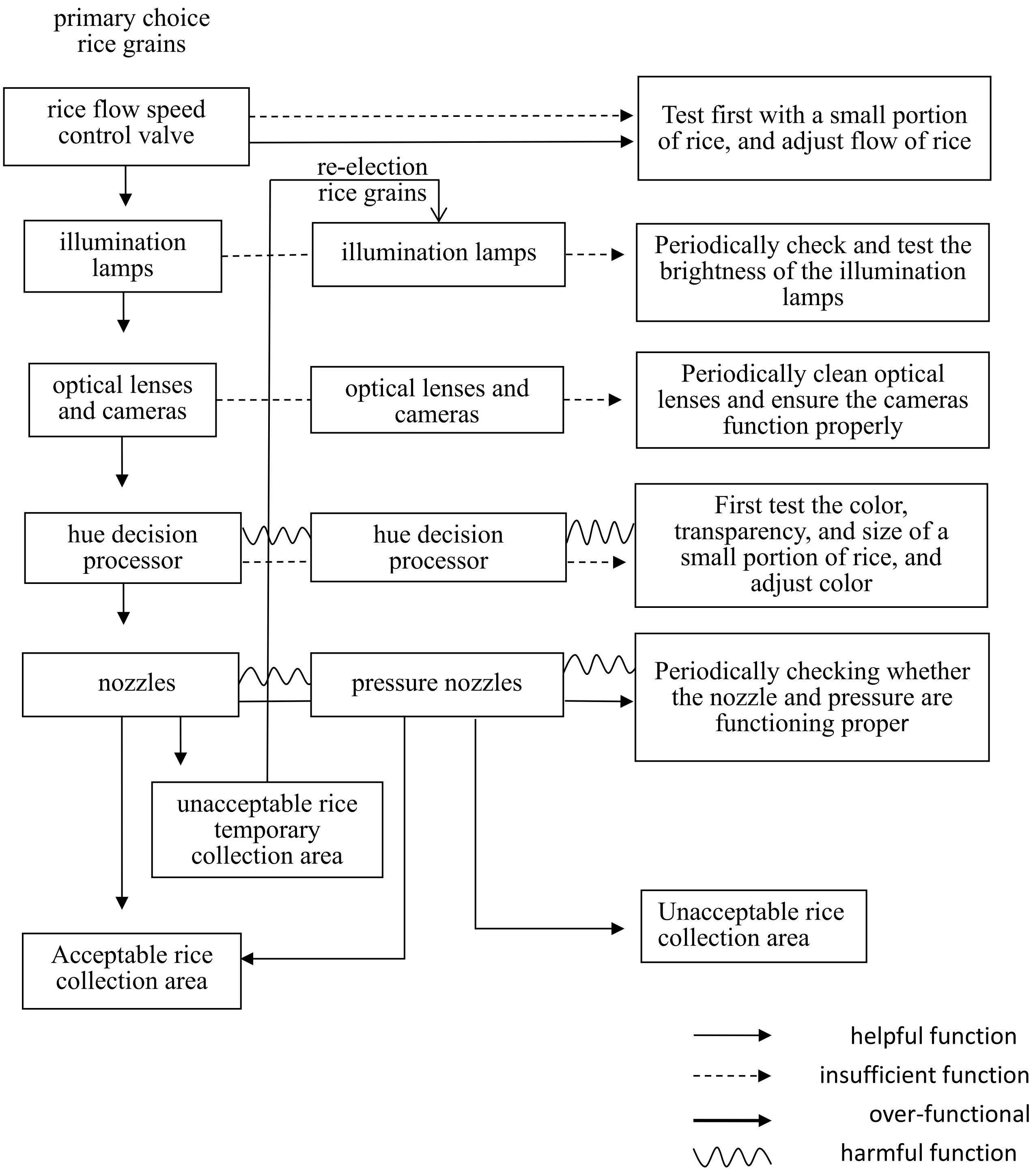

Figure 6. Improvement plan of five important functional components in a color sorter

▪3.2 Using TRIZ to improve the cold storage structures and ventilation pipelines

This study found that two other key factors in the quality of rice milling are the refrigerated barrel structure (A) and the ventilation pipe (B). The technical contradiction approach may be used to solve problems, as described below.

▪3.2.1 Refrigerated barrel structure (A)

Each refrigerated barrel consists of four large soldered steel plates and can hold 100,000 kg of rice. Over time, the weight of the grains deforms the cold storage barrels. Cracks are produced at the seams and some of the rice is not refrigerated properly. This problem is a typical technical contradiction in a systematic innovation technique (TRIZ), specifically described as follows: "A refrigerated barrel saves more rice but does not exhibit structural deformation of the chilled barrel.” Some of 39 engineering parameters were reviewed to solve this problem. The parameters which might improve the problem were item 11 "tension, pressure" and item 13, "object stability", while item 2, "fixed object weight", may reduce the problem. On the basis of this analysis, a technical contradiction matrix table was created as shown in Table 2. In the next Table the helpful innovative principles were principles 1, 10, 13, 18, 26, 29, 39, and 40.

Table 2. Technical contradiction matrix table for the refrigerated barrel structure (A)

parameters that cannot be changed / parameters that may changed		Fixed object weight
		item 2
pressure, tension	item 11	13, 29, 10, 18
object stability	item 13	26, 39, 1, 40

Based on the above-mentioned eight innovative principles, the problem resolution plan was:

(1) Principle 10: pre-action:

The problem resolution plan for this principle was that the internal steel plates of the four sides of the refrigerated barrel were riveted and the plates bound tightly with steel cables to reinforce the structure.

(2) Principle 26:

The plan called for the seams of the barrels to be welded to reinforce the structure.

(3) Principle 39:

The problem resolution plan using this principle was to eliminate rust in the steel plate joints and to paint the exteriors of the steel plate to prevent rusting.”

(4) Principle 40: composite materials:

The company installed Teflon insulation inside the four plates of the refrigerated barrel to ensure energy savings.

(5) Four additional innovative principles were “segmentation”, “reverse”, “vibration”, and “hydraulic”. Because they had no significant application to the problem, they were not put to use.

▪3.2.2 Ventilation facilities (C)

There are 33 refrigerated barrels in the refrigerator. Cold air is generated by the refrigeration unit and circulated from each ventilation pipe to each refrigerated barrel. If the ventilation pipes become clogged or the ventilation gates fail to control the flow of cold air, cold air cannot enter barrels when needed. This is a typical technical contradiction, described as "barrels maintain long-term temperature, and ventilation facilities do not allow exceptions." The 39 engineering parameters were again used to review the problem. The parameter which may address the problem was item 13, "the stability of object" and the parameters which might prevent further deterioration were item 17, "temperature" and item 23, "material loss." The technical contradiction matrix table was created on the basis of the problem as shown in next Table. The helpful innovative principles were principles 1, 21, 31, 32, 35, 36, and 39.

Table 3. Technical contradiction matrix table of ventilation facilities (B)

parameters that cannot be changed / parameters that can be changed		temperature	material loss
		item 17	item 23
stability of object	item 13	35, 1, 32	2, 14, 30, 40

On the basis of the above-mentioned seven innovative principles, the problem resolution plan was:

(1) Principle 1: the role of segmentation

Principle 2: separation/ extraction

The temperature inside the refrigerated barrel should be controlled at 14-18 °C. If too high, rice quality declines. Based on these two principles, the problem resolution plan was to install temperature sensors in the 33 refrigerated barrels and a networked computer system was used in the monitoring room for displaying the temperature of each refrigerated barrel.

(2) Principle 30: flexible films and thin films

Using this principle, the resolution plan was when the temperature sensors were installed inside the refrigerated barrels, automatic gate controllers replaced less accurate manual turning on/off to ensure refrigeration quality.

(3) Principle 32, changing color

Based on this principle, the resolution plan was to install temperature stickers on common pipelines. If the temperature was unusual, staff can inspect the different colored temperature stickers to determine which ventilation pipeline has abnormal air supply.

(4) Principle 40, composite materials

The problem was resolved by installing insulating films on the ventilation pipe exteriors to keep pipe air from leaking during the pipeline transportation process.

(5) Two innovative principles, “spherizing” and “physical or chemical state change” had no significant application to the problem and were not adopted.

4. Conclusion and Suggestions

This study has investigated the rice milling production process of Taiwan Yixing Rice Milling Company. The eight steps of rice milling production process were first analyzed using risk assessment theory to determine the three steps with the greatest risk, drying, refrigeration, and color sorting. Next, using a cause-and-effect diagram, the authors identified eight factors that cause poor quality rice milling in the three steps. The authors then analyzed the eight vital factors using quality functional deployment techniques to determine the four key factors: the hue recognition subsystem, the refrigerator structure, the ventilation system, and the air pressure nozzle subsystem. Finally, The authors used TRIZ to address the problems of the four key factors. This study emphasizes the four key factors involved in color sorting and refrigeration. The authors recommended that Yixing Rice Milling Company address them to enhance rice milling quality. We made five recommendations for color sorting (1) a small portion of grains entering the color sorting system should be checked first to test the rice flow speed control valve, and to adjust the size to ensure the quality of color sorting; (2) the brightness of illumination lamps should be periodically checked and tested to maintain them at the recommended 990 to 1100 lumens; (3) the optical lenses and cameras should be cleaned and proper camera function checked periodically; (4) the hue decision processor should be tested with a small amount of grain first to ensure that the processor can correctly identify the grain color, transparency, and size of the grain; and (5) the nozzles and the compressor pressured need to be periodically checked.

Two recommendations were made for the refrigeration system: (1) to reinforce the refrigerated barrel, its steel plates of the four sides of each refrigerated barrel were tightly bound with steel cables. Rust should be regularly removed from the plate joints, and Teflon insulation lining installed inside the four side steel plates of the refrigerated barrel to ensure no leakage of cold air. (2) Networked temperature sensors were installed in 33 refrigerated barrels. These enable temperature monitoring in the control room. Automatic gate controllers were used to replace less accurate and slower manual turning on/off. (3) Temperature stickers were affixed on common pipelines. If the temperature was outside normal parameters, the colors change, which staff can see.

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Challenges and Countermeasures Regarding the Operation of Apple App Store

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Abstract

Apple Inc. pioneered in App stores to set the stage for myriad business opportunities, as evidenced by firms who follow our lead. We use Porter five forces analyses to evaluate challenges facing Apple Application Stores. Finding the advantages of Apple application platform mainly came from many loyal customers. Faced with such application of platform use, other companies use open operating systems and launch diverse styles of devices to compete with Apple's closed operation system and fewer styles. Study suggests Apple should increase friendness interface, raise proportion of free applications, launch cheap mobile devices, and offer consumers more choices.

Keywords: App Store, mobile device, industry business model, five-force model

1. Introduction

Under advancement of technology, daily article have become diverse and user friendly, leading to rapid replacement of consumer electronic products. Apple Computer innovated a mobile application platform known as Apple App Store, which has created vast opportunities and led other brands to follow suit by launching similar mobile application platforms: e.g., Nokia's Ovi Market,[1] Google's Google Play App Store, BlackBerry's BlackBerry World, and Microsoft's Windows Phone Store.

Besides the leading mobile application platform, Apple Computer made more amazing achievement in the application online store development and sales. According to the report released by Gartner international research firm in September 2013 [3], total downloading of applications on various platforms in 2012 amounted to 63.9 billion times in 2012, almost doubling to 102 billion in 2013. Total downloading in 2014 is expected to reach 138.8 billion times. Among all these application online stores, Apple App Store leads in downloading. By gleaning data from newspapers, magazines,

[1] Nokia Corporation announced in January 2014 that Ovi Market stopped releasing new applications.

academic reports and/or other secondary data, this study applied industry analysis proposed by Porter (1985) to analyze and explore challenges and countermeasures regarding the operation of Apple App Stores.

2. Literature Review

Porter's "Competitive Strategy" (1980) and "Competitive Strength" (1985), proposed an industry analysis model based on the unique concept of five strengths [7, 8], integrating the perspectives of industrial economy and enterprise management to measure competitiveness of enterprises by comprehensive means. He argued that market forces are on an individual versus overall economic level: 1. potential entrant's threat, 2. degree of competition between existing competitors, 3. threat of substitute products or substitute services, 4. bargaining power of consumers and 5. bargaining power of suppliers.

Development of enterprises must show innovation, the key to opening up a new situation. To match demands of innovation, many firms use Facebook to establish fan pages online and invite professional fans to manage web pages, so that enterprises better understand patrons' ideas, improve commodity sales or use search engines integrated with websites to provide multiple services to create value for enterprises.

Apple Computer pioneered in 2007 by providing developers with the service of free downloading of iPhone application development kit. Its innovative business model created a good reputation for itself and is generally recognized by other brands. Karla and Bröker (2011) argued that application executed on the mobile application platform is the sum of a series of value creations and also the direction of future market development [6]. Bergvall-Kåreborna and Howcroft (2013) suggested that Apple Computer avoids cost and responsibility of managing high-tech workers by crowd sourcing to make it a global application development base [2]. Montgomerie and Roscoe (2013) indicated that Apple Computer has been promoting its ecosystem and thus has a large number of consumers [5].

Bergvall-Kåreborna (2013) compared advantages and disadvantages of Apple App Store and Google's Android mobile application platform, finding Apple App Store a high-end brand marketed earlier than Google Play App Store; its success laid a good foundation for development of Apple App Store [1]. Jauhari (2012) conducted qualitative analysis of Apple App Store and summarized reasons for success of Apple Computer as the focus on consumer experience and blending of the experience in product design. The same brand mobile devices (iPad, iPhone, iPod touch) connected by Cloud serial connection have convenience [10]. Drew (2013) argued that strict monitoring of Apple App Store prevents negative news about the platform and establishes a good quality reputation. This is the major reason for Apple App Store's leading position of [4]. All these scholars conducted comparative study of differences between Apple App Store and its chief rival, Google's Android mobile application platform, and proposed excellence of Apple App Store. Yet no one has cited the reasons for strengths of the platform of Apple Computer, the challenges and countermeasures. This study tried to identify the direction of its future development by Porter five forces model.

3. Apple App Store Industry Analysis

The so-called mobile application platform allows consumers to use mobile devices to download various applications via network. Some of these applications are free and some of them are not free. The current mobile application platforms on the market include Apple App Store, Ovi Market, Google Play App Store, BlackBerry World and Windows Phone Store, all of which expect to make rich profits by using different business strategies.

1) Apple App Store Business Model

Apple was founded in California in 1976. In 2007, it released the first-generation iPhone and provided free downloading of the application development kit to facilitate development of applications by software vendors. In July 2008, 552 applications were available on Apple App Store in 62 countries. By June 2013, applications of Apple App Store amounted to more than 900,000; downloading reached more than 50 billion times.[2] The business model divides into four modules: Apple Inc., mobile application platform, software vendors and consumers, and relevant business procedures, as shown in Figure 1. Apple provides development tool kits to software vendors who develop applications. If deemed by Apple Inc. as qualified, these are sold in Apple App Stores, price determined by the software vendor through the mobile application platform and revenue split at a 7:3 ratio—i.e., software vendor gets 70%, Apple Inc. 30%. Contents include education, amusement, game and community. Consumers can pay by credit care as long as registered with Apple App Store. Apple has a feedback mechanism via Internet and provides consumer data to software vendors for reference.

This study collected and compared data on users of major mobile application platforms in terms of overall downloading proportion, profitability, total number of applications, mobile device brands, and profit-sharing proportion (Table 1). As shown, downloads of Google Play App Store are most numerous and Apple App Store most profitable; total number of applications in Apple App Store is equivalent to that of Google, but from a market share and profitability perspective, Apple ranks first. Though downloads of Google Play App Store rank first, its profitability is far below that of Apple. To compete with Apple App Store, Google is bound to provide more free applications and support more brands of mobile devices; Apple App Store's response is the next subject for discussion.

[2] Please refer to website http://en.wikipedia.org/wiki/App_Store_(iOS).

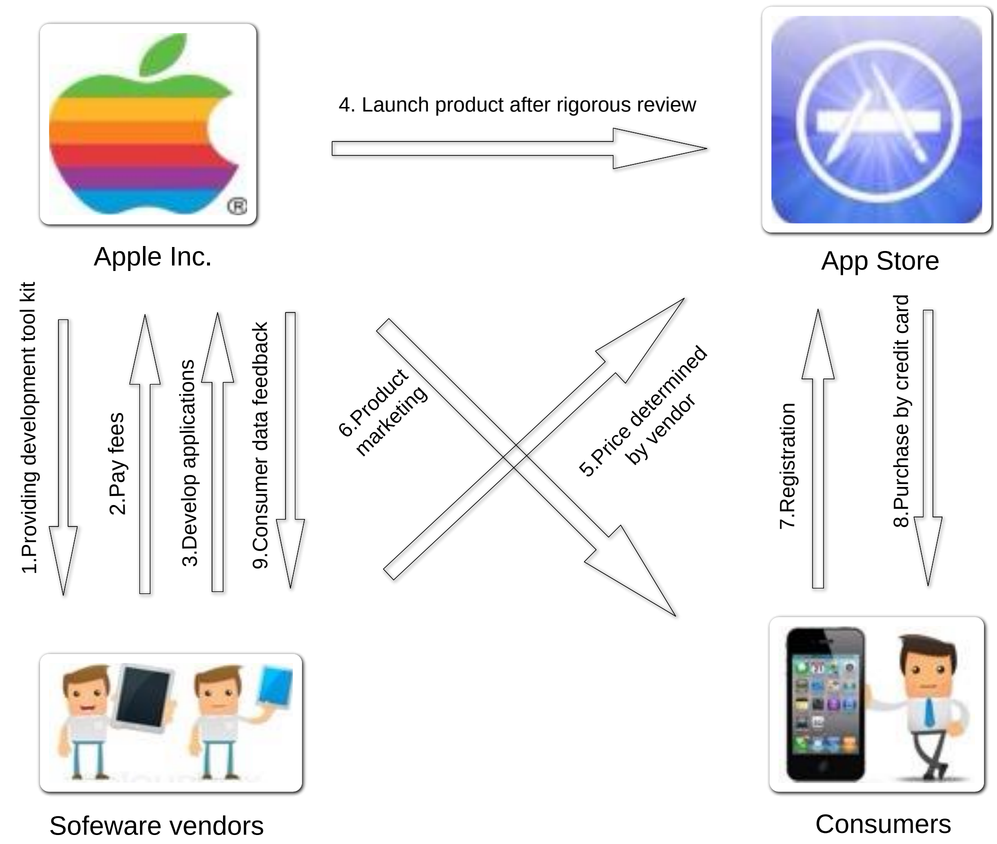

Figure 1. Apple App Store 4 modules: Apple Inc., mobile application platform, software vendors and consumers

Table 1. Use of consumers of major mobile application platforms in 2013

App Store	Application overall downloading proportion	Profitability	Total number of applications	Mobile device brands	Profit-sharing proportion
Apple App Store	33%	65%	More than 800,000	iPod touch, iPhone, iPad	Apple 30%, the software vendor 70%
Google Play App Store	58%	27%	More than 800,000	Samsung, LG, HTC, Sony, Ericsson, ASUS	Google 30%, software vendor 70%
Windows Phone Store	4%	8%	About 145,000	htc HD2, Nokia Lumia, HTC Windows Phone 8X	Microsoft Corporation 20%, software vendor 80%
BlackBerry World	3%		More than 120,000	Battery series smart phone	RIM 30%, software vendor 70%

Note: Summary according to Global mobile statistics 2013 Section E: Mobile apps, app stores, pricing and failure rates, Website: http://mobithinking.com/mobile-marketing-tools/ latest-mobile-stats/e#toomanyappstores

2) Apple App Store Industry Analysis by Using Porter Five Forces Model

To understand major brands' challenges to Apple App Store, this study used a Porter model in analyzing competitive forces: potential entrant's threat, degree of competition among existing competitors, threat of substitute products or services, bargaining power of consumers and/or suppliers to measure competitiveness of Apple Computer.

(1) Potential entrant's threat: pressure of new vendors on existing vendors, regarding threat of potential entrants to Apple App Store. Porter (1980) discussed this in 10 dimensions: economies of scale, product differentiation, capital requirements, distribution channels, exclusive product technology, favorable location, government subsidies, learning curve, transfer cost, and government policies. This study found only five of these dimensions (economies of scale, product differentiation, distribution channels, exclusive product technology and learning curve) impacting Apple App Store and therefore discussed the potential entrant's threat in these dimensions, as shown in Table 2.

Table 2. Assessment of Apple App Store competitiveness by potential entrant's threat

Dimension	Analysis Specific Explanations	Competitiveness assessment		
		High	Medium	Low
Economies of scale	Number of applications on Apple App Store tops major platforms of existing markets, growing continuously to keep a leading edge.	✓		
Product differentiation	Applications developed by software vendors for Apple App Store have been strictly reviewed to ensure information safety and prevent downloading of information with sexual or violent contents. In addition, applications of Apple App Store can only be used in mobile devices produced by Apple Inc.	✓		
Distribution channels	Apple Inc. launched advertising platform of iAd in 2010 to let software vendors provide consumers with interactive and emotional advertising contents.	✓		
Exclusive product technology	Apple Inc. provided Cloud downloading by combining iPod with iTunes applications and developed the mobile application platform Apple App Store to combine with iPad, iPod touch, and iPhone to complete App settlement and payment mechanisms. In addition, consumer interface design of iPhone and iPad is simple and human-oriented, so that adults and children can easily learn to use.	✓		
Learning curve	In addition to mobile application platform, Apple Inc. developed two shopping platforms including iTune store and iBook. Thanks to learning effect, development experience is superior to other mobile application platforms.	✓		

According to results shown in Table 2, Apple App Store has palpable competitiveness in these five dimensions, rendering potential entrant's threat insignificant. It is recommended that Apple Inc. keep the existing competition strategy with existing competitiveness.

(2) Degree of competition between existing competitors: threat of industrial competitors to each other. To understand competition of the existing competitors and Apple App Store, Porter (1980) discussed degree of competition among such competitors in 10 dimensions: numerous or balanced number of competitors, slow industrial growth, fixed or high warehousing cost, lack of differentiation or transfer cost, considerable growth in production, diverse competitors, high strategic risk, professional asset, fixed pullout cost, mutual strategic relationship. This study found that the system open degree, competitor marketing and professional asset can affect Apple App Store and therefore discussed the degree of competition between existing competitors with Apple App Store in three dimensions, as shown in Table 3.

Table 3. Competitiveness of Apple App Store by degree of competition between existing competitors

Dimensions	Analysis Specific Explanations	Competitiveness assessment		
		High	Medium	Low
System open degree	Apple App Store's operating system is iOS, all the mobile devices relating to iOS are developed by Apple and manufactured by Foxconn or other Apple partners. Therefore, it does not support non-Apple mobile devices. By comparison, Google's Android operating system with open original code can be used in software and hardware of other brands.			✓
Competitor marketing	Available mobile application platforms are marketed in diverse ways to attract software vendors to establish platform differentiation and gain profits. However, Apple App Store enjoys the strength of uniqueness, mature software development and relative low costs.	✓		
Professional asset	Apple Computer has more patents and technological strength in mobile application platform as compared to other mobile application platforms on the market. [8]	✓		

According to results shown in Table 3, the system open degree of Apple App Store is the lowest as compared with existing competitors in these three dimensions. Therefore, our suggestion regarding system open degree is that Apple regularly launch new marketing methods in response to openness strength of Android operating system. Regarding security as a major factor to keep closeness of iOS operating system and mobile device, Apple should quickly launch more mobile devices and increase software friendliness and convenience.

(3) Bargaining power of consumers: the negotiating and bargaining power of consumers. To understand consumers' bargaining power, Porter (1980) discussed it in eight dimensions: large purchase concentration of sales volume on buyer groups, considerable proportion of purchase cost or volume of consumers in the industry, standard products, extremely low transfer cost, low profitability, consumer backward integration, no impact on consumer product or service, ample consumer information. This study found that only transfer cost, the large purchase concentration of sales volume on buyer groups and easiness of getting information affect Apple App Store and hence discussed bargaining power of consumers in three dimensions, as depicted in Table 4.

Table 4. Competitiveness of Apple App Store by the bargaining power of consumers

Dimensions	Analysis Specific Explanations	Relative competitiveness assessment		
		High	Medium	Low
Transfer cost	Apple Computer mobile device consumers have to use mobile devices of other brands if planning to transfer to other mobile application platforms. The applications purchased on Apple App Store cannot be used anymore, making transfer cost huge.	✓		
Large purchase concentration of sales volume on buyer groups	Consumers purchase applications with personal account without concentrated purchase and facts, therefore, consumers have no negotiating room.	✓		
Consumers' capabilities to get information	At present, online information transmission is fast; consumers rapidly get information on any product, fully comparing product price and performance to make the best choice. By comparison, proportion of free applications on Apple App Store is relatively low. For more free applications, consumers choose mobile devices with other operating systems. Other manufacturers provide cheap and diverse mobile devices, posing considerable threat to Apple.			✓

As indicated in Table 4, given high transfer cost and low concentrated purchasing power, the price of can be high. Yet as functions and prices of existing mobile devices on the market are easily available to consumers, they may find prices of similar devices like Sony Xperia, Samsung Note, Samsung Galaxy sx, and HTC One series lower. This study suggests that Apple launch low-priced mobile devices for greater market share and higher percentage of free applications on the platform.

(4) Threat of substitute products and substitute services: the threat from other industries or services. Regarding this threat to Apple App Store, Porter (1980) discussed it in four dimensions: consumer preference to substitute products, price-utility ratios of substitute products, consumers' transfer cost, and consumer perceived differences about brands. This study found all these dimensions affecting Apple App Store and therefore analyzed with specific explanations, as detailed in Table 5.

Table 5. Competitiveness of Apple App Store by substitute products and substitute services

Dimensions	Analysis Specific Explanations	competitiveness assessment		
		High	Medium	Low
Consumer preference to substitute products	Due to the unique closeness of Apple iOS operating system, transfer cost of buy other mobile device brands is too high, so that consumers' motivation to use substitute products will be lower.	✓		
Price-utility ratios of substitute products	If consumers regard low price as the major consideration, they will choose to buy applications and mobile devices of other brands such as Google Android operating system. Comparatively, if consumers tend to focus on product utility as the major consideration, they will choose to buy Apple App Store applications and mobile devices.		✓	
Consumers' transfer cost	Apple Computer mobile device is superior to other major brands. If consumers are used to iOS system, they will face difficulty in transferring stored data to other operating systems. Moreover, data of iOS operating system can be connected and shared via Cloud. Hence, cost of changing operating system is considerably high.	✓		
The consumer perceived differences about brands	Founded in 1976, Apple Computer has a longer history, unique style, and high degree of consumer recognition, hence many consumers of high loyalty.	✓		

According to Table 5, regarding threat of substitute products and substitute services to Apple App Store, in the dimensions of relative price-utility ratio of substitute products and consumer transfer cost, as Apple App Store only provides applications for mobile devices produced by Apple, Android operating system adapts to different brands, lending consumers diversity in choice. Therefore, in addition to launching low-priced mobile devices, this study suggests that Apple should supply more varieties to allow consumers more diverse choices and increase percentage of free applications to enhance the competitive strength.

(5) Bargaining power of suppliers: negotiating or bargaining power of upstream suppliers. As for this threat, Porter (1980) discussed it in five dimensions: dominance and relative concentration of buyers, no need to compete with substitute products of the same industry, industry and major consumers, whether supplier product is a major input of the buyer, driving force of supplier integration. This study found no need to compete with substitute products of the same industry

and supplier backward integration capabilities affecting Apple App Store; bargaining power of suppliers was discussed in these two dimensions, as detailed in Table 6:

Table 6. Assessment of competitiveness of Apple App Store by the bargaining power of suppliers

Dimensions	Analysis Specific Explanations	Competitiveness assessment		
		High	Medium	Low
No need to compete with substitute products of the same industry	Mobile application platform software vendors can enter competition as long as they have professional technology. Due to low threshold, software vendors compete with each other, so that Apple App Store enjoys significant strengths in applications.	✓		
Driving force of supplier integration	Apple launched application subscription policy in February 2011 to allow consumers to trade outside the accounting system of Apple: i.e., transaction on the websites of software vendors are not charged by Apple. However, the pricing of the same application to Apple should be lower or equivalent to the price on websites of software vendors.	✓		

According to Table 6, regarding the bargaining power of suppliers, in the dimension of technology provided by the software vendor, as threshold of software vendors is relatively low, software vendors compete with each other on the platform, so that Apple has absolute dominating power. In the aspect of driving force for integration of suppliers, though Apple allows software vendors to deal with consumers directly without charge, price to Apple should be lower or equal to the price on websites of software vendors. Therefore, it can reduce intention of purchasing on websites of software vendors. As a result, driving force for software vendors to integrate will be weakened. Based on the above analysis, it can be learnt that Apple has absolute power in negotiation with suppliers, yet to provide a better service platform and face increasingly fierce competition from competitors, we suggest that Apple adopt flexile profit sharing with software vendors of different sizes and levels to enhance the intention of software vendors to sell in Apple App Store.

4. Conclusion

Consumer electronics products evolve quickly. Apple App Store has created mammoth opportunities for themselves and caused other brands to follow. Aside from the lead position of mobile application platforms, Apple Computer garnered more amazing achievements in application online store development and sales volume.

According to the five-force model of Porter, toward development strategy, in regard to potential entrants' threat, maintenance strategy should be adopted; as for existing competitors, Apple Computer should consistently renew marketing tactics and vary mobile devices, augmenting software interface friendliness and convenience; in the aspect of consumer bargaining power and threat of substitute products and substitute services, Apple Computer must launch low price mobile devices and raise percentage of free applications; as for bargaining power of suppliers, Apple must diversify profit-sharing ratios among software vendors. This study provides countermeasures for Apple App Store in the face of its challenges.

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Motivating innovation with a structured incentives scheme under continuous states

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Abstract –
The problem of incentive is an important component of the separation of ownership and control. A large literature focuses on the problem of how to use pay-for-performance schemes to both inspirit agents to exert effort and to deter agent-based resource tunneling. Manso (2011) proposes the use of structured incentive schemes with two periods to motivate innovation under discrete states. In combining these two perspectives, this paper propose a version with continuous states and point that agent can simultaneously innovate while exerting effort to obtain greater output per unit time. By offered the suitable incentive contract, the agent will take the action plan of exploration though he may get a failure. At the mean time, he will exert his all effort to get more production which determines his reward. This will explain many things in managerial compensation, such as a combination of stock options with long vesting periods, option re-pricing, golden parachutes and managerial entrenchment.

Keywords: Motivating innovation; Structured incentive scheme; Exploitation and exploration; continuous state

I. Introduction

Since Berle and Means' (1932) point the drawbacks with the separation of ownership and control, the incentive problem becomes the interest of this field, see Harris and Raviv (1978) and Holmstrom (1979) and the sequel. Most of them focus on the problems of how to inspirit the agent to exert effort or deter the agent from tunneling resources away from the corporation by applying principal-agent models. Manso(2011) presents a different view. He studies how to build a certain structure of incentives to motivate the agent to be more innovative with a two-period model. He shows that incentive schemes that motivate innovation should be structured differently from standard pay-for-performance schemes used to induce effort or avoid tunneling. Innovation involves the exploration of new untested approaches that are likely to fail. Therefore, standard pay-for-performance schemes that punish failures with low rewards and termination may in fact have adverse effects on innovation. In contrast, the optimal incentive scheme that motivates innovation exhibits substantial tolerance (or even reward) for early failure and reward for long-term success. Under this incentive scheme, compensation depends not only on total performance, but also on the path of performance; an agent who performs well initially but poorly later earns less than an agent who performs poorly initially but well later or even an agent who performs poorly repeatedly.

Based on the framework of Manso(2011), this paper study the incentives for innovation with non-fixed reward for the agent. Our model absorbs the advantages of the two directions above mentioned: incentive schemes for motivating innovation and standard pay-for -performance schemes. We give the standard of success, and the reward of the agent depends on the amount of the excess output over the baseline. The fixed wage and non-fixed wage (wage rate) are designed. These structured incentives can motivate the agent to select a more innovative work method and stimulate the agent to exert effort to get a better output at the mean time. The reward of the agent comprise of two parts: one fixed part which is independent at any situations, and another non-fixed part which depends on the output. The fixed part mainly be used to tolerate the failure of the exploration, and the on-fixed part is used to stimulate the agent to engage the innovation action and to exert his all effort to get the best reward.

Similar to Manso(2011), we use a two-period innovation process to deal with the incentives problem. To model the innovation process, we use a class of Bayesian decision models known as bandit problems. We focus on the central concern that arises in bandit problems: the tension between the exploration of new untested actions and the exploitation of well-known actions. The related literature see Holmstrom (1989), Aghion and Tirole (1994), Arrow (1969), March (1991), Moscarini and Smith (2001), Hellmann and Thiele (2009), Tian and Wang (2010), Ederer and Manso (2010) and other literature cited in Manso(2011).However, there are differences here, too. The model of Manso(2011) just consider two states: success and failure, and the optimal contracts depend only on the probability of success or failure, not on the amount of outputs. Our model is treated under the continuous states, and the optimal contracts depend on the distribution of the production---not only on the probability of success or failure, but also on the amount of outputs.

The rest of the paper is arranged as follows: section Π gives the bandit problem for tension between exploration and exploitation; section Ш presents the principal-agent problem about the tension; section IV gives the solutions of the principal-agent problem, namely the optimal incentive contracts for exploration and exploitation, respectively; and the last section concludes.

II. The Bandit Problem for tension between Exploration and Exploitation

Here, We review the two-armed bandit problem with one known arm as Manso(2011) and Zheng&Chen(2012). It illustrates the tension between exploration and exploitation. The original models are under discrete states. We extend it to be one model with continuous states.

We assume that the agent lives for only two periods. In each period $t \in T = \{1,2\}$, the agent takes an action $i \in I$, producing output R_{ti}, which is a random variable with cumulative distribution function $F_{R_{ti}}(x) = P[R_{ti} \le x]$. The principal gives the baseline B_t of output for each period $t \in T$ to evaluate the performance of the agent. If $R_{ti} > B_t$, the agent is judged as "success"; if $R_{ti} \le B_t$ the agent is judged as "failure". The cumulative distribution function $F_{R_{ti}}(x)$ may be unknown for some actions. To obtain information about $F_{R_{ti}}(x)$ for these actions, the agent needs to engage in experimentations in the first period. We let $h(R_{ti})$ denote the return function on output R_{ti}. And we let $E[h(R_{ti})]$ denote the unconditional expectation of $h(R_{ti})$, let $E\left[h(R_{ti}) \middle| R_{t-1j} > B_{t-1}\right]$ denote the conditional expectation of $h(R_{ti})$ given a success on action j in last period, and $E\left[h(R_{ti}) \middle| R_{t-1j} \le B_{t-1}\right]$ denote the conditional expectation of $h(R_{ti})$ given a failure on action j in last period. When the agent takes action $i \in I$ in period $t \in T$, he only learns about the information for the distribution of R_{t+1i} for the next period, so that

$$E[h(R_{ti})] = E[h(R_{ti}) | R_{t-1j}] \text{ for } i \ne j$$

This means that if the agent wants to know the information for the distribution of R_{t+1i} for the next period, he must engage in experimentation of action i with unknown distribution in this period.

Because there is no new information for unconditional expectation of $h(R_{ti})$, namely, it is independent of time, so we denote $E[h(R_{ti})] = E[h(R_i)]$ in this situation.

Our main interest focus on the tension between two actions: action 1 is exploration and action 2 is exploitation. We assume that in each period $t \in T$ the agent chooses between these two actions. Action 1 is the conventional work method, has a known distribution of R_{t1} in any period $t \in T$, namely $R_{t1} = R_1$, such that

$$E[h(R_{t1})] = E[h(R_{t1}) | R_{t-11}] = E[h(R_1)]$$

Action 2 is the new work method, has an unknown distribution of R_{t2} such that[1]

$$E[h(R_{t2}) | R_{t-12} \le B_{t-1}] < E[h(R_{t2})] < E[h(R_{t2}) | R_{t-12} > B_{t-1}]$$

This means that if the agent observes a success with the new work method, then he updates his beliefs that there is more possibility the new work method will succeed. Or, if the agent observes a failure with the new work method, then he updates his beliefs that there is more possibility the new work method will fail.

We assume that Action 2 has exploratory nature. This means that when the agent experiments with the new work method, he is initially not as likely to succeed as when he conforms to the conventional work method. However, if the agent observes a success with the new work method, then he updates his beliefs about the probability of success with the

[1] Here we assume that $h(R_{t2})$ is increasing function on R_{t2}.

new work method, so that the new work method becomes perceived as better than the conventional work method. This is captured as follows:

$$E[h(R_2)] < E[h(R_1)] < E\left[h(R_{t2}) \middle| R_{t-12} > B_{t-1}\right]$$

In fact, the agent may shirk, he do not choose any of the two work method above mentioned. This action 0 is allowed in the model. Shirking has zero private cost, but has a lower expected return than either of the two work methods. Here, we assume that action 0(shirking) has a return R_0 with known distribution in any period $t \in T$. Without lose generality, we assume that there exist stochastic dominances relationship as follows:

$$\left(R_{t2} \middle| R_{t-12} > B_{t-1}\right) \overset{FSD}{\succ} R_1 \overset{FSD}{\succ} R_2 \overset{FSD}{\succ} \left(R_{t2} \middle| R_{t-12} \le B_{t-1}\right) \overset{FSD}{\succ} R_0$$

Where $X \overset{FSD}{\succ} Y$ means that X stochastically dominates Y in first order, namely $F_X(\eta) \le F_Y(\eta)$ for all $\eta \in \mathrm{R}$.

So, if $h(\bullet)$ is non-decreasing function, we have

$$E[h(R_0)] < E[h(R_{t2}) | R_{t-12} \le B_{t-1}] < E[h(R_2)] < E[h(R_1)] < E[h(R_{t2}) | R_{t-12} > B_{t-1}] \qquad (1)$$

In fact, the model is a three-armed bandit problem, namely $I = \{0,1,2\}$, but we only consider the tension between exploration and exploitation. The agent is risk-neutral and has a discount factor normalized to one. The agent thus chooses an action plan $\langle i_k^j \rangle$ to maximize his total expected payoff. Where $i \in I$ is the first-period action, $j \in I$ is the second-period action in the case of success in the first period, and $k \in I$ is the second-period action in the case of failure in the first period.

Two action plans need to be considered. Action plan $\langle 1_1^1 \rangle$, which Manso(2011) call exploitation, is just the repetition of the conventional work method. Action plan $\langle 2_1^2 \rangle$, which Manso call exploration, is to initially try the new work method, stick to the new work method in the case of success in the first period, and revert to the conventional work method in the case of failure in the first period. Apparently, the total payoff of action plan $\langle 2_1^2 \rangle$ from exploration is higher than that of action plan $\langle 1_1^1 \rangle$ from exploitation if and only if

$$E[R_2] > E[R_1] - E\{1_{R_{12} > B_1}(E[R_{22} | R_{12} > B_1] - E[R_1])\}$$

If the agent tries the new work method, he obtains information about R_{t2}. This information is useful for the agent's decision in the second period, since the agent can switch to the conventional work method if he learns that the new work method is not worth pursuing. The agent may thus be willing to try the new work method even though the initial expected return $E[h(R_2)]$ with the new work method is lower than expected return $E[h(R_1)]$ with the conventional work method.

III. The Principal-agent Problem

In this section, we introduce incentive problems to the three-armed bandit problem with two known arms as reviewed in the previous section.

The principal hires an agent to perform the task described in the previous section. In each period, the agent incurs private costs $c_i \ge 0$ if he takes action $i = 1,2$, but can avoid these private costs by taking action $i = 0$, shirking ($c_0 = 0$).

We assume that the principal does not observe the actions taken by the agent. As such, before the agent starts working, the principal offers the agent a contract $\langle \vec{\lambda}, \vec{w} \rangle = \{\langle \lambda_1, w_1 \rangle, \langle \lambda_2, w_2 \rangle, \langle \lambda_3, w_3 \rangle\}$ that specifies the agent's wages contingent on future performance. The agent has limited liability, meaning that his wages can not be negative. Here, w_s ($s = 1,2,3$) are fixed wages, which are the minimum wages in any situations. And λ_s is the wage rate for extra return at situation of success. This means that if it is a failure, the agent will get a fixed wage w_s, if it is a success, he will get a fixed wage w_s plus flexible wage $\lambda_s(R_s - B_s)1_{R_s > B_s}$. Specifically, $\langle \lambda_1, w_1 \rangle$ is the wage rate and fixed wage in the first period, respectively. $\langle \lambda_2, w_2 \rangle$ is the wage rate and fixed wage in the second period conditional on the situation of success in the first period, respectively. And $\langle \lambda_3, w_3 \rangle$ is the wage rate and fixed wage in the second period conditional on the situation of failure in the first period, respectively.

Different from that of Manso(2011), the contract $\langle \vec{\lambda}, \vec{w} \rangle$ in our model is not a fixed wage. While fixed wage in the situation of failure, but $\vec{\lambda}$ is fixed wage rate in the situation of success. When the agent succeed in one period t, according to the baseline of success B_t given by the principal in advance, he will get a payoff w_s plus $\lambda_s(R_s - B_s)1_{R_s > B_s}$, $s = 1,2,3$, which is dependent of the output. The more output it produces, the more wage reward he gets. So, the contract $\langle \vec{\lambda}, \vec{w} \rangle$ of our Principal-agent model has two functions: one is to motivate the agent to be more innovative and the other is to inspirit the agent to exert effort.

And it is different from that of Zheng&Chen(2012), where the w_s is not minimum wage, which may lead to the situation that the wage in success will be lower that in failure. Here, we revise this fault.

In addition to these differences, another feature is that the models here are built with continuous states. To illustrate the process with reward structure, see the figure 1 as follows.

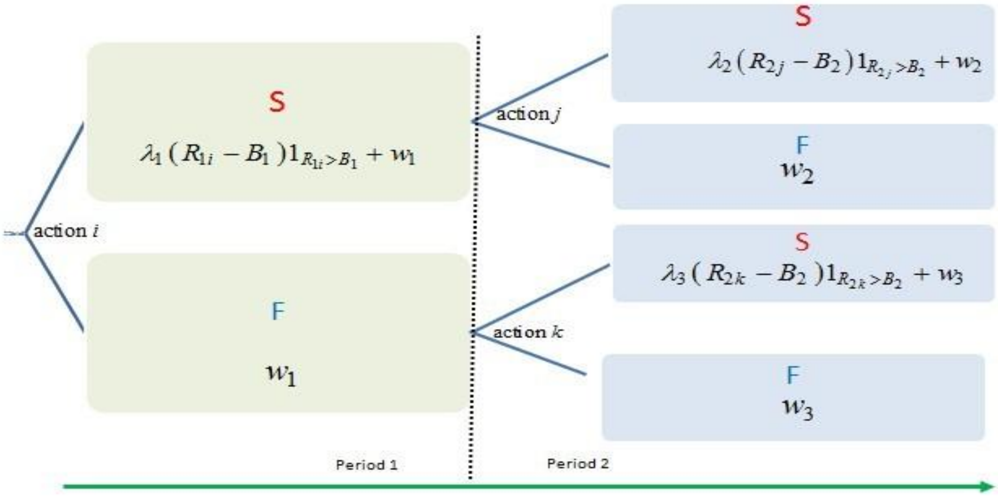

Figure 1 structured reward of action plan $\langle i_k^j \rangle$

S—success, F--failure

We assume that both the principal and the agent are risk-neutral and have a discount factor of one, just for simplicity. When the principal offers the agent a contract $\langle \vec{\lambda}, \vec{w} \rangle$ and the agent takes action plan $\langle i_k^j \rangle$, the total expected payments from the principal to the agent are given by

$$\begin{aligned} W\left(\vec{\lambda}, \vec{w}, \langle i_k^j \rangle\right) &= E[\lambda_1(R_{1i}-B_1)1_{R_{1i}>B_1}+w_1] \\ &+E\left\{1_{R_{1i}>B_1} E[\lambda_2(R_{2j}-B_2)1_{R_{2j}>B_2}+w_2 \mid R_{1i}>B_1]\right\} \\ &+E\left\{1_{R_{1i}\le B_1} E[\lambda_3(R_{2k}-B_2)1_{R_{2k}>B_2}+w_3 \mid R_{1i}\le B_1]\right\} \end{aligned} \tag{2}$$

Apparently, the model of Manso (2011) and Zheng & Chen (2013) are special discrete cases of our model.

Because $E\left[(R_{ti}-B_t)1_{R_{ti}>B_t}\right]$ can be viewed as a call option whose underlying asset is output R_{ti} and strike price is B_t, we denote $op_{ti} = E\left[(R_{ti}-B_t)1_{R_{ti}>B_t}\right]$.

Similarly, we denote

$\overline{op}_{2j}^{1i} = E[(R_{2j}-B_2)1_{R_{2j}>B_2} \mid R_{1i}>B_1]$, and $\underline{op}_{2k}^{1i} = E[(R_{2k}-B_2)1_{R_{2k}>B_2} \mid R_{1i}\le B_1]$.

So the equation (2) can be rewritten as

$$\begin{aligned} W\left(\vec{\lambda}, \vec{w}, \langle i_k^j \rangle\right) &= \lambda_1 op_{1i} + w_1 \\ &+ E\left\{1_{R_{1i}>B_1}(\lambda_2 \overline{op}_{2j}^{1i} + w_2)\right\} \\ &+ E\left\{1_{R_{1i}\le B_1}(\lambda_3 \underline{op}_{2k}^{1i} + w_3)\right\} \end{aligned} \tag{3}$$

It means that the total expected payments comprise of a series of options.

According to the assumptions in the previous section, we have

$$op_{t0} < \underline{op}_{22}^{12} < op_{t2} < op_{t1} < \overline{op}_{22}^{12} \tag{4}$$

When the agent takes action plan $\langle i_k^j \rangle$, the total expected costs incurred by the agent are given by

$$C\left(\langle i_k^j \rangle\right) = c_i + E\left[1_{R_{1i}>B_1}\right]c_j + E\left[1_{R_{1i}\le B_1}\right]c_k \tag{5}$$

Here we consider a non-cooperative game (Stackelberg game). It needs to be pointed that the model assumes a common knowledge framework in which all information is known to both agents. This assumption is because of the nature of Stackelberg game. However, the problem here is a little different from the standard solution. We only want to know what kind of wage structure can lead the agent to take the objective action plan $\langle i_k^j \rangle$, such as the innovative action plan $\langle 2_1^2 \rangle$ or conventional action plan $\langle 1_1^1 \rangle$.

We say that contract $\langle\vec{\lambda},\vec{w}\rangle$ is an optimal contract that implements action plan $\langle i_k^j\rangle$ if it minimizes the total expected payments from the principal to the agent,

$$W\left(\vec{\lambda},\vec{w},\langle i_k^j\rangle\right) \quad (6)$$

subjected to the incentive compatibility constraints,

$$W\left(\vec{\lambda},\vec{w},\langle i_k^j\rangle\right)-C\left(\langle i_k^j\rangle\right)\geq W\left(\vec{\lambda},\vec{w},\langle l_n^m\rangle\right)-C\left(\langle l_n^m\rangle\right) \quad (IC_{\langle l_n^m\rangle})$$

This is a linear program with six unknowns and 27 constraints because $l,m,n\in I$. When more than one contract solves this program, we restrict attention to the contract that pays the agent earlier as Manso(2011).

The principal's expected profit from implementing action plan $\langle i_k^j\rangle$ is given by

$$\prod\left(\langle i_k^j\rangle\right)=Y\left(\langle i_k^j\rangle\right)-W\left(\vec{\lambda}\left(\langle i_k^j\rangle\right),\vec{w}\left(\langle i_k^j\rangle\right),\langle i_k^j\rangle\right) \quad (7)$$

Where

$$Y\left(\langle i_k^j\rangle\right)=E\left[R_{1i}\right]+E\{1_{R_{1i}>B_1}E\left[R_{2j}\,|\,R_{1i}>B_1\right]\}+E\{1_{R_{1i}>B_1}E\left[R_{2k}\,|\,R_{1i}\leq B_1\right]\} \quad (8)$$

is the principal's total expected revenue when the agent uses action plan $\langle i_k^j\rangle$ and $\langle\vec{\lambda}\left(\langle i_k^j\rangle\right),\vec{w}\left(\langle i_k^j\rangle\right)\rangle$ is the optimal contract that implements action plan $\langle i_k^j\rangle$ .The principal thus chooses the action plan $\langle i_k^j\rangle$ that maximizes $\prod\left(\langle i_k^j\rangle\right)$.

The assumptions in the principal-agent problem studied here are standard except that there is learning about the technology being employed. This gives rise to the tension between exploration and exploitation, since there is nothing to be learned about the conventional technology, but a lot to be learned about the new technology.

IV. Incentives for Exploration and Exploitation

Here we presents the optimal contracts that implement exploration and exploitation.

IV.1. Incentives for Exploitation

Recall from Section II that exploitation represented by action plan $\langle 1_1^1\rangle$.

$$\begin{aligned}W\left(\vec{\lambda},\vec{w},\langle 1_1^1\rangle\right) &= \lambda_1 op_{11}+w_1\\ &+E\left\{1_{R_{11}>B_1}(\lambda_2\overline{op_{21}^{11}}+w_2)\right\}\\ &+E\left\{1_{R_{11}\leq B_1}(\lambda_3\underline{op_{21}^{11}}+w_3)\right\}\end{aligned} \quad (9)$$

Given the goal of action plan $\langle 1_1^1\rangle$, the principal must offer the optimal contracts that the agent implement the exploitation. The optimal contracts $\left\langle\vec{\lambda},\vec{w}\right\rangle$ must maximizes $\prod\left(\langle 1_1^1\rangle\right)$, namely

$$\text{minimizes } \; W\left(\vec{\lambda},\vec{w},\langle 1_1^1\rangle\right)$$

subject to the incentive compatibility constraints,

$$W\left(\vec{\lambda},\vec{w},\langle 1_1^1\rangle\right)-C\left(\langle 1_1^1\rangle\right)\geq W\left(\vec{\lambda},\vec{w},\langle l_n^m\rangle\right)-C\left(\langle l_n^m\rangle\right) \quad (IC_{\langle l_n^m\rangle})$$

Now we derive the optimal contract that implements exploitation. The following definitions will be useful in stating Proposition 1:

$$\beta_0=\frac{1}{1+E\left[1_{R_2>B_1}\right]}\left(\frac{E[1_{R_2>B_1}(\overline{op_{22}^{12}}-op_{20})]}{op_{21}-op_{20}}+\frac{op_{12}-op_{10}}{op_{11}-op_{10}}\right)$$

Because the distribution of return R_2 in the first period is unknown, so we use expectation to $E[1_{R_2>B_1}]$ to denote it. And we denote $p_0=E[1_{R_0>B_1}]$, $p_1=E[1_{R_1>B_1}]$ directly.

PROPOSITION 1: The optimal contract $\left\langle\vec{\lambda},\vec{w}\right\rangle_1^*$ that implements exploitation is such that

$$w_1=w_2=w_3=0,\ \lambda_2=\lambda_3=\frac{c_1}{op_{21}-op_{20}}$$

$$\lambda_1=\frac{c_1}{op_{11}-op_{10}}+\frac{\left(1+E\left[1_{R_2>B_1}\right]\right)c_1}{op_{11}-op_{12}}\left(\beta_0-\frac{c_2}{c_1}\right)^+$$

where $(x)^+=\max(x,0)$.

The formal proofs of all the propositions are omitted limited to the length. However, the main intuition behind Proposition 1 is as follows. To implement exploitation, the principal must prevent the agent from both shirking and exploring. If c_2 is high relative to c_1, only shirking constraints are binding, and thus the optimal contract that implements exploitation is similar to the optimal contract used to induce the agent to exert effort in a standard word-shirk principal-agent model. If c_2 is low relative to c_1, the exploration constraint is binding. To prevent exploration, the principal must pay the agent an extra premium in the case of success in the first period. This extra premium is decreasing in c_2 / c_1, since as c_2 / c_1 increases the agent becomes less inclined to explore.

Similarly, the baseline B_t will affect the result. If $B_1 \geq B_2$, then $\lambda_1 \geq \lambda_2 = \lambda_3$. This can be interpret as that when the baseline of standard for success decreases, the difficulty for success in second period decreases, the exploration constraint may be binding. To prevent exploration, the principal must pay the agent an extra premium in the case of success in the first period. However, if $B_1 < B_2$, the difficulty for success in second period increases, the exploitation constraint may be binding, the principal may not need to pay the agent an extra premium in the case of success in the first period. It means that the following $\lambda_1 < \lambda_2 = \lambda_3$ may be hold in this time.

To encourage the agent to take the conventional method, there are no any fixed minimum wages. This means that no any failure is tolerated in the whole process.

IV.2. Incentives for Exploration

Proposition 2 derives the optimal contract that implements exploration. Recall from Section II that exploration is given by action plan $\langle 2_1^2 \rangle$.

$$\begin{aligned} W\left(\vec{\lambda}, \vec{w}, \langle 2_1^2 \rangle\right) &= \lambda_2 op_{12} + w_1 \\ &+ E\left\{1_{R_{12} > B_1}(\lambda_2 \overline{op_{22}^{12}} + w_2)\right\} \\ &+ E\left\{1_{R_{12} \leq B_1}(\lambda_3 \underline{op_{21}^{12}} + w_3)\right\} \end{aligned} \qquad (10)$$

Given the goal of action plan $\langle 2_1^2 \rangle$, the principal must offer the optimal contracts that implement the exploration. The optimal contracts $\left\langle \vec{\lambda}, \vec{w} \right\rangle$ must maximizes $\prod\left(\langle 2_1^2 \rangle\right)$, namely

$$\text{minimizes } W\left(\vec{\lambda}, \vec{w}, \langle 2_1^2 \rangle\right)$$

subject to the incentive compatibility constraints,

$$W\left(\vec{\lambda}, \vec{w}, \langle 2_1^2 \rangle\right) - C\left(\langle 2_1^2 \rangle\right) \geq W\left(\vec{\lambda}, \vec{w}, \langle l_n^m \rangle\right) - C\left(\langle l_n^m \rangle\right) \qquad (IC_{\langle l_n^m \rangle})$$

The form of the optimal contract that implements exploration will depend on whether exploration is moderate or radical.

DEFINITION 1: Exploration is radical if

$$\frac{E\left[1_{R_2 \leq B_1}\right]}{E\left[1_{R_1 \leq B_1}\right]} \geq \frac{E\left[1_{R_2 > B_1} \overline{op_{22}^{12}}\right]}{E\left[1_{R_1 > B_1}\right] op_{21}}$$

and moderate otherwise.

Exploration is radical if the likelihood ratio between exploration and exploitation of a failure in the first period is greater than the reward ratio between exploration and exploitation of two consecutive successes. We call this exploration radical because it has a high expected probability of failure in the first period relative to the probability of failure of the conventional action.

The following definitions will also be useful in stating Proposition 2:

$$\beta_1 = \frac{E[1_{R_2 > B_1}(\overline{op_{22}^{12}} - op_{20})]}{(1 + E[1_{R_2 > B_1}])(op_{21} - op_{20})}$$

$$\beta_2 = \beta_1 + \frac{1}{1 + E\left[1_{R_2 > B_1}\right]} \frac{E\left[1_{R_2 > B_1} \overline{op_{22}^{12}}\right] - p_0 op_{21}}{(p_1 - p_0) op_{21}}$$

PROPOSITION 2: The optimal contract $\left\langle \vec{\lambda}, \vec{w} \right\rangle_2^*$ that implements exploration is such that

$$\lambda_1 = 0, \ \lambda_3 = \frac{c_1}{op_{21} - op_{20}} \text{ and } w_2 = w_3 = 0$$

If exploration is moderate, then $w_1 = 0$ and

$$\lambda_2 = \frac{c_1}{op_{21} - op_{20}} - \frac{(1+E[1_{R_2>B_1}])c_1}{E\left[1_{R_2>B_1}\overline{op_{22}^{12}}\right] - p_0 op_{20}}\left(\beta_1 - \frac{c_2}{c_1}\right)^+$$
$$+\frac{(1+E[1_{R_2>B_1}])c_1}{E\left[1_{R_2>B_1}\overline{op_{22}^{12}}\right] - p_0 op_{21}}\left(\frac{c_2}{c_1} - \beta_1\right)^+ +$$
$$\frac{(1+E[1_{R_2>B_1}])(p_1 - p_0)op_{21}c_1}{\left(E\left[1_{R_2>B_1}\overline{op_{22}^{12}}\right] - p_1 op_{21}\right)\left(E\left[1_{R_2>B_1}\overline{op_{22}^{12}}\right] - p_0 op_{21}\right)}\left(\frac{c_2}{c_1} - \beta_2\right)^+$$

If exploration is radical, then

$$w_1 = \frac{c_1(1+E[1_{R_2>B_1}])op_{21}}{E\left[1_{R_2>B_1}(\overline{op_{22}^{12}} - op_{21})\right]}\left(\frac{c_2}{c_1} - \beta_2\right)^+$$

And

$$\lambda_2 = \frac{c_1}{op_{21} - op_{20}} - \frac{(1+E[1_{R_2>B_1}])c_1}{E\left[1_{R_2>B_1}\overline{op_{22}^{12}}\right] - p_0 op_{20}}\left(\beta_1 - \frac{c_2}{c_1}\right)^+$$
$$+\frac{(1+E[1_{R_2>B_1}])c_1}{E\left[1_{R_2>B_1}\overline{op_{22}^{12}}\right] - p_0 op_{21}}\left(\frac{c_2}{c_1} - \beta_1\right)^+ + \left(\frac{c_2}{c_1} - \beta_2\right)^+ *$$
$$\frac{(1+E[1_{R_2>B_1}])(E[1_{R_2>B_1}] - p_0)op_{21}c_1}{E\left[1_{R_2>B_1}(\overline{op_{22}^{12}} - op_{21})\right]\left(E\left[1_{R_2>B_1}\overline{op_{22}^{12}}\right] - p_0 op_{21}\right)}$$

To implement exploration, the principal must prevent the agent from shirking or exploiting. The principal does not make payments to the agent after a failure in the second period, since this only gives incentives for the agent to shirk. Moreover, the principal does not make payments to the agent after a success in the first period for two reasons. First, rewarding first-period success gives the agent incentives to employ the conventional work method in the first period, since the initial expected probability $E[p_2]$ of success with the new work method is lower than the probability p_1 of success with the conventional work method. Second, in the case of success in the first period, additional information about the first-period action is provided by the second-period performance, since the expected probability of success with the new work method in the second period depends on the action taken by the agent in the first period. Delaying compensation to obtain this additional information is thus optimal.

Anyway, the principal expect the agent choose conventional work method in the second period after a failure in the first period. To prevent the agent from shirking in this situation, the principal pays the agent $\lambda_3 = \frac{c_1}{op_{21} - op_{20}}$.

Then, at last, to encourage exploration the principal must reward the agent second-period success after a success in the first period. The wage rate λ_2 depends on the difficulty of implement exploration relative to exploitation. With the increase of c_2 / c_1, the difficulty of implement exploration relative to exploitation increases, and wage rate λ_2 must increase, too.

If $c_2 / c_1 < \beta_1$, then exploitation is too costly for the agent, but exploration is not costly for the agent. At this situation, the principal pays the agent $\lambda_2 < \lambda_3$. If $c_2 / c_1 \geq \beta_1$, then exploitation is not too costly for the agent, but exploration is costly for the agent. At this situation, the principal must pays the agent $\lambda_2 \geq \lambda_3$. When $c_2 / c_1 \geq \beta_2$, the rage rate λ_2 must increase further. At this case, if $\frac{E[1_{R_2 \leq B_1}]}{E[1_{R_1 \leq B_1}]} \geq \frac{E\left[1_{R_2>B_1}\overline{op_{22}^{12}}\right]}{E[1_{R_1>B_1}]op_{21}}$, namely Exploration is radical, it has a high expected probability of failure in the first period relative to the probability of failure of the conventional action, expected reward for exploration of two consecutive successes can not compensate the risk of failure. So, the principal must pay the agent a higher λ_2, and reward the agent for failure in the first period at the same time.

Similarly, the baseline B_t will affect the result. If $B_2 \geq B_1$, then λ_3 and λ_2 increase. This can be interpret as that when the baseline of standard for success increases, the difficulty for success in second period increases, the exploitation constraint may be binding. To prevent exploitation, the principal must pay the agent an extra premium in the case of success in the second period.

To illustrate the differences of the optimal contracts between these two action plan, see figure 2 as follows.

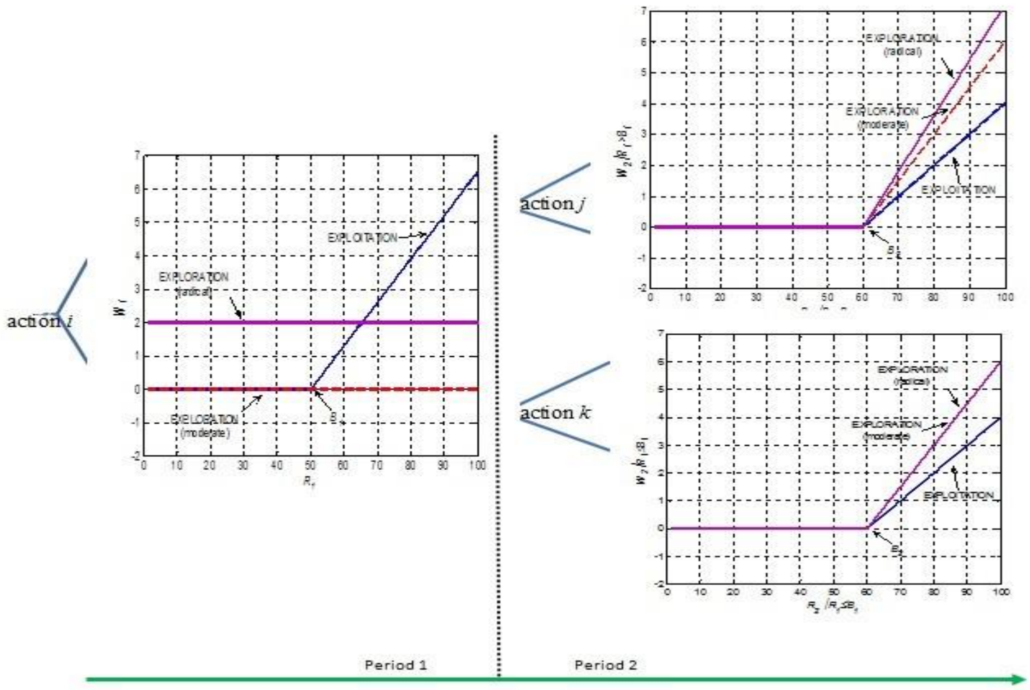

Figure 2. structured reward of action plan $\langle i_k^j \rangle$

The blue line for action plan $\langle 1_1^1 \rangle$ (exploitation), the red dashed line for action plan $\langle 2_1^2 \rangle$ (moderate exploration) the purple line for action plan $\langle 2_1^2 \rangle$ (radical exploration)

V. Conclusion and limitations

Based on the framework of Manso(2011), this paper study the incentives for innovation with non-fixed reward for the agent. We give the standard of success, and the reward of the agent depends on the amount of the excess output over the baseline. The fixed wage and wage rate for success are designed. These structured incentives can motivate the agent select a more innovative work method and stimulate the agent to exert effort to get a better output.

The optimal contract that implements both exploitation and exploration comprise of a series of options, which are structured. To stimulate exploration, the principal must offer a proper fixed reward to tolerate the possibility of failure; at the same time, the non-fixed reward must not be offered. The optimal contract depends on the baseline of success and the private cost of the agent, especially for the cost ratio of exploration and exploitation.

There are some limitations for the paper. 1). we only consider the first-order stochastic dominances relationship between the returns. They are may be second-order or higher-order. So, more real distributions need to discuss on the problem.

2)In the paper, the information is assumed symmetry . In fact, the information may be asymmetry, which will impact the results severely.

3) the interest rate and time preference are not considered. The span of periods may have important impact on the solutions.

4)Some of the predictions of the model remain untested though, and additional empirical work seems wanted.

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Discontinuous Improvement: Continuing to Improve when Continuous Improvement Stalls

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Abstract

The idea of Continuous Improvement goes back at least as far as Dr. W. Edwards Deming's work in the quality field. Deming promoted an idea he called "Continual Improvement", of which "Continuous Improvement" is a part but not the whole. Western industry, wanting to emulate the methods used by Japan in their rise in the 1980's and 1990's have adopted the Continuous Improvement (CI) part of Continual Improvement, often in the form of Kaizen. Their adoption of this method was often rewarded and apparently confirmed by outstanding early successes. As time went on, many of the companies who had adopted CI found the improvements to be more and more disappointing. But still, many of them continue to use the methods of CI without understanding why the returns are diminishing. We believe that TRIZ actually predicts this result of Continuous Improvement, and also provides tools for analyzing the situation and plotting a new course that will again offer the potential of the kind of gains that were enjoyed when CI was first adopted. In this paper, we will explain how TRIZ predicts this outcome, and give examples of stalled development and renewed development (with or without TRIZ). Then we will examine some of the tools within TRIZ that can be used to jump the discontinuities in the continual development of products and processes. The goal is to provide a way of communicating to executives the reason that their efforts are yielding disappointing returns and offering them a new course that will help correct that situation.

Keywords: Continuous improvement, jumping discontinuities, managing innovation, TRIZ.

1. Introduction

Although Deming promoted an idea he called "Continual Improvement", Western industry has largely narrowed its focus to "Continuous Improvement" (Bicheno & Holweg, 2009) which is a part but not the whole of Continual Improvement (CQI 2014). In the mathematical understanding of these terms (which applies equally well in many industrial situations), the difference in meaning is the difference between "ongoing and sustainable improvement" and "incremental, stepwise improvement". The adoption of the "Continuous Improvement" method was often met with success that was taken as confirmation of the wisdom of the program. However, as the programs progressed, the effects of the apparently subtle difference between the two terms often began to be seen, although it was rarely understood.

The author has had a long interest in trying to understand why approaches like Lean and Six Sigma are main stream, whereas it is obvious to anyone who takes the time to review the area that tools like TRIZ have much greater problem solving and creative potential to improve products/ services. The author originally assumed that it was individual’s mindsets that dominated engineers to be, safe/ incremental thinkers (Filmore 2008a & b), then personality (Filmore & Crust 2009). Later in 2010 Filmore (2010), focused on the ‘engineer come manager’ and looked at why discontinuous innovation (breakthrough thinking) is still not promoted even in challenging times. In hindsight, the author has come to realize that perhaps it is the system that dominates (the engineers) and even the managers without them often being aware of this. This comes across in the paper by Larsen & Bogers 2014) in what they term “Innovation (as Improvisation) ‘In the shadow’ “ (NB our brackets). This will be discussed later.

2. Innovation

Unfortunately, just as with Six Sigma, a lot of executives have "drunk the Kool-Aid" very uncritically, and their paradigm is firmly that CI principles are unquestionably correct. Early on, there seemed to be some evidence to support this. Many processes in their companies were low on the S-Curve, and so the energy that was put into developing those systems was rewarded hand- somely. The CI consultants called that "low-hanging fruit". But more recently, it seems that the gains are much smaller and require much greater input of effort. TRIZ predicts this, for as systems approach their limits of ideality, there are fewer and fewer inefficiencies to be removed, i.e., less and less scope for continuous improvement. This is where the S-Curve is near horizontal (Figure 1).

An easy way to understand continuous improvement is using the S-Curve which developed from technological forecasting (Meredith & Mantel 1995) and more recently TRIZ trends of evolution (Mann 2002). The S-Curve (see Figure 1) shows how the value of a product or service increases over time towards the ideal product or service, from the initial birth of an idea, through the initial development, to the rapid innovation when launched/ deployed, to the slowdown in innovation with a mature product/ service and finally to its retirement. In TRIZ terms the ideal is a product or service that becomes very cheap (or even free), has no harmful effects, and has all the benefits possible. On the way to the ideal, using CI methods is highly efficient as there is much ‘waste’ in the system. The standard quality methods are thus useful to use and have a good track record of success. As one approaches the ideal however, the S-Curve becomes closer to the horizontal and however many resources or amount of person-power (e.g., research time) is thrown at the product/ service, basically one has hit some limit of doing things in this particular way and so it is futile to continue. This is because the basic system cannot become much better and because so much waste has been removed (to use CI terms) that it really isn’t possible to make it much cheaper!

Breakthrough innovation is considered to be the jumps between 'S-curves' (see Figure 1). NB Lumsdaine and Lumsdaine (1995) call this jump a 'paradigm shift'. The 'jumps' identify a key attribute of innovative engineers, namely that they actively look for the 'breakthrough' compared to less innovative engineers who tend to only explore incremental innovation. It should be noted that breakthrough thinking is central to TRIZ and not generally practiced within the quality tools arena such as Six Sigma (Filmore 2008b). The author has discussed in the past how engineers need to spend '95%' of their time thinking continuous improvement (incremental thinking) and using the appropriate tools for these, but what is essential for a company to stay competitive, is to '5%' think discontinuous innovation (breakthrough thinking) and use a completely different (e.g., TRIZ) toolset. What is essential is that unless managers and company leaders understand this, then the pressures on 'engineers' to stay in the safe continuous innovation thinking arena, will predominate and the company will ossify.

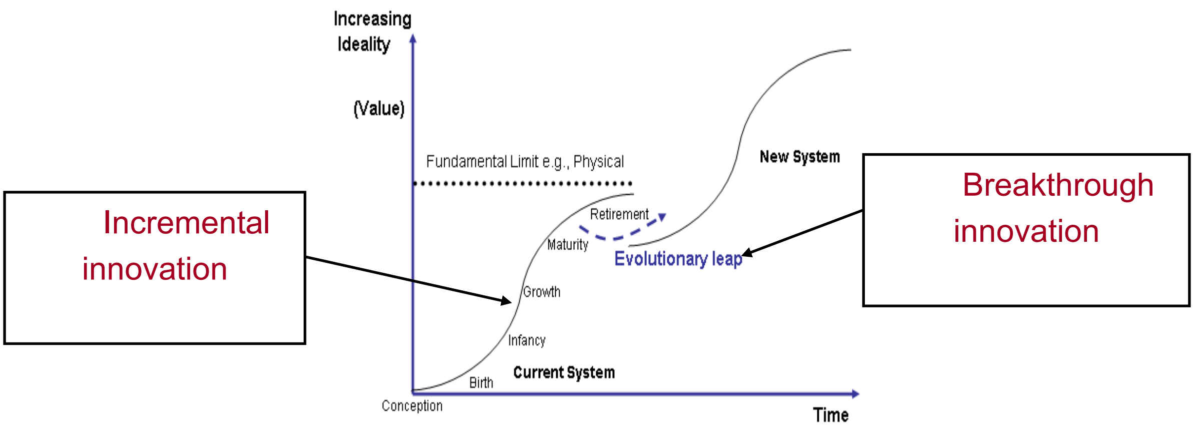

Figure 1: Showing the jump ('creativity leap') between s-curves. Note that the new system initially has lower ideality e.g., efficiency than the old system, but very rapidly improves (see case study).

As a well-known example (see Clayton Christensen 1997), Intel's chairman realized that the Pentium processor was getting too large and expensive for many applications and that it was not going to be easy to persuade managers and engineers (all focused on speed and power) to build a smaller slower processor, within the present organizational structure. He thus set up a separate company not obviously related to Intel and got the staff there to focus on the job in hand. When the Celeron processor became a hit, it was then bought back into the company. The lesson here is that different company structures and engineers/ managers mindsets are required to make breakthroughs happen.

The incremental methods of Continuous Improvement seem reasonable to many people because they simply seem to be sensible. After all, a journey of 1000 miles begins with a single step. But after collecting data and talking about the importance of "thinking outside the box" and applying all the other tools in the CI toolkit, CI really offers very little for actually finding the new, improved state beyond brainstorming and asking how nature does it. Even though the shortcomings of both individual and group brainstorming activities are well documented, CI offers nothing of substance that is better. So, even if we understand that we are nearing the end of an S-Curve and need to find a new one, we are left with a process (if you want to call it that) that is ultimately random and depends largely on good fortune to find the new S-Curve. The problem with being admonished to "think outside the box" is that we first need to get out of the box, and for that, we need a tool.

TRIZ offers a rich set of tools for accomplishing just that. TRIZ experts often speak of the idea of "psychological inertia"—the tendency of our thoughts to continue along the same trajectory that they began on. And without an outside influence to change their path, they will continue on that trajectory. The tools of TRIZ provide us with an array of tools to help us break the natural psychological inertia that we all have—that offer the needed outside influence that can alter the trajectory of our thoughts. Some of the tools are more useful in some situations than in others, just as in some situations a mechanic will reach for a screwdriver and in other situations he will use a socket wrench. The selection of tools offered by TRIZ allows us to define in a conceptual, abstracted way what the solution for a problem will look like, and then helps us to analyze the problem in ways that promote the kind of deeper understanding that makes a solution possible.

3. Case Studies

One company—one of the leaders in its industry—faced a market need to improve the performance of one of its most important and profitable products. There had been a history of improvements in this kind of product over the previous years in which the product's performance improved quite well using incremental changes in the design. This line of incremental changes was well known in the industry, and virtually all the manufacturers used it in some way. But the product's design had come to a point where continuing along the line of incremental changes had begun to increase customer dissatisfaction because another characteristic of the product was being degraded. Continuing along the original line of continuous change to get to the new performance requirement would have resulted in intense customer dissatisfaction.

It should be noted here that this company has a long and successful history of using Continuous Improvement principles in both its manufacturing processes as well as in its product design processes. Because of this successful history, the management had become very committed to the use of CI principles, and had thoroughly incorporated these principles into the company's culture. So the natural thing for the product team to do was to try to make continuous, incremental changes to the product, but it was clear that this kind of change had begun to produce larger and now unacceptable compromises.

Almost completely separated from the team that was tasked with improving the product, another engineer working alone and apart from the CI system, who had applied the TRIZ ideas of Ideal Final Result and identification of Physical Contradictions created a solution to the problem that abandoned the previous line of improvements and applied an entirely new principle to solving the problem of improved performance. It was, in fact, on a new S-Curve. While the performance potential of the new system was significantly better than that of the previous system, the new principle was not trusted by those who were in charge of the project. Predictably, the performance of the system at first was not quite as good as that of the previous system, so those who were used to evaluating ideas based on Continuous Improvement initially rejected it on the grounds that it appeared to be a step backward. But with a little development, it soon was shown that the new system responded very quickly to development effort. The new system has now overcome the resistance of those who originally insisted on solving the problem using incremental changes. The new system not only delivers the improved performance that the market demanded, but it has a lower cost and is also easier to manufacture while actually improving the characteristic that would have been degraded by the Continuous Improvement methods.

4. Communicating with company leaders

For many companies, one of the highest values of management is stability and predictability. Even though many companies begin with an innovative product, and continue to innovate for quite some time after its beginning, quite quickly they evolve into organizations in which most of the leaders are very focused on being safe and on preserving what they have. Things must be done according to defined processes in order to ensure predictability of outcomes. This mindset (Filmore & Crust 2009) is closely connected with their embracing of DMAIC and CI. Both of these programs are focused on small, continuous, evolutionary changes, and look for solutions to problems either within the existing system in the case of DMAIC, or possibly at the edges of the existing system in the case of CI. Both have the appearance of maintaining a safe course of action that is heavily based on the past.

On the other hand, leaders recognize at some level that innovation is important—maybe even necessary. But even though they recognize the importance, they are reluctant to allow any “processes” for innovation other than those that are dominated by DMAIC and CI thinking. These processes will yield very little that could be considered innovative.

Somehow there needs to be created in the minds of the company leaders, the recognition that truly innovative activity necessarily involves instability. The quotation “Where there is no standard, there can be no Kaizen” is well known, and it is often thought to direct our thinking in a good way. By some means, one needs to understand that when we truly innovate, we are leaving the old standards behind, and forging new ones. The author believes this can be done by executives understanding: 1) the positioning of each of their products on the S-Curve (Ikovenko 2013) and 2) understanding that a) a different company process, associated with b) different engineer/ management thinking, has to occur to jump to a new S-Curve i.e., move from the CI stagnation. This requires executives to manage their fear of the likely short term instabilities as the company moves, into an uncertain innovation playing field. An example of this has been seen by the author working with a conservative, safety paramount industry moving their products from an analogue to a digital electronics platform. Initially the company did not even have engineers with enough digital electronics knowledge to do this in-house. In this case the knowledge was bought in with the help of a local university. The patents developed have placed the company in a very powerful position over the competition.

Company leaders can take solace in the fact that some large corporations understand working outside the safety of CI, and are now training their staff in breakthrough thinking tools (e.g., TRIZ). Samsung and POSCO are such companies that have the equivalent of the Six-Sigma belt cascade training approach, but for TRIZ (Korean Times 2014). These tools are now well established. An example from a previous paper (Filmore 2008a) shows a Table of these available tools (see Table 1).

TRIZ tool/ approach	Points helping in breaking mind-sets
Resources and Constraints	* Helps understand and define the problem, and that everything available may be a resource
Functional analysis	* See the problem visually/ holistically/ overview as a system of interactions. * Understand relationships and the different types of interactions e.g., excessive, harmful, insufficient etc. * Identifies intangibles e.g., missing links that need to be explored.
Ideal Final Result (IFR)	* Balancing trade-offs is a limited way of thinking. Start with the ideal and work backwards to a practical position. * It helps identify the benefits. * Some things are free! NB these may be unused resources etc. Believe it!
Contradictions	* Do not use the word 'problem'. Defining a contradiction in terms of an improving and worsening pair(s) makes the issue seem more manageable. * Formulate the contradiction in terms of space or time etc. further helps to open possibilities of understanding and so by reduce mental blocks.
The Matrix	* A great resource of solution triggers * Brainstorm, or use other creative approaches e.g. using Synetics, starting with these given triggers
Trends	* There is a (physical) limit where putting in large effort will get very little reward i.e., little increase in efficiency/ ideality etc. * Other industries have jumped s-curves already, so why reinvent the wheel? * The difference between incremental thinking and breakthrough thinking (i.e., jumping s-curves). * Which trends have you not considered as being relevant? * Shows us where and when to invent.
9-Windows	* Gets one away from the 'present' and 'systems' level thinking, by forcing one to consider the past and future and sub and super system level. * Helps to zoom in and out of problems e.g., identifying invisible problems and design points.
Problem Hierarchy tool	* Elucidates why you want to solve the problem and what is stopping you etc. * Helps define broader and narrower problem levels
Trim	* Helps to re-simplify a system, as the solving process often adds more complexity e.g. parts. Trim solution to same functionality.

Table 1: Initial ideas as to how TRIZ helps to break mind-sets

5. Conclusion

In an effort to ensure the safe, predictable, sustainable ongoing operations of their companies, many company executives have set up systems in their companies that actually fight against the innovation that they recognize they need. Within that system, people's thinking becomes constrained by what they think the "system" will approve, and the "system" only approves small, safe changes. The paper by Larsen & Boger (2014) reports Salvador (2010) from Intel, describing "innovation as a violent act against a system whose purpose is to survive. What he calls 'strategic innovation' therefore only becomes possible by leaving the system. Consequently, Salvador finds the innovator's work equal to the 'hero's journey' (Campbell, 1968) – that is, a call to adventure and a hero who overcomes various difficulties: in this context, the individual fighting against the system. He notices that such individuals often see themselves as oppressed by the system, and concludes that strategic innovation requires an 'inverse, converse perspective from the individual to that of the system and of the landscape' (Salvador, 2010)." From the discussion in this paper, what Larsen & Boger (2014) call "Innovation (as Improvisation) 'In the shadow'" (NB our brackets), should now become a thing of the past. Executives should and can understand the roles of both CI and disruptive innovation (breakthrough thinking), and how when the need arises for DI it is going to lead to short term uncertainty and perhaps personal fear as the company walks into the unknown. They should also understand that it is ultimately unprofitable to leave their innovative employees to fight the system (of their making) and go on the 'hero's journey' to help their company survive. Instead they should be supporting the balance of CI and DI innovation and leading the distinctly different innovation approaches by changing their company systems where necessary. Finally there are tool sets (e.g., TRIZ) readily available for DI and these can be taught as many companies have found, but kept quiet for competitive advantage.

6. Acknowledgement:

I would particularly like to thank an overseas colleague for adding the essential US company perspective which gives the paper practical purpose and meaning.

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Combining BDD Process with Software Development for Reducing Software Project Risk

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Abstract

System requirements quality is one of major factors affecting the software project failure. Unclear and incomplete description on important requirements are critical items to impact system requirements quality. These items are called the critical requirement items (CRI). BDD (Behavior Driven Development) is a suitable process applying in agile development method. Using IID (Iterative & Incremental Development) methods, BDD process is suitable for the small-scale requirements like CRI. The paper discusses CRI description, recognition and surveys CRI quality factors. Based on BDD features, collects CRI quality factors, proposes the CRI Quality Measurement (CRIQM) model and plans a BDD-based Quality Enhancement Procedure (BQEP) for improving CRI quality. Applied the CRIQM model, CRI quality defects can be identified. Utilize BQEP with quality improvement operation, CRI quality can be enhanced continuously and software project development risk can be reduced. CRI quality insufficient or defect, which can't timely be identified and modified, will cause the software project failure. BQEP can timely identify and improve CRI quality defects to avoid more manpower and cost expense and effectively reduce software project failure risk.

Keywords: BDD, BQEP, software project, quality factor, critical requirement items

1. Introduction

Software engineering concept had been proposed about 50 years, in the period, many scholars and experts continuously released new software development tools and methodologies to resolve and improve software crisis. In 1970s, Waterfall development model have been proposed and applied a long period time, it always is a favorite model in large organizations and enterprises. Waterfall model requests exact for each phase development documents. The documents except have high completeness and correctness, and must be passed formal review activity before entering next development phase. In addition, for the discovered defects in review activity, waterfall model has flexibility and features to feedback to the related phases. Timely modification and revision can avoid the problems and defects extension. However, waterfall model does not allow iterative and incremental requirements. It's meaning that overall system requirements must be accomplished, then development procedure can enter follow-up phase. Some important requirement items existed unclear scenario description, ambiguous state definition and lack changeability to cause large software project failure risk.

Standish Group is a famous company for project management services. According to the CHAOS research report, only 29% software projects are success, 18% projects are canceled in software process, and the remainder 53% belongs to schedule delay, over budget or unsatisfied requirements (Hayes, 2004). Deeply discussion, the cause of software project failure is highly correlated with system requirements (Boehm, 1991) (Mantel etc., 2011). System requirements are the basis of software follow-up development, parts of important requirements existed unclear scenario description, incorrect or inconsistent interface definitions may not accomplish communication and common recognition. System requirements are also the foundation of software verification and validation, requirements lack verification and validation features may cause the system can't pass acceptance test and become a failure project. Some important requirement items existed quality defects, which may impact project development risk, are called Critical Requirement Items (CRI). For reducing project failure risk, CRI should integrate communication, change and assurance quality characteristics to overcome the challenges in software development process.

BDD (Behavior Driven Development) is a suitable process for agile software development (Keogh, 2009) (Bellware, 2008). One of major advantages of BDD is test cases must to be preplanned and designed before implementation (Solis and Wang, 2011). Therefore, based on BDD process, the behavior description should have high quality to continue the follow-up development operations. Quality defects of behavior description can be identified timely. CRI uses BDD processes can collect key quality factors to timely identify CRI quality defects. In this paper, based on BDD feature, collects CRI quality factors, proposes the CRI Quality Measurement (CRIQM) model and plans a BDD-based Quality Enhancement Procedure (BQEP) for improving CRI quality. Applied the CRIQM model, CRI quality defects can be identified. Utilize BQEP with quality improvement operation, CRI quality can be enhanced continuously and software project failure risk can be reduced. In Section II, studies importance of software requirements and major features of BDD. In Section III, discusses the relationship between CRI and BDD, and quality factors of CRI. In Section IV, based on quality measurement model, plans a CRI quality improvement mechanism. In Section V, evaluates the efficiency of BQEP. Finally, in Section VI, describes advantages of the CRIQM and the future work.

2. Importance of software requirements and major features of BDD

Well system organizations select waterfall model to develop large scale software. The Section discusses the advantages of waterfall model and major features of BDD.

2.1 Development models and software requirements

In 1967, for resolving software crisis, the software engineering concept was proposed and discussed in the NATO international conference (Pressman, 2010). In recent ten years, with the growth of information technology, operational environments and user requirements, the software development methodology continuously evolved. From the early Fix-code to the recent Model-driven architecture (MDA) (Schach, 2011), the agile development model has about a dozen variations. Most software development models have high relationship with the user requirements. The waterfall model defines clear phase missions and very concerns the phase documents. The quality of system requirement specification must keep the characteristics of correctness, completeness, and consistency, otherwise the requirement phase documents will be requested to revise or redo. Existing development models have flexible modified the requirement specification style. For instance, in the iterative and Incremental development (IID) model, users can incrementally provide the requirements, i.e., it is unnecessary to deploy entire requirements in a certain period of time (Larman and Basili, 2004). Therefore, software development risk can be greatly reduced. In the rapid prototyping model, prototype products are quickly developed; this helps in quickly and accurately determining user requirements. Prototypes help in identifying incomplete, inconsistent, or incorrect requirement specification. Spiral development model primarily focusses on development risks and has high flexibility. In the development process, the spiral method offers adaptability for encountering different risks. Further, if the development risks can't be effectively reduced then the spiral model recommends terminating or aborting the software project. In February 2001, seventeen software developers met at a ski resort in Utah, USA for two days and drafted the Manifesto for the agile software development process. Many of participants had previously authored their own software development methodologies, including Extreme programming, Crystal, and Scrum (Szalvay, 2004) (Schach, 2011). Agile software development proposes several critical viewpoints:

(1) The development process should not involve more of the analysis and design phase operations and documents.

(2) The programming phase should be started as soon as possible because a workable software is more practical than a development document.

(3) The software being developed should have and support high modifiability.

(4) The cooperative relationship between the system developers and system users should be enhanced.

Each development model has own features and an adjustment strategy for environment or requirement change (shown as Table 1). If the adjustment strategy cannot effectively reduce the requirement change risk then the success ratios of the software projects are affected. In software development process, requirement analysis phase always occurs many problems and defects (Ian, 2011). The major reasons include

- User can’t clearly describe the system requirement items.
- User can’t concretely confirm the proposed requirement. Therefore, causes requirement change or modification are high frequency.
- In review or assurance activities, system requirement can’t become a basis for verifying the system correctness or usability.

Table I. Agile process to compare with others critical development models

Development Models / Features	Agile	Water fall	Spiral	Prototyping
Entirely System Requirements	*	***	***	*
Phase Documents	*	***	***	*
Maintainability	*	***	***	**
Version cycle	***	*	*	**
Refactoring	***	*	*	**
Adaptable scale	S & M	M or L	L	M or L

*: weak; **: middle; ***: strong; S: Small-scale; M: Middle-scale; L: Large-scale

System requirements should accomplish three major missions. First, requirements are the importance basic of the follow-up phases development operations. Second, requirements have to accept the challenge of environment and requirement change. Third, requirement must provide complete test cases and review checklists for the phase verification and system acceptance. In early development model, system requirements must be entirely proposed and passed review at same time, then development procedure can enter design phase. However, system requirements often can't build the consensus among the user, the developer and the stakeholder, and can't avoid inconsistent, incorrect and incomplete quality defects. In addition, system requirement also have to accept the challenge of environment and requirement change. Requirement quality is a major impact factor for the software project fail or success. Quality defect of system requirement can't timely be modified always causes the software project failure. How to reduce the software project failure risk become an important issue.

2.2 BDD process and agile method

BDD (Behavior Driven Development) is a suitable process for agile software development method. Advantages of BDD (shown as Figure 1) (North, 2006) (Beck, 2003) (Solis and Wang, 2011) include:

- In software development phases, test cases can be preplanned and designed.
- Assist to build a consensus among the stakeholder, developer and user.
- Very concern the communication between clients and development teams.
- Emphasize fixed time features or simple requirements that can be accomplished in three weeks.
- Provide automatic regression testing.
- Assist behavior description revision and design refactor.

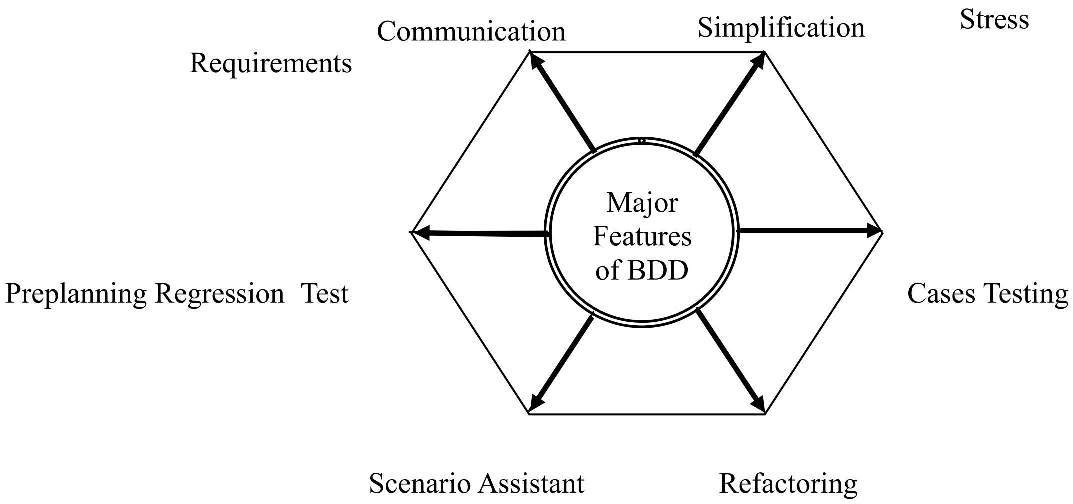

Figure 1. BDD major features

Based on BDD process, behavior description should have high quality to continue the follow design and development phase. Behavior description can't assist to generate the complete test cases, it shows behavior description existed several unrecognized or undetermined problems and defects. Therefore, in the early development phase, BDD process can actively discovery behavior description problem and defect, and assist requirement revision and adjustment. Unclear, unstable and core items description are critical items to impact system requirement quality. The paper calls these items are critical requirement items (CRI). CRI existed some situations:

(1) CRI belongs to the important items of the system requirements.
(2) CRI contents cover range too large and too complicated.
(3) CRI exists unclear scenario description, incomplete and inconsistent interface definition.
(4) CRI lacks communication capability and a consensus among the user, the developer and the stakeholder.
(5) CRI can't assist phase review and system acceptance activities in the follow-up development process.

According to Pareto principle (80/20 rule), CRI just cover about 20% in the system requirement. Enhancing CRI quality, system requirement quality can be improved and software project fail risk can be effectively reduced.

BDD process and agile development methods have several well features can help modify CRI deficiencies. In BDD process, user stories are broken down for the fixed time and simple requirements that should be accomplished in 3 or 4 weeks. The fixed time features and simple requirements can effectively modify the second deficiency of CRI. BDD borrows the concept of the ubiquitous language from domain driven design. A ubiquitous language is a semi-formal language that is shared by all members of a software development team (North, 2006). Apply the ubiquitous language of domain driven design, can modify the third deficiency of CRI. In BDD process, user stories (behaviors) need plan test cases before design and implementation. Therefore, user stories have to build a consensus of among the user, the developer and the stakeholder, and client representative works with the development team at all time. Building a consensus and all time participation can effectively improve communication capability and modify fourth deficiency of CRI. In agile method, the workable software is more important than development documents and another common features is to have a short meeting at regular time every day. The workable software and every day short meeting can effectively modify the fifth deficiency of CRI.

3. BDD Process and CRI

From 80/20 theory can deduce system requirements just only few belong to CRI. However, CRI quality defects will impact project failure or success, applying BDD process features can assist inspect CRI quality defects.

3.1 Critical requirement items

Some core requirement items of large scale and complexity software system always exists ambiguous scenario description, inconsistent interface definition, high complexity and low cohesion situations. These situations may cause the requirement items lack communication, assurance and change characteristics. According to 80/20 theory can deduce system requirements just only some items belong to CRI. However, CRI will impact project failure risk. Timely recognize CRI improve CRI quality defects, software project failure risk can be effectively reduced. Based on CRI quality defects, discussed as follows:

(1) Undefined or unclear precondition: requirement items should clearly define precondition and become a basic of follow-up development. Undefined or unclear precondition will affect the implementation of the follow-up review or validation activities.
(2) Undefined or unclear end state: requirement items should clearly define an end state and become a basic of requirement assurance. Undefined or unclear end state will affect the implementation of the follow-up review or validation activities.
(3) Ambiguous and incomplete scenario description: user can't global understand the system requirements, so the requirements can't clear and complete expression. Requirements with ambiguous and incomplete scenario description of will cause great distress for the design and follow-up development operations.
(4) High complexity and coupling: In BDD process, user story is a simple and high cohesion requirement item. CRI should have the attributes of user story. Some special requirement items have to tightly connect with external entities, related resources or planning contents. These items belong to high coupling degree and have high modification or adjustment risk for overcoming the change of environment or requirement.

Strictly speaking, CRI belongs to core requirements but existed quality defects. In the system requirements, few parts CRI have to be recognized and improved timely, otherwise the defects may extend to follow-up phases and continues to expand the influence range. Finally, CRI causes to the revision cost and resources have to be increased, seriously schedule delay and product quality does not satisfy to the requirements, to become the main cause of software project failure.

3.2 CRI quality defects inspection by BDD process

Review activity of requirement phase should identify the unclear scenario description, incorrect format and high complexity requirement items. Most of defects belong to partial mistakes. According to the review suggestions, requirement items can be revised and keep quality criteria. However, some requirement items are important items but implied major quality defects. The items must be sent back and require to revise or rewrite for avoiding to affect follow-up development and impact software project failure. These requirement items are critical requirement items (CRI). Timely identified and improved CRI quality defects, the project failure risk can be reduced. Advantages of BDD process can recognize CRI quality defects in early phase and assist to proceed revision operations for concretely improving CRI quality. Requirement items can be described by use case model and template documents. Applying BDD process and checklists to inspect CRI quality and collect CRI quality factors (shown as Figure 2). Checklists items and contents describe as follows:

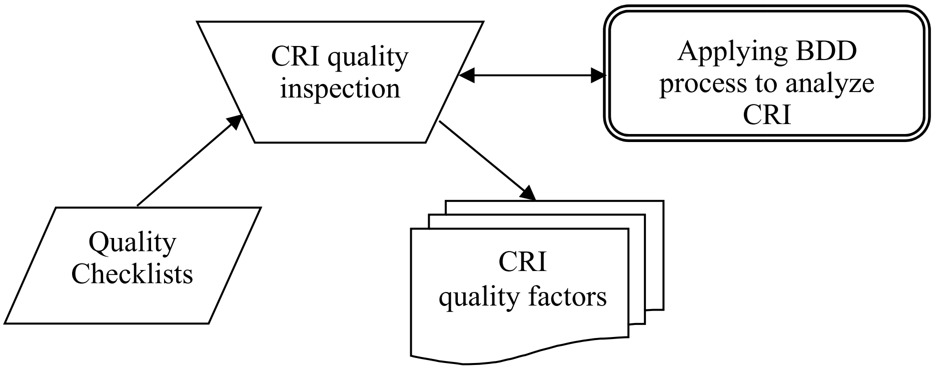

Figure 2. CRI quality inspection of BDD process

(1) Precondition and Post condition inspection:

- Precondition: Precondition of requirement item whether have been clear and complete description and definition.
- Post condition: Post condition of requirement item whether have been clear and complete description and definition.

(2) Scenario description and interactive inspection:

- Scenario description: Requirement items should detailed describe operation flow of basic path and alternative path. The description contents need have correctness, completeness, consistency and readability characteristics.
- Interactive interface definition: Requirement items should concretely describe the interactive relationship with the others items. For example, items how to interact with system, what message exchange for interactive operations, normal process of interactive operation, and the others interactive operation procedure.

(3) Phase verification and validation inspection:

- Phase verification: Requirement items description should have the verification basis for each phase development. For example, the design specification is satisfied with requirements, source program is satisfied with requirements, the review activities is a critical task to assure the quality of phase development documents.
- Acceptance validation: Requirement items description should have the basis of system testing and product validation. For example, product functions whether satisfied with functional requirements, product performance whether satisfied with nonfunctional

requirements criteria, the validation activities is a critical task to recognize the system quality whether have satisfied with user requirements.

3.3 CRI quality characteristics and quality factors

Applied BDD process, the review activity with checklists can collect CRI quality characteristic factors. CRI should have three quality characteristics which include communication, assurance and change. For three quality characteristics discussion and corresponding factors of quality characteristics identification are described as follows:

(1) Communication quality: CRI communication quality should consider scenario description and interface definition two factors:

- Scenario description: System requirement is the basis of follow-up development. Therefore, CRI Scenario description must have correctness, completeness and consistency and readability characteristics to create a common consensus among the user, the developer and the stakeholder. CRI Scenario description should consider correctness, completeness and consistency and readability factors.
- Interface definition: Interface definition is a basis of the requirement items communication and integration. Well defined interface can build the interactive relationship between CRI and others items. CRI interface definition should consider explicitness and consistency factors.

(2) Assurance quality: CRI assurance quality should consider phase review capability and system acceptance capability two factors:

- Phases review capability: Requirement documents are the base of phases review activity. CRI must have the capability to plan the review checklists and test cases for testing. Phase assurance activity can identify the quality problems and defects in early phase to reduce extra development resource expense.
- System acceptance capability: Requirement documents are major basic of system validation activity. CRI must have the capability to plan acceptance test cases for acceptance testing. System acceptance activity can identify the quality problems and defects before system delivery to reduce extra disputes. System acceptance capability should consider the acceptance checklists planning and acceptance test case design factors.

(3) Change quality: CRI change quality should consider low complexity and high modularity two factors:

- Low complexity: CRI should have simplify and low complexity to reduce change impacts. Environment changes or requirement revisions, CRI can adapt the environment or requirement to modify or adjust quickly. Low complexity should consider requirement items size, tables, files, data items and operation behaviors quantified factors.

- High modularity: CRI should have low coupling and high cohesion to overcome change affects. CRI can be easy isolated for adapting the environment changes or requirement revisions and to modify or adjust quickly. High modularity should consider requirement items coupling and cohesion affect factors.

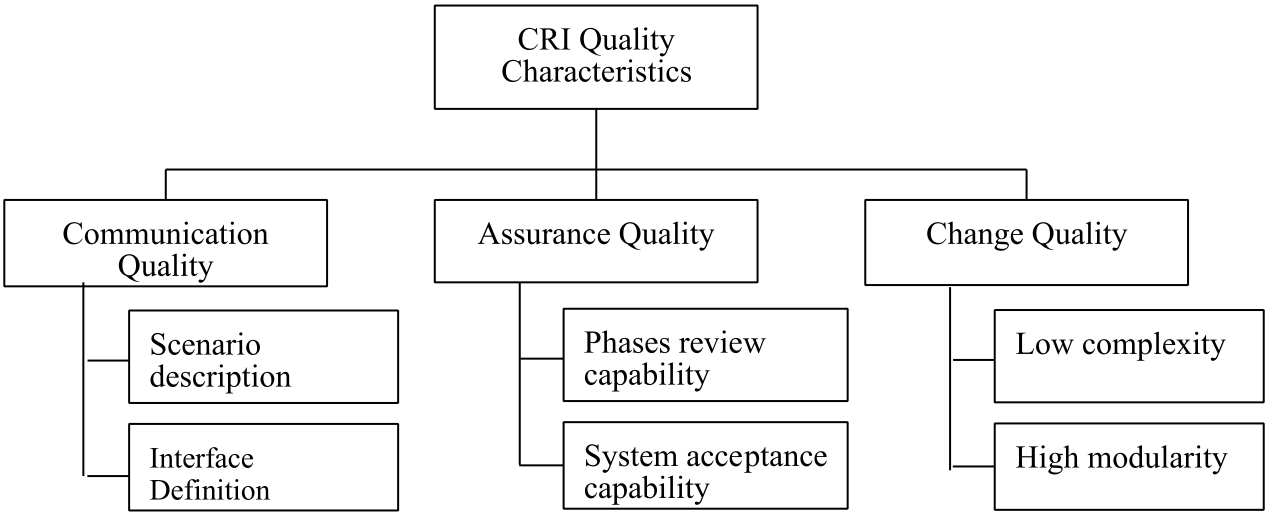

Figure 3. CRI Quality characteristics and factors

4. CRI Quality Measurement Model and Improvement Procedure

Quantified indicator that generated by the quality measurement model can help evaluate, identify and modify CRI quality defects to reduce software development risk.

4.1 CRI Quality Measurement Model

In order to effectively monitor and assess CRI quality, individual metric should make the appropriate combination (Boehm, 1991) (Galin, 2004). CRI quality should consider three quantified measurements that include communication, assurance and change. Using the LCM (Linear Combination Model) (Fenton, 1991) (Conte, Dunsmore and Shen, 1986), the basic quality factors can be combined into the primitive metric, and then the related primitive metrics can be combined into a quality measurement. Finally, three critical quality measurements are combined and CRI quality indicator is generated. The following formulas describe the quality measurements generation process:

(1) Communication Quality Measurement (CmQM) is combined scenario description factors and *interface definition factors*. CmQM generation steps describes as follows:

Step1. Quality metric of CRI scenario description is combined items documents correctness, completeness, consistency, and readability etc. quality factors

Step2. Quality metric of CRI interface definition is combined requirement items compliance, completeness and consistency factors.

Step3. Combining scenario description and Interface definition quality metrics into a CmQM, shown as Formula (1).

CmQM: Communication Quality Measurement

SDQM: Scenario Description Quality Metric — W_1*: Weight of SDQM*

IDQM: Interface Definition Quality Metric — W_2*: Weight of IDQM*

$$CmQM = W_1 * SDF + W_2 * IDF \qquad W_1 + W_2 = 1 \qquad (1)$$

(2) Assurance Quality Measurement (AQM) is combined phase review factors and system acceptance factors. AQM generation steps describes as follows:

Step1. Quality metric of CRI phases review is combined review checklists and functional test case planning factors.

Step2. Quality metric of CRI system acceptance is combined acceptance checklists and acceptance test cases factors.

Step3. Combining scenario description and Interface definition quantified values into an AQM, shown as Formula (2):

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AQM: Assurance Quality Measurement

PRQM: Phases Review Quality Metric — W_1*: Weight of PRQM*

SAQM: System Acceptance Quality Metric — W_2*: Weight of SAQM*

$$AQM = W_1 * PRQM + W_2 * SAQM \qquad W_1 + W_2 = 1 \qquad (2)$$

(3) Change Quality Measurement (ChQM) is combined complexity and modularity. ChQM generation steps describes as follows:

Step1. Quality metric of CRI complexity is combined size and related data items amount factors.

Step2. Quality metric of CRI modularity is combined cohesion and coupling factors.

Step3. Combining complexity and complexity quality metrics into a ChQM, shown as Formula (3):

ChQM: Change Quality Measurement

CQM: Complexity Quality Metric — W_1*: Weight of CQM*

MCM: Modularity Quality Metric *W_2: Weight of MQM*

$$ChQM= W_1 * CQM + W_2 * MCM \qquad W_1 + W_2 = 1 \qquad (3)$$

Finally, combining CmQM, AQM and ChQM into a CRI quality indicator, shown as Formula (4).

ICQM: Indicator of CRI Quality Measurement

CmQM: Communication Quality Measurement *W_{cmq}: Weight of CmQM*

AQM: Assurance Quality Measurement *W_{aq}: Weight of AQM*

ChQM: Change Quality Measurement *W_{chq}: Weight of ChQM*

$$ICQM = W_{cmq} * CmQM + W_{aq} * AQM + W_{chq} * ChQM = 1 \qquad W_{cmq} + W_{aq} + W_{chq=1} \qquad (4)$$

Using three factor combination formulas to generate three major CRI quality measurements and combine three CRI quality measurements into a CRI quality indicator. Through six groups of quality factor and four combination formulas to generate a CRI quality indicator called as the CRI quality measurement model.

4.2 CRI quality improvement procedure

In system requirements review activities, the CRI can be found and recognized. In this paper, combining BDD process to plan the BDD-based Quality Enhancement Procedure (BQEP) for identifying CRI quality defects and timely improving CRI quality. BQEP divides into 5 steps (shown as figure 4) described as follows:

Step 1. Recognize the CRI: review activities before the end of the requirements phase, the requirement items existed unclear scenario description, incorrect statuses definition or major quality defects will be requested to revision. Parts of the requirement items belong to the core of system requirements, but quality can't be effectively improved, this paper called the requirement items as CRI. CRI must be sent back to redevelop and rewrite, to avoid impacting the follow-up development operations and increasing project failure risk. CRI redoing or modification should be combined with BDD process and quality measurement model to detect and improve CRI quality.

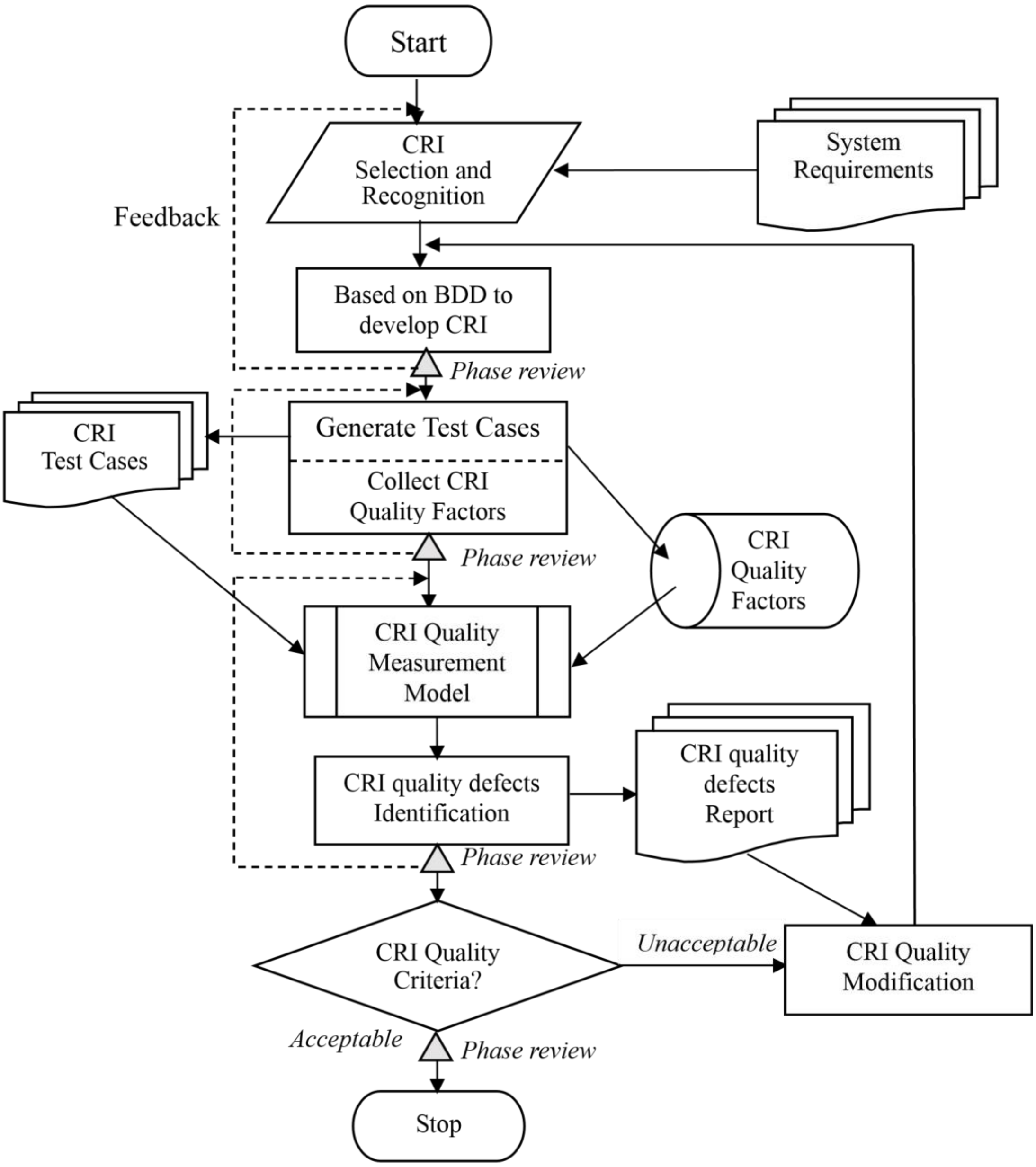

Figure 4. A flowchart of BDD-based Quality Enhancement Procedure

Step 2. Apply BDD process to collect CRI quality factor: Using IID methods, BDD process is suitable for the fixed-time features or decomposed requirement items. CRI belongs to decomposed requirements. Before software development enters the design and programming phases, CRI must complete of the test case design and planning,

enough to help collect relevant factors affecting the quality of CRI. These quality factors become a basis of quality measurement model to generate the quality indicator

Step 3 Determine CRI quality level: Apply Section 4.1 proposed quality measurement mode, CRI quality measurement indicator can be generated. Predefined "Quality Criteria" is use to determine the CRI quality level, if meet criteria, represents CRI satisfy established quality, otherwise CRI should enter the defects identification and quality improvement operations.

Step 4 Identify CRI quality defects: quality measurements is a relative judgment indicator, also is a major basis for identifying CRI quality defects [9]. Therefore, CRI quality measurement indicator doesn't meet established "quality criteria", CRI quality defects should be identified. From combination formulas of quality measurement model can recognize inferior factor, the factor corresponds to CRI related documents and details to identify to be revised defect items of CRI.

Step 5. CRI quality improvement measures: CRI quality defects will cause negative impact of software development, determine the CRI quality defects can timely correspond to CRI document items and details defects for correction. Makes CRI keep communication, assurance and change quality characteristics to reduce software project development risks.

5. Benefit evaluation of BQEP

Parts system requirements belong to important items but implied major quality defects. The items must be sent back and require to modify or rewrite for avoiding to affect follow-up development and impact software project failure. CRI quality defects must be timely identified and improved, otherwise the quality defects impact may expand and cause the project failure risk. Based on BDD feature, the paper proposes the CRI Quality Measurement (CRIQM) model and plan the BDD-based Quality Enhancement Procedure (BQEP) for improving CRI quality. Efficiency evaluation of BQEP describes as follows (shown as Figure 5):

(1) Timely recognize CRI: In system requirements review activities, according to item importance and major quality defects that include ambiguous scenario description, inconsistent interface definition, high complexity and low cohesion, can timely recognize CRI. CRI are critical requirement items but implied major quality defects. CRI can be recognized in early phase, sent back and require to modify or rewrite for avoiding to affect follow-up development and impact software project failure risk.

(2) Combine BDD process with quality measurement model to identify CRI quality defects: BDD process major features and CRI existed major deficiencies were described in Section 2.2. Advantages of BDD process can effectively modify the deficiencies of CRI.
Based on BDD process to develop and verify CRI, CRI quality factors can be timely collected and quantified. Quantified quality factors and quality measurement model can help timely identify CRI quality defects.

(3) Combine BDD process to enhance CRI quality: According to the identified CRI quality defects, the formula of quality measurement model can correspond to the defect items. Communication quality can be improved by the BDD consensus creation, behavior description and status definition activities. Assurance quality can be improved by BDD test cases planning and acceptance testing design development activities. Change quality can be improved by the time box management of agile method. Timely recognize CRI, timely identify and improve CRI quality defects to make CRI communication quality can build consensus and continue the follow-up development phases, assurance quality can assist phases review and acceptance testing, and change quality can overcome environment or requirement change, software project failure risk can be effectively reduced.

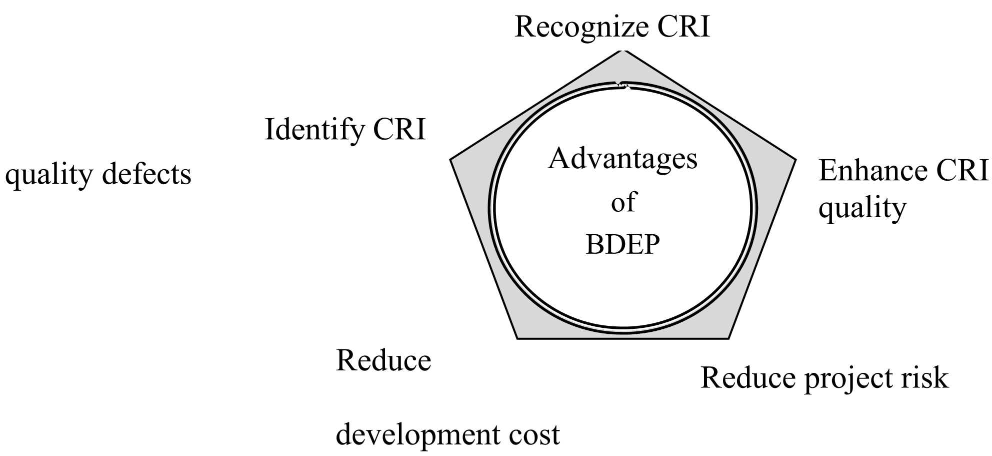

Figure 5. Advantages of BDD-based Quality Enhancement Procedure

6. Conclusion

According to the statistic data of research report, cost over budget, time delay and product quality mismatch requirement are three major factors of software project failure. In large scale software system, system requirements cover great amount and complex items. Parts of system requirement items belong to important items, but lack communication, assurance and change features. The requirement quality defects cannot be concretely revised, the defects may expand to follow-up phases, affect project cost, schedule and acceptance operations and cause to software project failure. In order to reduce project failure risk, CRI quality defects must be identified and improved timely. In this paper, the quality factors of CRI are discussed, IID methodology and BDD process are investigated. Combining BDD process with quality measurement model, collect CRI quality factors and identify CRI quality defects. And, based on BDD process and quality measurement model, planning a BDD-based quality enhancement procedure to increase CRI communication, change and assurance quality features. BDD-based CRI quality improvement mechanism has three advantages:

(1) Timely recognize CRI which may affect software development process.
(2) Apply BDD process and quality measurement model to identify the CRI quality defects and assist the quality improvement operation.
(3) System requirements quality can be increased and software project failure risk can be reduced.

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New Piezoelectric Bolt Sensor for Estimation of Dynamic Properties of Wooden Structures

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Abstract

Applicability of new piezoelectric sensor to estimate dynamic properties of traditional wooden structures is discussed in this paper. Forced vibration tests were performed on a prototype that corresponds to a framed wooden construction with traditional connections between columns and beams without nails and with wedges inserted into joints to fix them. Test series were performed by using forced vibration machine and dynamic response was measured using proposed sensors and also commercial accelerometers and laser displacement transducer. The new bolt sensor is intended to be used for structural health monitoring of important and small structures like historical shrines or other small historical buildings. Bolt sensors were installed in selected frame joints and changes in voltage signal were detected when the prototype is subjected to dynamic excitation. The response of the new sensor is comparable with that obtained by high precision commercial accelerometers and laser displacement transducer. In addition dynamic response of the structure and response of the bolt senor were analytically verified using finite element method. For analytical modeling semi-rigid joint is used where moment rotation relationship is specified for each beam end. This research serves also to calibrate the analytical model by using experimental results obtained from forced vibration test.

Keywords: Structural health monitoring, Bolt sensor, Timber structure, Finite element method

1. Introduction

To verify the applicability of a new type of piezoelectric bolt sensor dynamic test series were performed on a wooden structure model. Also commercial accelerometers and laser displacement transducer were used for comparison. The prototype structure corresponds to a framed wooden construction with traditional connections between columns and beams without nails and with wedges inserted in joint to fix them.

The new bolt sensor is intended to be used for structural health monitoring of important and small structures like historical shrines or other small traditional buildings. Bolt sensors were installed in selected frame joints and changes in the voltage signal were detected when the prototype is subjected to dynamic excitation. The response of the new sensor is comparable with that obtained by high precision commercial accelerometers and laser displacement transducer.

From the forced vibration test, for a range of frequencies from 1Hz to 20 Hz, the corresponding resonance curve was obtained from the sensor response. Therefore, it is possible to identify the predominant frequency of the test specimen by using the proposed bolt sensor.

In addition the dynamic response of the structure and the response of propose bolt sensor were verified analytically using finite element method. For analytical modeling semi-rigid joint is used where rotational stiffness is specified for each beam end. Finite element model was formulated to compare the response of the sensor with the horizontal displacement of the correspondent joint. For this purpose an average conversion factor of 17 mm/V was estimated by comparing analysis results for displacements and sensor response. The resonance curve obtained from the sensor response resembles in a good manner the analytical resonance curve.

2. Characteristics of the Piezoelectric Bolt-Type Sensor

The piezoelectric-bolt sensor is shown in Figure 1, and it consists of a piezoelectric cable covered by an envelope of urethane resin. In a previous research Shimoi et al. (2011) investigated the characteristics of a new type of bolt sensor, however in that case the nominal diameter of the bolt was 20 mm. Then in this research diameter of bolt sensor was reduced to 10 mm to produce a minor disturbance in the structure where the bolt must be installed. This reduction of the diameter is necessary since dimensions of structural elements of traditional wooden structures are smaller than those of tall buildings or large span bridges.

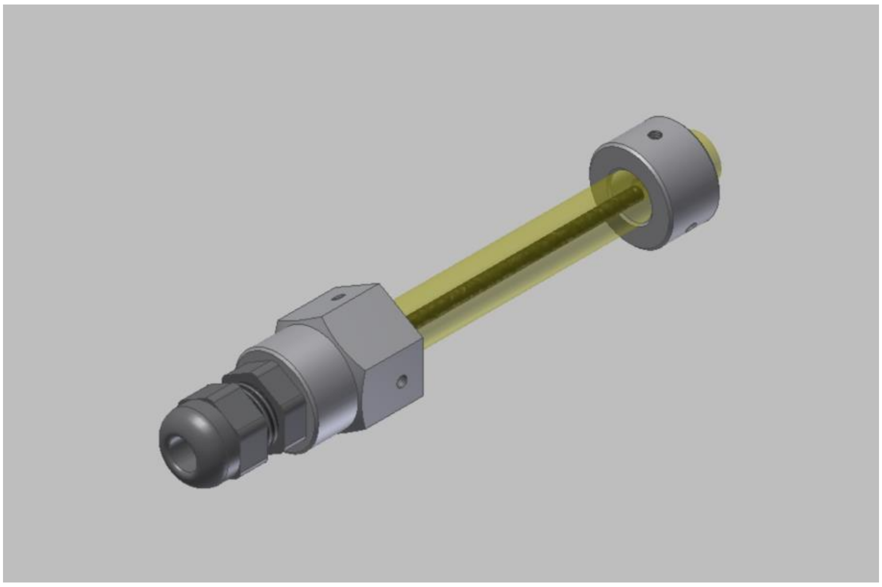

Figure 1. New bolt-type piezoelectric sensor

The structure of the inner piezoelectric cable is shown in Figure 2. The piezoelectric film which acts as electric condenser emits voltage when the cable is subjected to an external action that produces deformation on the cable, especially in case of dynamic action or vibration. This cable is connected to a computer board by means of a connection cable and signal can be recorded directly by a computer for its posterior analysis. In this research relation between output voltage and relative displacements and vibration of wooden structure joints are investigated. As was described the sensor itself does not need input energy to emit its response. Moreover, characteristics of the sensor like sampling frequency permits to send signal to a four channels computer board for automatic data acquisition. In this way signals from four sensors can be recorded simultaneously with a direct input computer board.

Figure 2. Piezoelectric cable

Figure 3 shows the general scheme of data acquisition system using the proposed bolt sensor. Data is recorded using a wireless system (Zigbee wireless module). Source energy (lithium battery pack Lipo2000mAh) is required for the board that receives signal from sensor and transmits it to computer for data acquisition. Personal computer requires its own source of energy for acquisition and posterior data processing. Recording directly to computer will permit to connect to remote computers and then monitoring structures in real time from different locations will be possible.

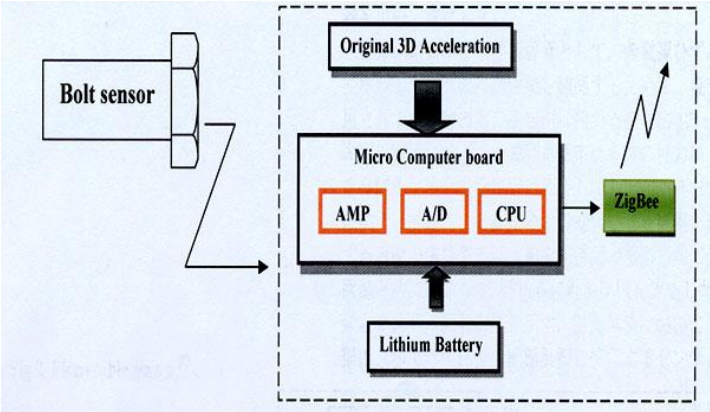

Figure 3. Scheme of data acquisition system

3. Specimen and Forced Vibration Test

A reduced scale prototype that resembles the characteristics of the main structure of a traditional wooden shrine was constructed and subjected to forced vibration test to investigate its dynamic properties and to verify the applicability of the proposed bolt sensor.

3.1 Characteristics of the Test Specimen

The reduced scale model was planned based on the structure of small traditional shrine which is shown in Figure 4. The shrine is a typical one located at Yurihonjo city, Akita Prefecture, Japan. The scale factor is approximately 1/5 and only the main frame structure has been considered. The roof is considered as additional weight to be added to test the prototype. For this purpose, a stiff wood panel was set up at the top of the specimen to simulate the effect of the weight of the roof. This panel supports also the weight of the forced vibration machine which is considered as a part of the roof.

Figure 4. Traditional wooden shrine and test specimen

Dimensions of model are shown in Figure 5 where values are expressed in mm. In direction parallel to the facade a central span of 600 mm was considered, while for the perpendicular direction spans of 300 mm were considered. The direction of vibration is perpendicular to the facade. Details of joints are also presented in this Figure 5, and the use of wedges to provide stiffness to joints can be appreciated. The cross sections of columns are of 60x60 mm and the cross sections of the girders or beams are of 15x60 mm. The top girder is of 60x80 mm to provide more stiffness to the upper part which supports the additional weight of the roof.

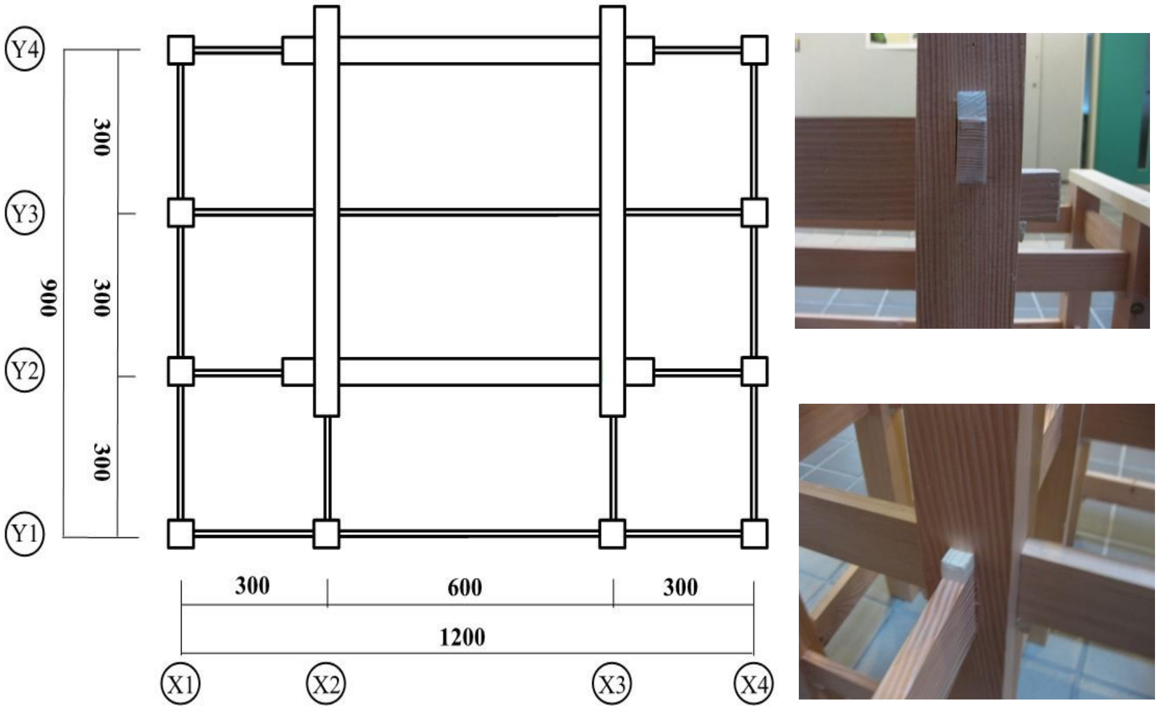

Figure 5. Dimension of the model and joint details

3.2 Forced Vibration Test

Forced vibration test was planned to verify the dynamic characteristics of the model and to verify the response characteristics of a new sensor develop for monitoring purposes. The forced vibration machine and accessories result in an additional mass of 50 kg applied on the top of the model. The loading direction is perpendicular to the façade or parallel to the ridge direction. The general layout of the test can be appreciated at Figure 6.

Figure 6. General layout of the forced vibration test

The vibration machine is controlled by a function generator which can applied harmonic waves at specific frequencies. Frequencies of 1 Hz, 2 Hz, 3Hz, 5 Hz, 7Hz, 10 Hz, 12 Hz, 15 Hz and 20 Hz were applied in separately runs. The amplitude for each run was increased by a controller and the applied acceleration was measured by accelerometers located at the top of the specimen.

The new bolt-type sensors were located in an intermediate joint and in a lower joint near a column base. The intermediate joint corresponds to the intersection of the central column of the upper part of the specimen with the first girder below the roof. The bolt sensor installed in the lower joint can be observed in the Figure 7.

Figure 7. Installation of the bolt sensor in a frame joint

Acceleration of the vibrating mass and acceleration of the top mass of the specimen was measured by means of accelerometers located on the machine and on the wooden plate that replace the roof of the model. All data was collected by the data acquisition system and storage at a computer for their posterior analysis.

Test series were performed for different conditions of specimen stiffness. First series of runs were performed for the initial condition with all wedges joints. Then a second series were carried out without wedges in the joints. Following are the results for the initial condition of the specimen. Table 1 shows the maximum response for each run at the selected frequencies.

Table 1. Maximum response for each run at different frequencies

Frequency (Hz)	Input Acc (m/s^2)	Top Acc (m/s^2)	Joint Acc (m/s2)	Disp. (mm)	Sensor Response
1	1.07	0.18	0.11	0.07	0.0002
2	4.40	0.18	0.11	0.06	0.0004
3	7.38	0.18	0.11	0.14	0.0005
5	5.81	0.54	0.25	0.10	0.0006
7	4.23	0.54	0.31	0.07	0.0006
10	2.96	0.90	0.50	0.06	0.0007
12	3.03	5.85	7.12	0.06	0.0010
15	2.20	2.93	1.80	0.06	0.0012
20	1.70	0.90	0.55	0.03	0.0004

The input acceleration corresponds to the mass acceleration of vibration machine. Top acceleration is that measured at top plate of test specimen. Joint acceleration is that measured near intermediate joint where bolt sensor was installed. Displacement corresponds to the horizontal one at the level where bolt sensor is installed. Response of the sensor is given in voltage.

4. Finite Element Model

To construct the FEM model first characteristics of joints must be estimated considering that joints present partial stiffness which means that these joints are not ideal rigid joints. Then joints are modelled with specific rotational stiffness. To estimate this stiffness two kinds of joints are considered as is show in Figure 8.

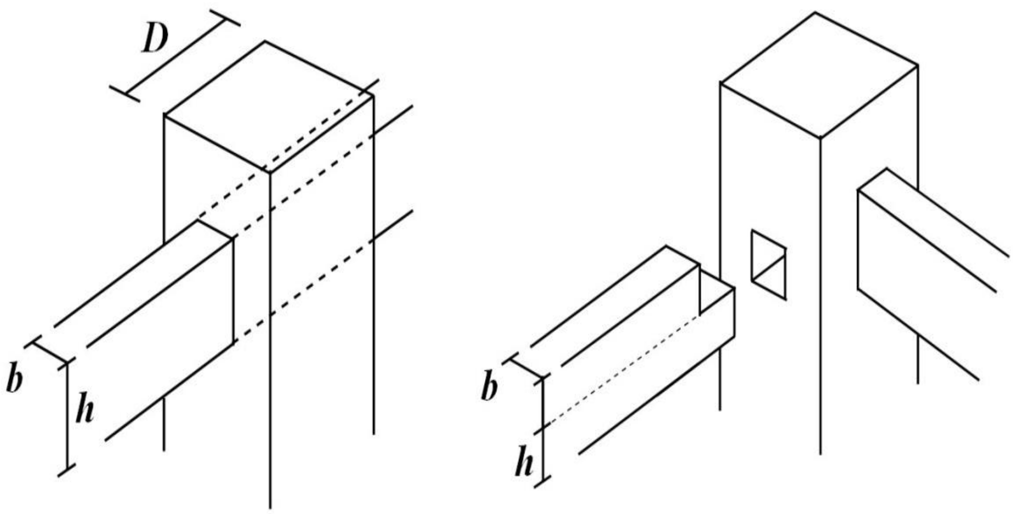

Figure 8. Typical tenon joint for the analytical model

To estimate the rotational stiffness of the joints, equations reported by Yamada et al (2005) are used. These expressions are as follows.

$$K = k_1 + k_2 \quad (1)$$

$$k_1 = \frac{D^3 bE}{4h}\left(\frac{1}{3} + \frac{4h}{3D} + \frac{16h^2}{9D^2}\right), \quad k_2 = \frac{\mu D^2 bE}{4}\left(\frac{1}{2} + \frac{4h}{3D}\right) \quad (2)$$

where

K : rotational stiffness (of the tenon joint)

k_1 : rotational stiffness due to the compressive stress inclines to the grain of tenon

k_2 : rotational stiffness due to the shear force by friction on the tenon

D : column depth b : width of tenon h : tenon depth

μ : wood to wood friction coefficient

E : Transversal elastic modulus of beam element

The analytical model is shown in Figure 9, and as can be appreciated the connections of beams to columns are modeled by link elements which permits to specify rotational stiffness for element ends. In this first step of research, supports are considered as hinge supports. For posterior analysis frictional properties of these supports will be considered. On the other hand, during tests it was observed that some columns, especially those located in the perimeter, were not in contact with the ground foundation and therefore for another case of analysis the hinge support of these columns are changed to free end.

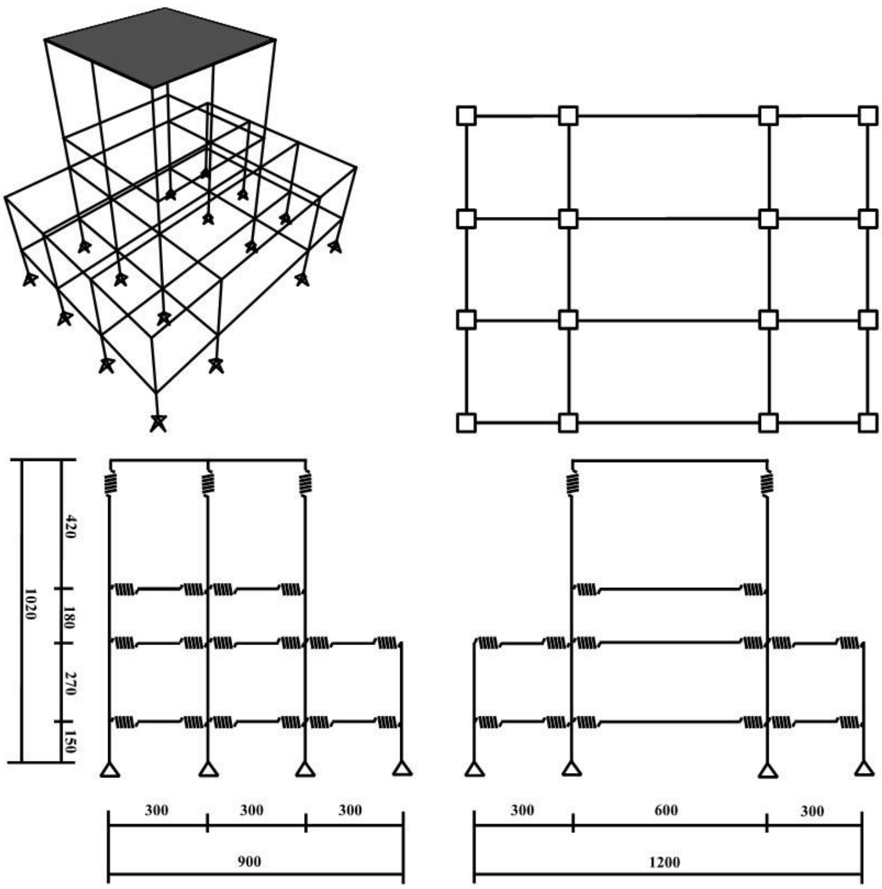

Figure 9. Finite element model

In the following paragraphs analytical results are shown for each selected frequency. The displacement corresponds to the joint that was experimentally monitored with a laser displacement transducer. Analysis was performed for a forced vibration that corresponds to a harmonic input with unit amplitude. Therefore to compare with experimental results, experimental results must be scaled to unit input acceleration.

The following Table 2 summarize maximum and minimum displacement obtained analytically. If they are compared with measured results great differences are observed because the amplitude of input acceleration during experiments is not unit input acceleration.

Table 2. Maximum response for each run at different frequencies

Frequency (Hz)	Displacements of Monitored Joint		Measured (mm)
	Max (mm)	Min(mm)	
1	0.001716	-0.00172	0.07
2	0.001750	-0.00175	0.06
3	0.001782	-0.0018	0.14
5	0.001986	-0.00199	0.10
7	0.002357	-0.00236	0.07
10	0.003779	-0.00378	0.06
12	0.007378	-0.00743	0.06
15	0.009570	-0.00968	0.06
20	0.001613	-0.00146	0.03

To compare experimental results with analytical ones it is necessary to normalized or scale experimental results in such a way that data must correspond to unit amplitude in the input acceleration. Since input acceleration has been measured experimentally the maximum response of the sensor is scaled by the maximum observed acceleration corresponding to each frequency. This scale down curve (corrected sensor response) together with the original curve is show in Figure 10. It can be observed that curve corresponds to a resonance curve which permits to identify the predominant frequency of test specimen.

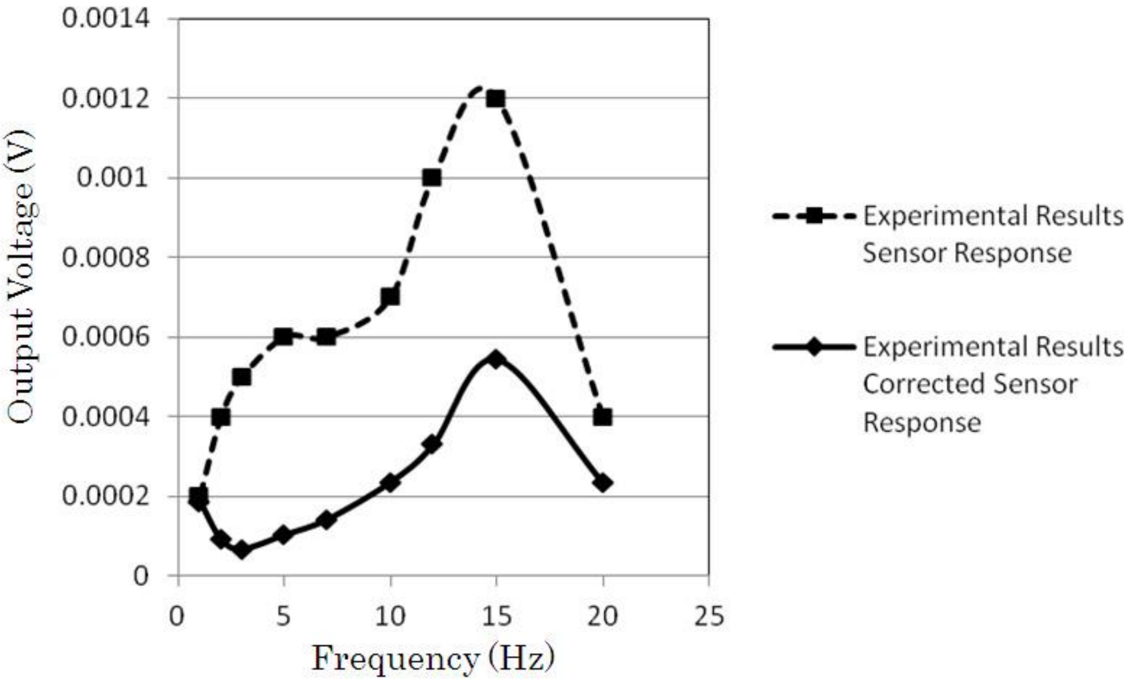

Figure 10. Bolt sensor response (original and corrected)

To compare sensor response with analytical displacement results, a conversion factor is required to express all results in mm. In this case from comparison of analysis and experiment results a conversion factor of 17 mm/V is obtained as average value. Then by multiplying this factor by the corrected sensor response, an equivalent displacement response given by sensor is obtained. This curve compared with analytical displacement is shown in Figure 11.

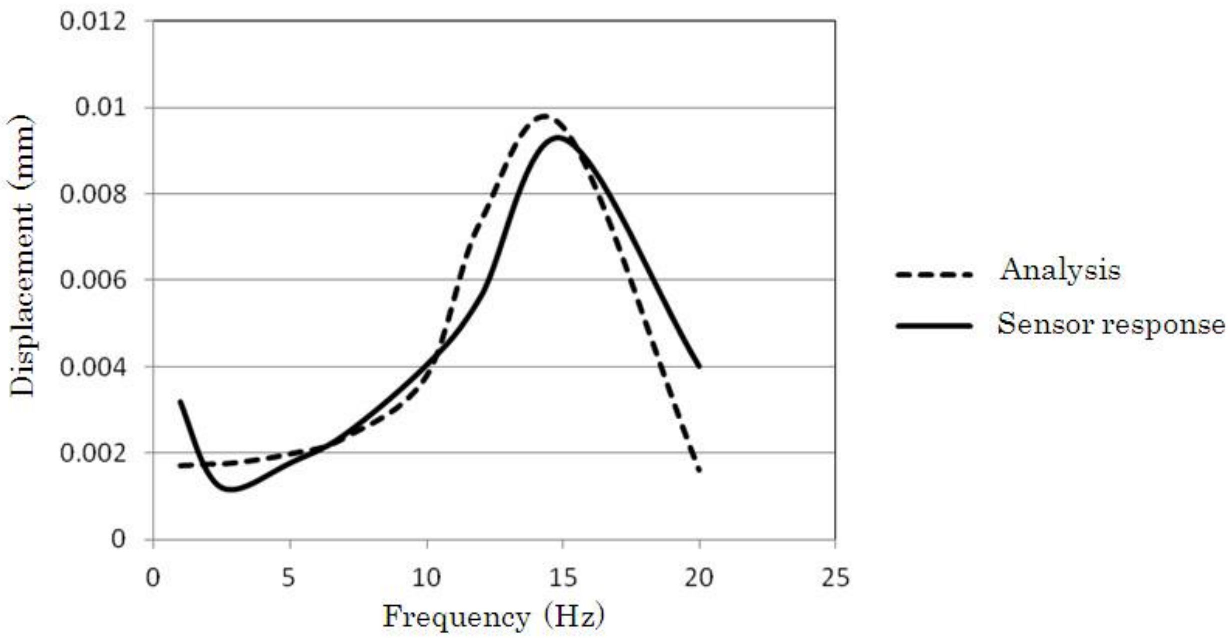

Figure 11. Comparison of analytical results and sensor response

5. Conclusions

The applicability of a new bolt- type sensor for structural health monitoring and estimation of dynamic characteristics of traditional wooden shrines was investigated.

The response of the proposed bolt sensor is directly related to deformation or strain state of the inner piezoelectric cable. During the experimental test horizontal displacements of the joint, where bolt sensor was installed, were measured. However since the joint is part of a frame structure it also experiments rotation. Therefore, for future research it is necessary to measure the joint rotation to establish the complete deformation state and how this affects the response of the sensor.

From the forced vibration test, for a range of frequencies from 1Hz to 20 Hz, the corresponding resonance curve was obtained from sensor response. Therefore, it is possible to identify the predominant frequency of test specimen by using the proposed bolt sensor.

Finite element model was formulated to compare response of sensor with horizontal displacement of the correspondent joint. For this purpose an average conversion factor of 17 mm/V was estimated by comparing analysis results for displacements and sensor response. The resonance curve obtained from the sensor response resembles in a good manner the analytical resonance curve.

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A TRIZ-based Strategic Reference Model for New Product Development

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Abstract

New product development (NPD) is a core function of any manufacturer facing competition. However, there is a significant amount of uncertainty involved. Managers think that there isn't any systematic approach required because there are too many uncertainties present in the process. However, if there was a process which could identify the trends and driving forces, possible futures could be envisaged and virtually experienced, with inventive problem solving throughout the process. This would help to overcome the uncertainties. A TRIZ-based Strategic Reference Model (SRM) has been developed. This model is divided into five building blocks: Idea Generation Block (IGB), Strategy Formulation Block (SFB), Strategy Determination Block (SDB), Problem Solving Block (PSB) and Learning Support Block (LSB). Integrated Definition (IDEF0) is used as the key modeling technique of the SRM. Although it has limitations due to its theoretical assumptions, the TSRM is a new approach to tackling the uncertainties connected with new product development. When walking through the process, managers in the organization are provided with a continuous learning experience, which simulates their thinking and results in the further enhancement of future products.

Keywords: new product development, Reference model, TRIZ.

1 Introduction

It is beneficial for an organization to develop new products. Doing so can help them to establish a strong position in the market. They can set an industry standard that is so high that it is a barrier to competitors; they can capitalize on investments in R&D and manufacturing; they can build up their image and nurture the organization with product development efforts thereby capturing the commitment, innovation and creativity of the entire organization. However, the business environment is continually changing, therefore it is also necessary for strategic planning to continually change in order to maintain a "balance" or "fit' with the external environment. The turbulent environment is affected by both technology and market changes. Technological innovations cause environmental turbulence by accelerating the rate of change. Market turbulence results in continuous changes in customers' preferences/demands, in price/cost structures, and in the composition of competitors. Robert (1995) did a survey on best practice companies. The results showed that 'none of them could give an answer on how new products are developed because whatever process they used, they were practicing it by osmosis.!. 'It could not be codified, cannot be explained rationally nor can it be transferred'. McGrath(1996) supported this and said that traditionally, product development had been looked upon as an art; that products were created by a mixture of genius and inspiration therefore it could not be 'managed'. Moreover, to meet the competitive environment companies have to create product ideas in a more innovative way.

TRIZ was founded by Genrich Altshuller as a systematic and creative approach towards reaching innovative results with the help of various tools. It is not purely a theory: the principles were developed based on in-depth analysis of numerous past patents. The basis of the approach is to extract the problem-solving knowledge of patent inventors to enhance practitioners' domain knowledge and invent problem-solving skills.

To fill this gap, the author developed a TRIZ-based strategic reference model (TSRM) for new product development strategic planning, based on the modeling technique of IDEF0.

2 New product development strategic planning

There are three paradigms for how to formulate strategies: the rationalist, the evolutionary and the processual (van der Heijden,2005).

The *rationalist* paradigm assumes that there is one 'best solution' of strategy (optimal strategy). It assumes predictability with no interference from outside; clear intentions; implementation follows formulation; a full understanding throughout the organization; and reasonable people will do reasonable things. The *evolutionary* paradigm (emergent strategy) is based on the assumption that many phenomena taking place in nature are unpredictable. It is not because we lack the knowledge and capacity to analyze them but just because they are unpredictable by their very nature. This paradigm assumes that strategy emerges and can only be understood in retrospect. The *processual* paradigm lies between the rationalist and the evolutionary paradigms. It assumes that the business environment is neither predictable nor non-predictable. The organization has a process to mobilize the brain power of the people to strengthen their skills. The process is to make room for ideas. Any idea which can be directed towards improving the link between the organization's competencies and the business environment will surface and be considered. Therefore when there are a lot of uncertainties, success is more related to having a good process than to having found the 'optimal strategy'.

New products are developed in a turbulent business environment therefore it could never be developed by a purely rational approach; nor through a passive approach as the environment is unpredictable. If there is a process that the organization can follow, new product development becomes a processual strategic planning activity.

Product strategy plays a critical role in most companies, in that they depend on a continuous stream of new products for their livelihood. Product strategy is the most important element of the entire business strategy and it is tightly integrated with product development strategy because it defines the plan for new products that a company intends to develop. There are four main purposes of a new product development strategy (Wheelwright and Clark,1992):

- Creating, defining, and selecting a set of development projects that will provide superior products.

- Integrating and coordinating functional tasks, technical tasks, and organizational units involved in development activities over time.
- Managing development efforts so they converge to achieve business purposes as effectively and efficiently as possible.
- Creating and improving the capabilities needed to make development a competitive advantage over the long term.

It should focus around the expectations of the customers by developing products through research and development efforts. It should be able to position the company effectively against its competitors in the competing markets to ensure the success of the company.

Conventional NPD strategic planning started from technology and market assessment and then moved to project management. Wheelwright and Clark pointed out that it failed to set boundaries and focus to provide sufficient up-front planning to link projects and strategies. He improved the new product framework as shown in Figure 1.

Although there is some improvement in the new product development strategy, several weaknesses can still be observed:

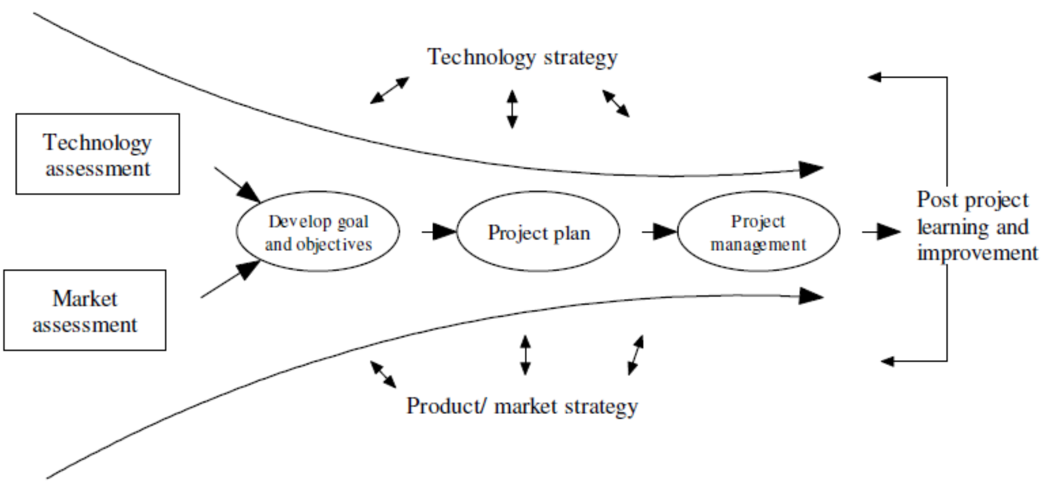

Figure 1: Improved new product development strategy by Wheelwright and Clark

- It is based on rational strategic planning, assuming that there is a best solution while going through different stages of the framework. It has not taken the continuously changing environment into consideration so as to be responsive. It does not clearly explain how to handle the idea and concept generation 'proactively'. Although in their later work, they developed the 'development funnel' and described the generation of ideas as "encouraging certain sources of new ideas and selecting which of those to support in development projects" (Wheelwright and Clark, 1992). It still did not cover how to create ideas for further development.

- Post project learning can provide an opportunity to learn from experience. However, every new product project is different and while experience can prevent similar mistakes occurring again, it may not automatically generate new concepts that are 'adaptive' enough to cope with the turbulent changing environment.
- Missing of idea creation and problem solving in an innovative way throughout the whole NPD process.

To fill up this gap, the author has developed a reference model for new product development strategic planning that can tackle the above weaknesses. This will be explained in more details in the coming sections.

3 Research design

3.1 Questionnaire survey on new product development

The hypotheses testing will test the characteristics of the key components of the model.

Questionnaire surveys were sent to manufacturers in Hong Kong. Responses from non-manufacturers were discarded. Names of the companies were obtained from the membership list of the Federation of Hong Kong Industries which is the representative association of Hong Kong Industries. Electrical and Electronic consumer product manufactures were chosen.

The first survey was concerned with the way the organization prepared its strategic plan for new product development. The second survey was a follow up survey about the actual performance of the new product. In the first survey 387 questionnaires were sent with 45 respondents which represented an 11.6 % response rate. The second batch of questionnaires was sent to the 45 respondents and asked for the actual new product performance. Respondents were reminded to respond by follow up calls. As a result, 35 questionnaires were returned representing a 77.8% response rate. A follow up survey were sent to the 45 respondents again to verify the problem solving practices of the organizations.

The objectives of the survey were two folds:

1. To identify the practices being used by manufacturers to determine new product development strategic planning and problem solving.
2. To verify the practices by comparing them with the actual achievement of the manufacturers.
3.

4 TRIZ-based Strategic reference model development

4.1 Rationale of using a reference model

A reference model is a pre-defined partial model, in several parts that may be reused and customized to facilitate the development of a particular model pertinent to an individual organization.

It should provide decision makers with a rational and holistic basis for decision making and evaluation. It can be shared and reused. Through the modeling process, it is possible to map activities and their interrelationships, resources and organizational units, as well as the flow of information through operational and supporting processes. It provides a graphical description of business activities. The value of the outcome document can illustrate the big picture, and act as a vehicle for development and communication.

Since the main objective of the present research is to construct a practical tool to help manufacturers in planning a strategy for new product development, a Reference Model with the advantages mentioned above would be suitable for the proposed strategic planning process. It is appropriately named the Strategic Reference Model (SRM).

There are many model construction techniques for business process modeling some of which are mentioned below: Structured analysis design technique (SADT); ICAM Integrated Definition (IDEF); Structure-Conduct-Performance (SCP),; Market Structure-Market Conduct-Market Performance (MMMP); Architecture for Integrated Information Systems

(ARIS); Unified Modeling Language (UML); Group de Recherché en Automatisation Integrere (GRAI); Generalized Enterprise Reference Architecture and Methodology (GERAM); Soft System Methodology (SSM); Viable System Methodology (VSM).

IDEF0 conforms to the CIMOSA modeling framework which is a diagrammatic representation of modeling dimensions. It is able to provide a simple method for communicating easily with understanding of the subject of the strategic reference model. It was chosen because it has the following advantages:

- Simple for non-experts to use
- Easily interpreted and discussed
- Used as a basis for further developments
- Able to identify opportunities for system improvements
- Agile and concise so that continuous maintenance may be viable
- It is a functional model popular with the industry
- It is a de facto international standard, and a US Federal Information Processing standard

An example of an IDEF0 diagram is shown in Figure 3 in which the arrow from the left is ‘input’, the arrow to the right is ‘output’, the arrow from the top is ‘control’ and the arrow from the bottom is ‘mechanism.’

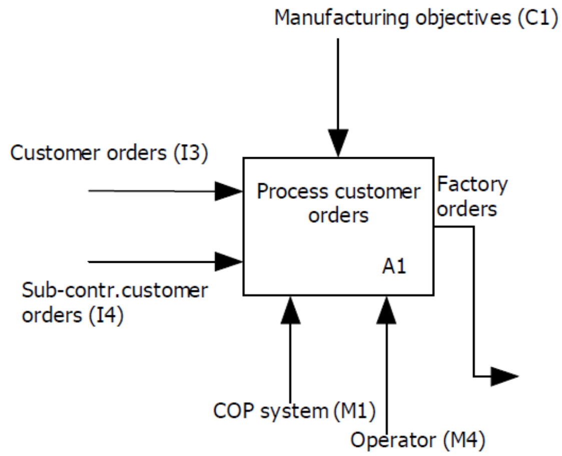

Figure 2: Example of an IDEF0 diagram

4.2 Framework infrastructure

Competitive sense-making (CSM)

The competitive sense-making process is the starting point of the NPD strategic planning.

Competitive sense-making (CSM) is one of the competitive intelligence activities to 'proactively' search for information about the competitive elements of product, market, competitor, technology and customer. Through this competitive sense-making searching process, ideas are developed which can be turned into product ideas for development. This competitive sense-making process is 'proactive' and also forward looking as it is used to search for information and opportunities. The starting point of new product development is to generate ideas. Rarely do organizations have a systematic way of corralling ideas, nor is anybody responsible for their identification (Wheelwright and Clark, 1992). Some researchers suggest listening to customers for ideas; however, customers tend to express their needs in terms of past and current experience so that blindly listening to customers' needs is not reliable.

H1: The collection of sense-making intelligence for new product development is positively related to the performance of new products.

Constructing scenarios

Scenario planning with sense-making in the organization will bridge the gap between strategy implementation and early warning processes (Fink, Siebe and Kuhle.,2004). It is an instrument that enables the organization to discuss futures with strategic planning issues when facing uncertainties. The power of scenarios as a process tool to handle uncertainty in the strategic area has been covered in many text books (van der Heijden, 2005; Walsh, 2005; Lindgren and Bandhold, 2003; Schwartz, 1996; Schoemaker, 1995). Scenarios enable managers to experience the future world ahead of time, creating memories which serve as guidelines to make sense of environmental signals and to act on them ahead of competitors. During the thinking process, the managers of the organization think through what will be happening in the future which is what Peter Schwarz (1996) called the rehearsing of the future. It allows the managers to rehearse the future by imagining different events which will lead to alternative futures. Scenarios can also identify 'trigger points' to indicate whether the market is moving in or away from a specific direction (Jennings, 2000). Research has also reported a positive relationship between scenario planning applications and business performance gains (Phelps, Chan and Kansalis, 2001). Based on these benefits, and taking into consideration that new product development is for products in a future in which a lot of uncertainties are involved; scenario planning is justified as a strategic planning tool for new product development strategic planning.

H2: The practice of competitive trend development for new product development is positively related to the performance of new products.

Identify trends

New products require a time span in which to develop, some need longer, some shorter. Anyhow, they are developed for the future not for today. The better the prediction of the changes in market, customers, technologies, and competitors, the better the chance of success the new product has (Lindgren and Bandhold, 2003). The information for the prediction does not come from nothing, but from the competitive sense making for which intelligence from many customers, competitors, markets, and technologies should have been on hand, for evaluation.

H3: The practice of trend analysis for new product development is positively related to the performance of new products.

Strategic learning

Product life cycles are becoming shorter and shorter. Today's new products become old products tomorrow; so the companies have to seek more ideas for new products in order to survive. Product development therefore needs to develop new competences continuously due to changes of customers' expectations. Many articles in the literature have stated that organizational learning is believed to be important to the competitive performance of the business. De Geus (1997) has stated that learning more quickly than competitors, is vital for a company's survival. Organizations are now competing on their ability to change more quickly and more effectively than their rivals. Learning in new product development is therefore vital in today's competitive, uncertain and turbulent environments. Even more important, learning faster to launch new products more quickly, will increase the probability of success.

New product development is not aimed at today's product; instead it carries the task of constantly developing products for tomorrow through continuous organizational learning and knowledge creation. Product innovation that draws on that knowledge has a higher chance of success. It builds on the accumulation of previous knowledge. Strategic learning is concerned with the processes by which organizations learn about themselves and their environment. It consists of discussions, debates and conversations during the competitive sense-making, idea generation, trend development, driving force development, scenario construction, strategy formulation, performance evaluation, ending in strategic decisions. This forms a strategic learning cycle (Figure 3) in the strategic planning process.

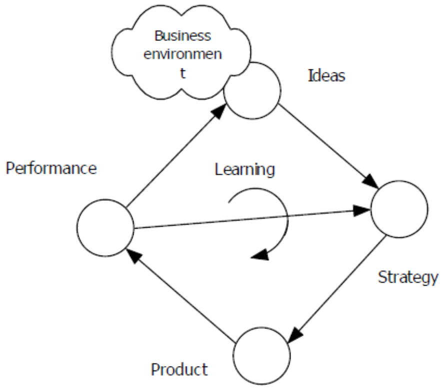

Figure 3: Strategic learning cycle

H4: The degree of learning in the organization is positively related to the performance of new products.

Problem Solving Ability

Throughout the new product development process, ongoing problems appear starting from customer requirements, product definition, concept design, product testing, market response, product launch to the markets. The performance of the new product is heavily related to the ability of the organization to continuously solving the problems with creative ideas. By doing this, it could keep the product development going in a smooth and faster way.

H5: The practice of problem solving ability is positively related to the performance of new products.

Performance measures

Performance metrics for NPD (Appendix 1) will be used in the SRM for consequent testing and actual performance measurements. Each strategic alternative will be evaluated against these three dimensions. The overall performance index (PI) is computed for comparing the performance project by project. The performance measures are grouped into three dimensions identified by Leavitt (2003) as the Objective dimension, the Success dimension and the Opportunity dimension.

The Objective dimension is to measure how well the new product:

- Meets sales objectives
- Meets profit objectives
- Meets market share objectives
- Meets budget control

The Success dimension measures how well the new product:

- Meets return on investments in the project

- Achieves customer satisfaction
- Is developed on time

The Opportunity dimension measures how well the new product opens an:

- Opportunity window on new categories
- Opportunity window on new markets
- Opportunity window on new technologies
- Opportunity window on learning

These performance metrics can also be used to evaluate the actual performance of a project if a particular strategy alternative has been chosen by the metrics for a product that has been put into real production.

5 Strategic process and architecture

The TRIZ-based Strategic Reference Model (TSRM) applies the techniques of scenario planning with the addition of a starting point for competitive sense-making (CSM) activities as well as the Performance Measurement concepts mentioned in section 4. The Model proactively searches for information as a function of sense-making, develops the intelligence to identify trends and driving forces, develops scenarios, proposes success factors and strategy alternatives, performs consequent testing by performance metrics and confirms the final determination of strategies. The heart of the Model (Figure 5) is to solve problems continuously with inventive solution and the creation of organizational learning throughout the entire process in order to achieve an adaptive nature for future product development.

5.1 Idea generation block (IGB)

The 'Idea Generation Block' (IGB) consists of step one through step three of the NPD strategic planning process.

Step 1- *Idea generation by competitive sense-making (CSM)*: There are specific areas that the company needs to 'sense' constantly in order to convert them into product opportunities.

The specific areas are unexpected successes, unexpected failures, unexpected external events, process weaknesses, industry/market structure changes, high growth of industry, converging technologies, demographic changes, perception changes, and new knowledge.

Step 2- *Identify trends*: There is no single rule to identify trends; Delphi, a focus group or an expert panel can be used. The outcome is a list of identified trends, product trends, market trends, customer trends, competitor trends and technology trends.

Step 3- *Identify driving forces* : Driving forces are the underlying and impacting factors that set the pattern of events and determine outcomes. They are the forces that make things happen. Therefore understanding the driving forces could uncover the reasons why the trends are as they are. The outcome from this step is a list of driving forces corresponding to the trends.

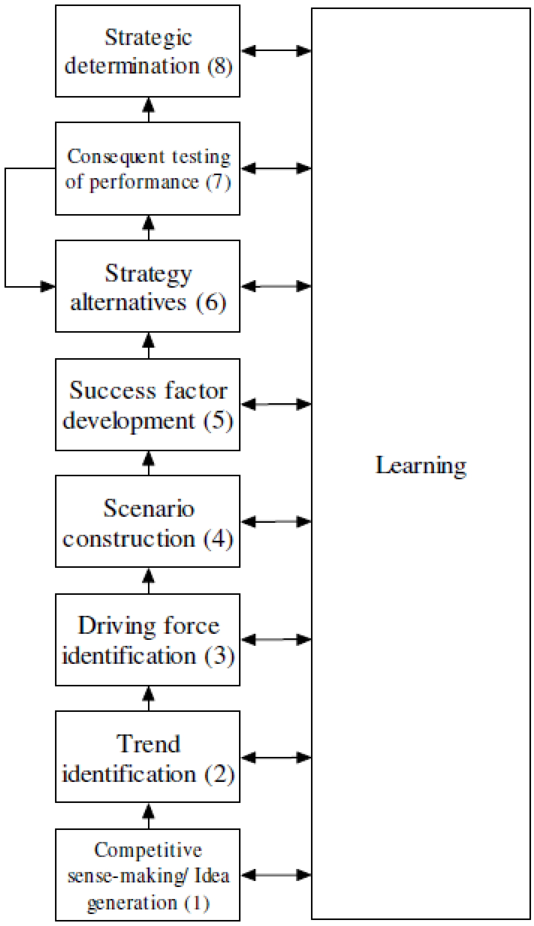

Figure 4: Strategy determination of SRM

(Numbers inside brackets are the steps of the SRM process)

This block provides intelligence for decision makers so that they can have further strategy development. It also opens up eyes and ears for scenario planning in the second block.

5.1 Strategy formulation block (SFB)

The 'Strategy Formulation Block' consists of steps four through six of the NPD strategic planning process. It is the block where scenarios are drawn from the ideas created in the IGB. Success factors of the scenarios are determined and finally strategy alternatives are proposed. It is the block in which strategy alternatives are proposed for further evaluation. It is constituted partly from the product development strategy phase of the NPD process.

Step 4- *Constructing scenarios*: Scenarios are constructed by adapting the methodology of Lindgren and Bandhold (2003) based on the uncertainties uncovered. This is the step that the team takes to make sense of complexity. It is a process of inclusion, where all previous thinking on trends, driving forces and competitive sense-making is combined with the thinking developed in the generation of the different 'types of futures'. It is a group scenario generation process that involves conversations among the people involved. The conversation couples the people together and it becomes a joint learning process. When this mental model has been built up over time within the group, it creates a common language that makes strategic conversation possible. The outcome from this step is a list of scenarios.

Step 5- *Developing success factors:* Key success factors are those capabilities of the organization which differentiate it from its competitors. For each of the scenarios developed in step 4, a list of required key success factors are determined by the team. The outcome from this step is a list of success factors corresponding to each scenario.

Step 6- *Generating strategy alternatives*: Strategy is related to survival and success and is used to steer actions to drive the success. To generate strategies, the mission and vision of the organization, the ideas from CSM, trends and driving forces, scenarios and key success factors are all the inputs for the strategy formulation. In addition, the expectations of stakeholders and resource limitations of the organization are considered. The strategies thus developed have to consider the internal perspective, the organizational capability and the external perspective, and the business portfolio (Van der Heijden, 2005) which are available from previous steps. It is a group dialogue addressing the questions the organization needs to answer when it faces the uncertainties of the future. The strategies being defined need to match with the unique characteristics of the organization. The outcome from this step is a list of strategic alternatives for further evaluation, so the most appropriate choice can be decided on.

5.3 Strategy determination block (SDB)

Activities of the 'Strategy Determination Block' include reviewing the performance metrics that were determined, consequent testing of each proposed strategy alternative and finally the strategic decision. This block consists of step seven through eight of the NPD strategic planning process. It complements the 'Strategy Formulation Block' to constitute the rest of the product development strategy.

Step 7: *Consequent testing of strategy alternatives:* Each alternative is tested by pre-set performance metrics (explained in previous section). The purpose of this consequent testing is to evaluate each alternative by forecasting the performance before an actual decision is made. The performance metrics are evaluated in a portfolio of objective, success, and opportunity dimensions. A performance index (PI) is calculated for each strategic alternative for evaluation.

Step 8: *Strategic choice*: Step 4 to 7 can be repeated several times if the expected performance index from step 7 is not satisfactory, or if it does not match the objectives, expectation of stakeholders or limitations of the resources. Alternative scenarios will be generated again for consideration until a final strategic decision is made.

5.4 Problem solving block (PSB)

Activities of the 'Problem Solving Block' include problem identification and problem solving. TRIZ problem identification tools such as Function Analysis, Flow Analysis, Technology Trend Analysis, Trimming Analysis are used continuously throughout the various stages of the product development process. TRIZ problem solving tools such as Contradiction Analysis, Substance-Field Analysis, Inventive Principles and ARIZ are used to solve the problems throughout the process. The determination of the problem identification and problem solution are feeding to the organizational learning of the company for future use.

5.5 Learning support block (LSB)

Activities of the 'Learning Support Block' involve identification and prioritizing of organizational learning dimensions and processes. It is the block which supports a long-term NPD strategic plan through continuous learning, and eventually results in knowledge generation in the organization. Throughout the eight-step process, learning has been generated to support the long-term growth of product development. Learning is generated during competitive sense-making (CSM), identifying trends and driving forces, creating scenarios, proposing strategy alternatives, testing of performance and making strategic choices. Discussion and agreement during the eight-step process improves communication and further enhance the thinking process of the team.

6 Hypotheses testing results

All the respondents had manufacturing facilities either in China or the Far East. The number of their employees was more than 100 in each company with significant product development every year. The performance measure was categorized into: Objective dimension performance, Success dimension performance and Opportunity dimension performance. The reliability of the scales for these three dimensions was evaluated using Cronbach's _ using SPSS 10 statistical software for analysis. For each scale, a value of _ >0.75 was found, (Table 1) suggesting that the scales were reliable (Nunnally,1988).

Correlation of the practices of the respondents to formulate the new product development strategies vis-à-vis the Objective dimension, Success dimension and Opportunity dimension was evaluated by Bivariate correlation. Pearson's correlation coefficient with two-tailed significance of the SPSS 10 statistical software was used for analysis. The result of the correlation is shown in Table 1.

H1: The collection of sense-making intelligence for new product development is positively related to the performance of new products is thus supported. Sense-making intelligence can provide valuable information for the entire new product development process from idea generation through to product realization. This intelligence includes competitor intelligence, customer intelligence, marketing intelligence, technology intelligence, as regular input which can serve as a knowledge database for immediate use.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.Use sense making intelligence	1.000							
2.Use trend analysis	0.445	1.000						
3.Use scenario thinking	0.626*	0.786*	1.000					
4. Problem solving analysis	0.543	0.765*	0.808*	1.000				
5.Organizational learning culture	0.353	0.350	0.740*	0.518*	1.000			
6.Objective performance	0.626	0.372	0.367	0.624	0.393	1.000		
7.Success performance	0.714*	0.468*	0.487	0.732**	0.562	0.876*	1.000*	
8.Opportunity performance	0.803*	0.477*	0.404	0.508	0.404	0.800*	0.809*	1.000

Table 1: Correlation analysis of NPD strategic planning practices and performance Dimensions

* Correlation is significant at the 0.05 level (2-tailed)

H2: The practice of competitive trend development for new product development is positively related to the performance of new products, is also supported. New products are developed for the future not for now. Therefore the managers look into the future to see what the market will need, what the customer will want, what technological changes there will be, and what competitors will do. However, the many uncertainties ahead create questions that are complicated to answer. Using the developed trend to identify driving forces could give managers some insight as to what the underlying factors are and to what degree of impact such factors might have.

H3: The practice of scenario analysis for new product development is positively related to the performance of new products, is also supported. Scenario analysis can handle uncertainties (Schwarz,1996). It does not focus on the existing ‘status quo’ like the conventional forecasting, nor is it a simulation model. While working out the scenarios, the managers develop and test the strategies by thinking through the situation, then build ideas around it. This memory of the future (van der Heijden *et.al*.,2002) provides strong support to new product development to develop products for future use. Besides, scenarios encourage people to think, to communicate, to deal with complex situations; and eventually, the organization learns.

H4: The degree of learning in the organization is positively related to the performance of new products is supported. Traditionally organizational learning is seen to be a supporting function to the entire new product development. There is a misconception that experience is already learning, therefore learning itself is not planned. Michael and Palandjia (2004) showed that the organizations do not learn from experience at all. When experience accumulates, the organization learns more and more about a specialized routine and this makes it difficult to assess new experience accurately. Therefore entirely relying on experience in order to learn would not result in improvement. Since new product development requires new ideas and new inputs, organized learning at each phase is required. Formal reviews of the products including the business environment, company’s products and competitors’ products, the whole strategy formulation process and the performance, are desirable.

H5: The practice of problem solving techniques in the organization is positively related to the performance of new product development. It is very obvious that organization to keep solving problems evolving throughout the product development process, it could enhance the speed of the development as well as the outcome of the product.

7 Conclusion

Although the success of new product development is critical to the making of profit in a manufacturing organization, it was found through an extensive literature review that no research study has focused on the generation of a strategy for new product development by using a Reference Model including solving problem inventively. Since the investment in the research and development for producing a new product is expensive, fast decision making in choosing the right target product to match the anticipated market needs, is essential. TRIZ has been identified as a powerful tool for problem identification and problem solving. Involving TRIZ in the TSRM could enhance the speed, quality and performance of the product outcome.

Therefore, the author attempted to identify the distinct features that need to be considered when formulating a strategy for new product development and presented it as a Reference Model in such a way that facilitates direct application by manufacturing organizations. Through an extensive literature review and study of real life practices employed by local manufacturing organizations, the author identified the conceptual framework of the eight strategic planning steps. To enable this strategy planning tool to be applicable to different organizations with their unique characteristics, the TRIZ-based Strategic Reference Model (TSRM) was presented by the technique known as Integrated Definition (IDEF0) that allows different organizations to fit in their data for assessment and for making choices. The architecture of the TSRM is mainly composed of five blocks: the ‘Idea Generation Block’, the ‘Strategy Formulation Block’, the ‘Strategy Determination Block’, the ‘Problem Solving Block’ and the ‘Learning Support Block’. While walking through the steps of the TSRM, problem solving capability and organizational learning are created for the long-term success of continuous new product development which can enhance the development of strategies to confront the uncertainties in the business environment in a proactive, adaptive and responsive way to meet the competition.

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Paper ID: 55

Definition of System Innovation Degree and Its Measuring Method

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Abstract

In classic TRIZ, G. S. Altshuller has proposed five levels of innovation, but in practical innovation tasks, people often confused how they to evaluate the degree of an innovation within the same innovation level. It is because the description of five levels classification is vertical and qualitative but horizontally and quantificational.

To fix the problems above, the authors of this paper to table a proposal in a new concept-***System Innovation*** D***egree*** (SID) and its measuring method with the help of IPC (International Patent Classification) to supplement the five levels classification . The purpose of SID is that it could help people who want to solve the problems in the real world to evaluating the difference of the inventions within the same level of innovation more easily and clearly. And this concept (SID) is also describe the five levels classification in a horizontally and a quantificational way well.

Finally, the authors give an example to explain the applications of SID concept and its measuring method in the real innovation jobs.

Keywords: Levels of system innovation, International Patent Classification, Method to evaluate the degree of an innovation.

G. Altshuller has proposed five levels of innovations(LOI) in last century:

Level 1. A simple improvement of a technical system: Requires knowledge available within the trade relevant to that system.

Level 2. An invention that includes the resolution of a technical contradiction: Requires knowledge from different areas within the industry relevant to the system.

Level 3. An invention containing a resolution of a physical contradiction: Requires knowledge from other industries.

Level 4. A new technology is applied which contains a resolution of contradictions with better approach to Ideal Final Result: This new technology includes a breakthrough solution that requires knowledge from different fields of science.

Level 5. Discovery of a new phenomena or substances: This new knowledge provides for the development of new technologies with utilization of the new phenomena, resolving existing contradictions with better approach to the Ideal Final Result.

With problems of the first level, the object (device or method) does not change. At the second level, the object is changed but not substantially. At the third level, the object is changed essentially and at the fourth, it is totally changed. In the fifth level, the entire technical system is changed in which this object is used. [1]

According to the definition of the levels of innovations by G. Autshuller. People can vertically distinguish the levels in different degrees. But if there are two or more innovations labeled in the same level, how can people to evaluate the degree of these innovations?

It is clearly that the classic kind of distinguishing of the levels of innovation needs a new method which can distinguish the degrees of innovations in horizontally. Even though some people think that distinguishing of the different levels of innovation is more important than the same levels [4], but in many enterprises, the innovation usually is an asymptotically process with the limited of the resource or some economic reasons.

Based on the above needs, Here we introduce a new concept which called System Innovation Degree (SID). What is System Innovation Degree (SID)? The System Innovation Degree (SID) is a measure of some innovations which are belong the same levels of innovations defined by G. Altshuller in classic five levels. With the SID, people can evaluate the degree of some innovations in the same level of innovations. SID is used to evaluate the degrees of an innovation in horizontally and quantificational way, which is different with the 5 levels of innovation. Now we got a picture on the degrees and levels of innovations, shown in Fig.1.

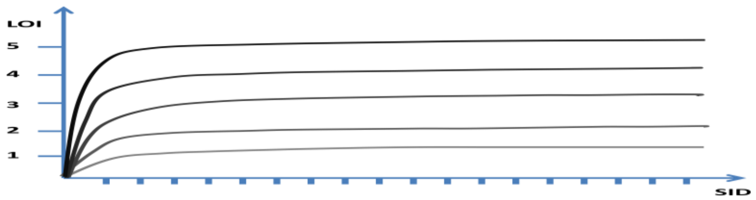

Fig.1 degrees and levels of innovations

Once we got the concept of SID, another question should come into our views at once. How to measure the SID of a series of innovations which are located at the same levels of innovations?

Here, we put forward a proposal by means of IPC (International Patent Classification) to measure the SID levels within the same levels of innovations (LOI). According to INTERNATIONAL PATENT CLASSIFICATION (Version 2013) which was entered into force on October 7, 1975. We know the objective of the IPC, is being a means for obtaining an internationally uniform classification of patent documents, has as its primary purpose the establishment of an effective search tool for the retrieval of patent documents by intellectual property offices and other users, in order to establish the novelty and evaluate the inventive step or non- obviousness (including the assessment of technical advance and useful results or utility) of technical disclosures in patent applications.

The layout of classification symbols in IPC is including four levels: Section, Class, Subclass and Group.

1. SECTION: The Classification represents the whole body of knowledge which may be regarded as proper to the field of patents for invention, divided into eight sections. Sections are the highest level of hierarchy of the Classification. The eight sections are entitled as follows:

A HUMAN NECESSITIES

B PERFORMING OPERATIONS; TRANSPORTING

C CHEMISTRY; METALLURGY

D TEXTILES; PAPER

E FIXED CONSTRUCTIONS

F MECHANICAL ENGINEERING; LIGHTING; HEATING; WEAPONS; BLASTING

G PHYSICS

H ELECTRICITY

2. SUBSECTION – Within sections, informative headings may form subsections, which are titles without classification symbols. Example: Section A (HUMAN NECESSITIES) contains the following subsections:

AGRICULTURE

FOODSTUFFS; TOBACCO

PERSONAL OR DOMESTIC ARTICLES

HEALTH; LIFE SAVINGS; AMUSEMENT

3. **CLASS:** Each section is subdivided into classes which are the second hierarchical level of the Classification.

4. **SUBCLASS:** Each class comprises one or more subclasses which are the third hierarchical level of the Classification.

5. **GROUP:** Each subclass is broken down into subdivisions referred to as "groups", which are either main groups (i.e., the fourth hierarchical level of the Classification) or subgroups (i.e., lower hierarchical levels dependent upon the main group level of the Classification).

COMPLETE CLASSIFICATION SYMBOL

A complete classification symbol comprises the combined symbols representing the section, class, subclass and main group or subgroup. Example: [2]

A Section – 1st level	01 Class – 2nd level	B Subclass – 3rd level	33/00 or 33/08 Group	Main group – 4th level Subgroup – lower level

Fig.2 Full structure of IPC class

Base on above description of IPC, Now, We can determine the SID by such a way. 1st, we choose the subject of the problem need to be solved as the main subject, say it is 1. And then we take the solution as the N, the N is countered from main subject. Thus the SID of the solution is equals N-1. For examples, If the problem is belong to A, the HUMAN NECESSITIES, while the solution is belong to E, FIXED CONSTRUCTIONS, then the SID of the solution is equals 4(E-A). This is the SID for the same class in IPC

(Section, Class, Subclass and Group), if the solution is located at the different class, the SID should be the summation at the different class (Section, Class, Subclass and Group). See Fig.3 for the details.

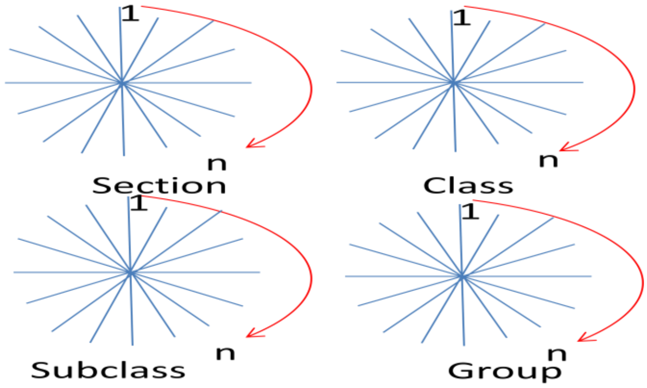

Fig.3 Calculating method based on IPC

After learn the method on how to determine the SID of the solutions, now we could use a real case to determine the SID.

Project name: Wind Turbine Development;

Project Description: Wind turbine works the opposite of a fan. Instead of using electricity to make wind, a turbine uses wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. The electricity is sent through transmission and distribution lines to a substation, then on to homes, business and schools.

Project Goal: Improves the productivity of the three blades wind turbine without increase the cost.

Solutions:

1. Stator of Permanent Magnet Synchronous Generator directly connects Blades;
2. Doubled propeller – Doubled blades
3. Efficient propeller - Stream stabilizer
4. Blade in form of Mobius strip
5. Variable-rigidity flipper – blade
6. Flexible Wing - Blade

SID of the Solutions:

	Solutions	SID
1	Blade in form of MOBIUS Belt	120
2	Flexible Wing - Blade	102
3	Efficient propeller - Stream stabilizer	88
4	Variable-rigidity flipper - blade	75
5	Stator of Permanent Magnet Synchronous Generator directly connects Blades	45
6	Doubled propeller – Doubled blades	24

Conclusion

Traditional or Classic TRIZ proposed five levels of innovations, but it is not enough to distinguish the difference of the innovations which belong to same levels in practice. The difference of these belong to the same levels of innovations is very important for enterprises sometimes. For the innovation is usually limited by some economic factors in enterprise. And the invention sometimes is a slowly and long process in enterprise.

Based on above analysis, authors proposed a concept and a method to distinguish the difference of innovations which belong to the same levels of innovations and hope which is useful to enterprise who want to make choose on innovations.

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Analogy Design Research and Application Based on Resource Analysis

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Abstract

Analogy is a method to enhance the creativity in the creation of science. When introduce analogy to design, it turns into analogy design.

This paper researches the way to add resource analysis into analogy design research based on analogy design as well as the '9-windows' tool in resource analysis, conclude the process of analogy design research based on resource analysis and seek to improve the success rate of analog design.

When we go through analogy design research based on resource analysis. Firstly, we convert domain problem to TRIZ problem. Secondly, we correspond between analog design state and TRIZ parameter. Thirdly, we use resource analysis methods ('9-windows' tool) to deal with specific TRIZ solution. Then, we choose one of the appropriate systems and study on its evolution resource. Finally, we find out unexpected discoveries (UXD) from these resources, and transfer UXD to target design, and fulfill it.

Finally, based on the analogy design combined with resource analysis, we redesign a new type of Bridge Girder Erection Equipment. The effectiveness of the proposed method is verified.

Keywords: analogy design, TRIZ, resource analysis, '9-windows' tool

1. Introduction

Situations, circumstances, scenes or events in the world are repeated; Slight changes in the world will lead to small changes on some of the concepts, these changes have regularity. The same or similar behavior, process will have the same or similar results. Many examples of past successful design can help designers to complete the design of today—this is the Analog Design.

According to its several same or similar properties, analogy is to compare two different things, speculated that these two things do have another property of the same or similar way of thinking. While in essence, it is mapping of knowledge from one area to another area.

Resources of this study, focused on the resources of inventions. In TRIZ, resources are an important analytical methods and tools to solve inventive problems. Its definitions are as a follows:

Any new substances transformed from systems or substances exist in the environment. Stored energy, free time, unoccupied space, information, etc. Technical capacity to implement additional functionality, including properties of the substance, physics, geometry, or other effects. The purpose of this research is that: Besides designers' experience, research or limited access to information, we take a more objective method--introducing resource analysis in analog design—to match better solution.

2. Analogy design research based on resource analysis

▪2.1 Concept of analog design

Let the initial state and the final state of the source design be A and B, the initial state and the final state of the target design be A' and B'. There is a relationship β between the initial state and the final state of the source design A and B, β is an implementation process or a series of operations, thus β is applied to A to produce B. The initial state of the target design A' is known, however, the final state B' is unknown. There is a relationship β' between A' and B', thus β' is applied to A' to produce B'. There is some similarity α between A and A', then β can be used to determine β '. B ' can be determined by A 'and β'. This process implies a similarity α' between B and B'. B' is the new design. We can see this relationship clearly in Figure 1.

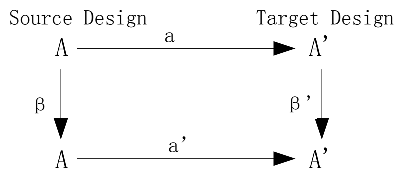

Figure 1. Basic principles of analog design process (Ma and Tan, 2006)

▪2.2 Corresponding between analog design state and TRIZ parameter

In order to combine resources analysis with analog design methods, we converted the issues to be studied, ie domain problem to TRIZ problem based on prior analog design research (Tan et al., 2006). Then we can find out TRIZ specific solution via matching it in TRIZ resolution process (Kolle, 2005). After that, we deal TRIZ specific solution with resource analysis methods and subsequent analysis. Finally, we can find out the field solution.

Source design is consists of problem A, implementation process or a series of operations β and solution B. It can be shown as follows:

Source design= $\{A, \beta, B\}$,

Meet the conditions: $A \xrightarrow{\beta} B$ (1)

$$A = \begin{Bmatrix} \text{39 standard engineering parameters, technology evolution model,} \\ \text{substance} - \text{field model, feature Set} \end{Bmatrix},$$

$$\beta = \begin{Bmatrix} \text{conflict matrix, technology evolution path,} \\ \text{standard solution search algorithms, function body} \end{Bmatrix},$$

$$B = \begin{Bmatrix} \text{40 inventive principles,} \\ \text{technical evolution of state, 76 standard solution, effect} \end{Bmatrix}.$$

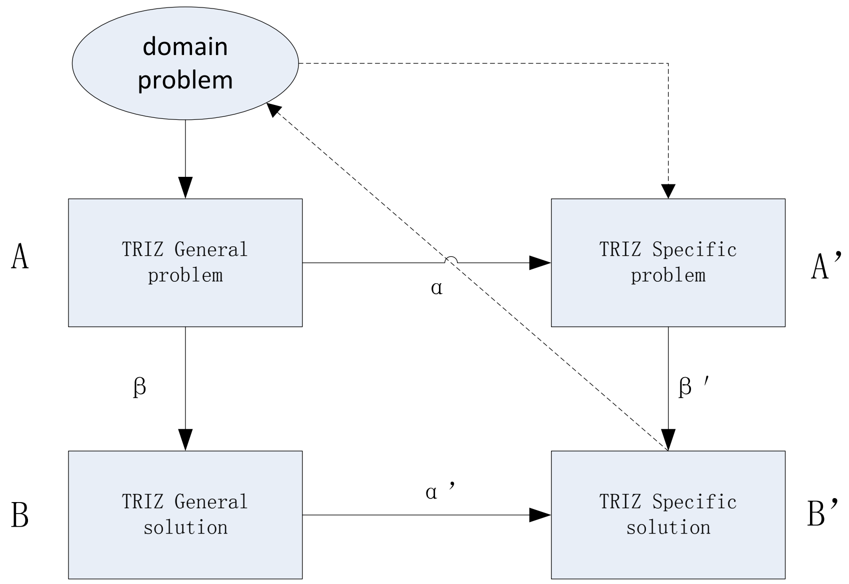

Figure 2. Corresponding between analog design state and TRIZ parameter (Tan et al., 2006)

When domain problem is converted to TRIZ problem (Tan, 2010), it is corresponding to a section in A. While A corresponds to TRIZ Specific problem A’. We use TRIZ tools to get the corresponding TRIZ specific solution .The models are listed in Figure 2.

Target design= $\{A', \beta', B'\}$,

Meet the conditions: $A' \xrightarrow{\beta'} B'$ (2)

Among: $A \in A'$, $B \in B'$, $\beta \in \beta'$

▪2.3 The overview of analog design combines resource analysis

We get TRIZ specific solution β' from domain problem through TRIZ methods. Then, we use resource analysis methods to deal with β' .

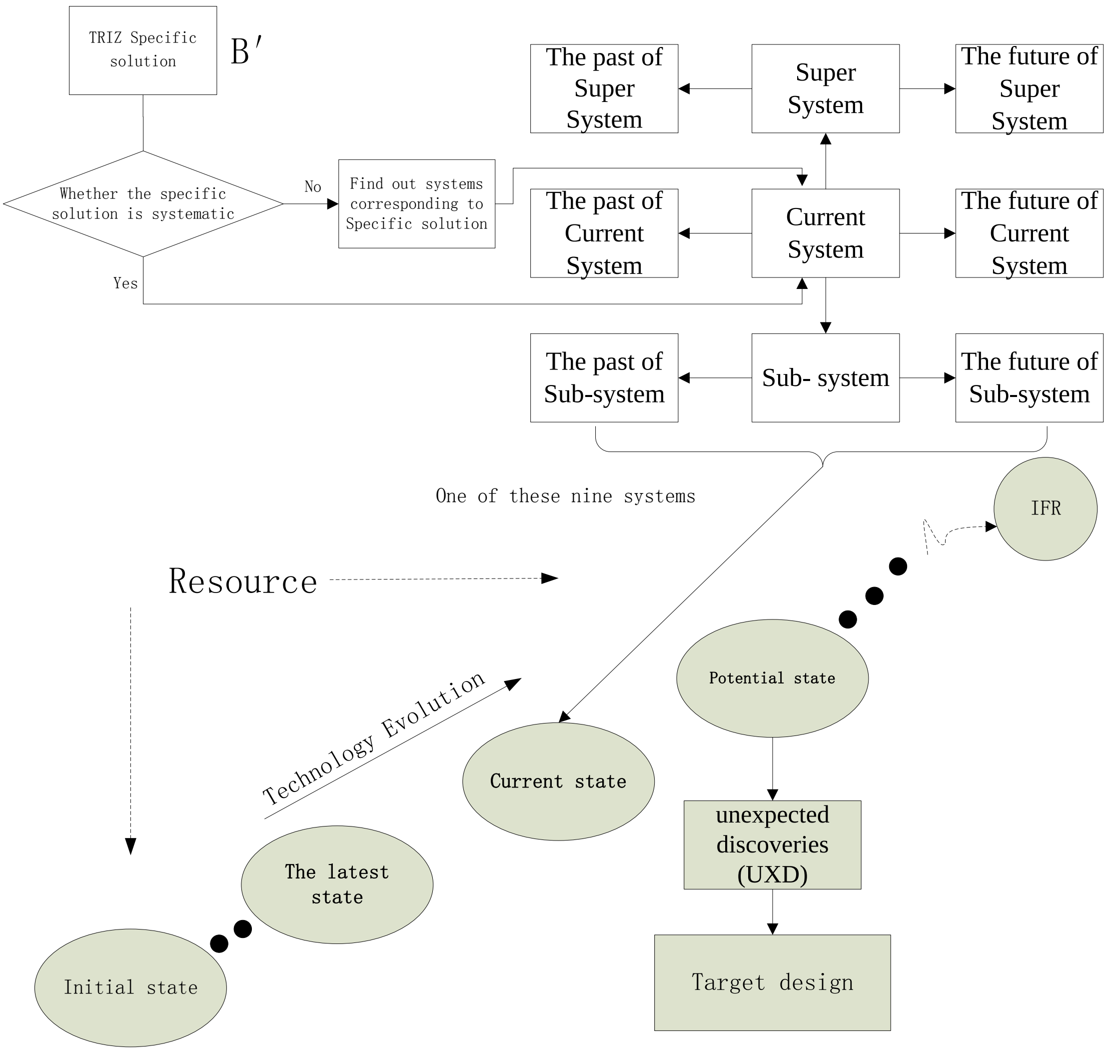

Figure3. Use resource analysis method to find UXD

Here, we use the '9-windows' tool to analyze the specific solution system or the system that the specific solution is corresponding to. We research on those nine modes of systems: the past of super system, super system, the future of super system, the past of current system, current system, the future of current system, the past of sub-system, sub-system, the future of sub-system. We use this excellent resource analysis method to get resource that we seldom take into consideration. Then, we will have more opportunity to find possible unexpected discoveries (UXD).

Since we have many resources, we can find possible ways, and then analyze the evolutionary line of the resources (Zhang et al., 2003). Following evolution path of resources, we could find the potential state of the resource we chose before. It may have some revelation to the target design. Then we continue to modify target design to meet the request we need to achieve. Finally, we get the field solution. These steps are shown in Figure 3.

3. Example

Beam bridge machine (Figure 4) is an indispensable machinery and equipment for bridging when laying railway lines and highways in an efficient way (Mao and Yu，2008). No matter machine for railway bridge construction or for road construction machine has become a vital construction equipment. Currently, in accordance with the structure, the 900 t class high-speed railway bridge girder erection equipment has several series: non-guide beam bridge machine, auxiliary guide beam bridge machine and transport aircraft machine.

Figure 4. Beam bridge machine

This case works on the advantages and disadvantages of these erecting machines. Then we put forward an improved scheme, so that we can complete the laying beams with faster efficiency and smaller energy consumption. In this case, the steps by using analogy design application based on resource analysis are as follows:

a. Analyze and summarize about the existing bridge machine:

Non-guide beam bridge machine needs a crane to work on the main beam. Auxiliary guide beam bridge machine can achieve point lifting, but its process is quite complex. Transport aircraft machine also have such short comings as the high overall complexity of the institutions.

In summary, these three types of machines need such steps as lifting, moving, putting down beams and adjusting the beams position, which resulted in an inefficient and high energy consumption beams erection. So, the domain problem is the need to reduce beams erection steps, avoid unnecessary energy consumption brought by the beams' vertical displacement. But if vertical displacement is forbidden, current beam bridge machine just can't work.

b. The domain problem above is a conflict solving problem. We can convert it to standard conflict by 39 standard engineering parameters in TRIZ, thus specific TRIZ problem A':

Improved features: 38 Degree of automation

Deteriorate features: 36 The complexity of the device

c. By looking up in the conflict matrix, the meted innovation principle—specific TRIZ solution to domain problem—B': Dynamic, mediator, pre-operation. The process is listed in Table 1 below.

standard engineering parameters	The name of innovation principle	Design Example
improved features:38 Degree of automation	NO.15 Dynamic	Shape memory alloy, floating roof.etc
deteriorate features:36 The complexity of the device	NO.24 Mediator	Use mechanical arm to crawl and move heavy weights.etc
	NO.10 Pre-operation	Self-extinguishing cigarettes, vacuum bag, Retaining relax nut.etc

Table 1. Part of the conflict matrix

d. Apply resource analysis to TRIZ specific solution

We use one of the methods in resource analysis called '9-windows' tool to deal with this issue. Innovation Principle NO.24 Mediator: Use mechanical arm to crawl and move heavy weights. Here, mechanical arm is a mediator. We treat this mediator as the current system, then we analyze as follows: the nine modes of systems are shown in the Figureure 5 below.

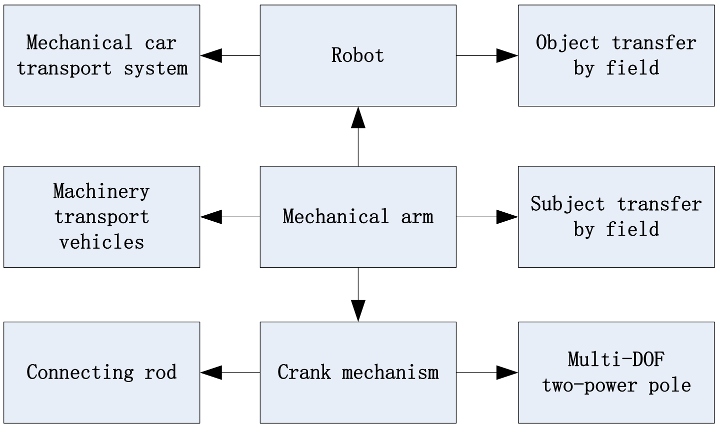

Figure 5. Nine modes of the mechanical arm system

When comparing the nine modes of the mechanical arm system, we decide to study on its super system's current state, potential state, etc.

As a kind of evolution resource, robot and Object transfer by field and its ideal final result (IFR) can be listed in the following Figure 6.

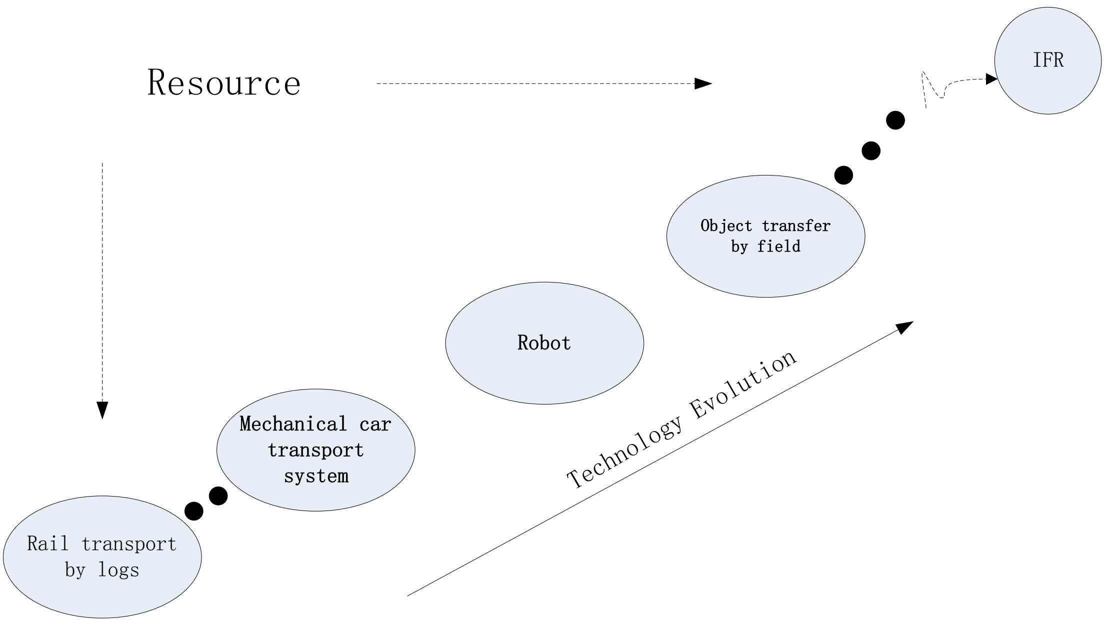

Figure 6. Resources evolutionary path about robot

As it's not so easy to find out source design by the example of mechanical arm, we pay attention to robot and its evolutionary path, robot's potential state is object transfer by field. So, we can consider using an electric, magnetic or gravity field to move the beams. While gravity field is a natural field and it is non-dissipative. This can be seen as

We use principle—Mediator, let gravity field, which belongs to the original resource's future of its super system.

Then, we redesign the structure of the beam bridge machine, avoiding the unnecessary vertical displacement by the crane. Then, we design a new part called: Sliding beams. We can see it in Figure 7 below.

When the beam reaches its limit position, the sliding beams let the beam can go even further. Consider that the sliding beams' bottom is not horizontal, it has a slight dip towards the direction we lay beams. So, beams can slide to the above of the position to be erected by gravity field as well as a little thrust force on the beams tail. At last, we just need to use simple crane to drop the beam. This is the field solution.

By using this field solution, we simplify the process step, use gravity field which is natural and energy conservation, avoid the unnecessary vertical displacement, enhance girder efficiency.

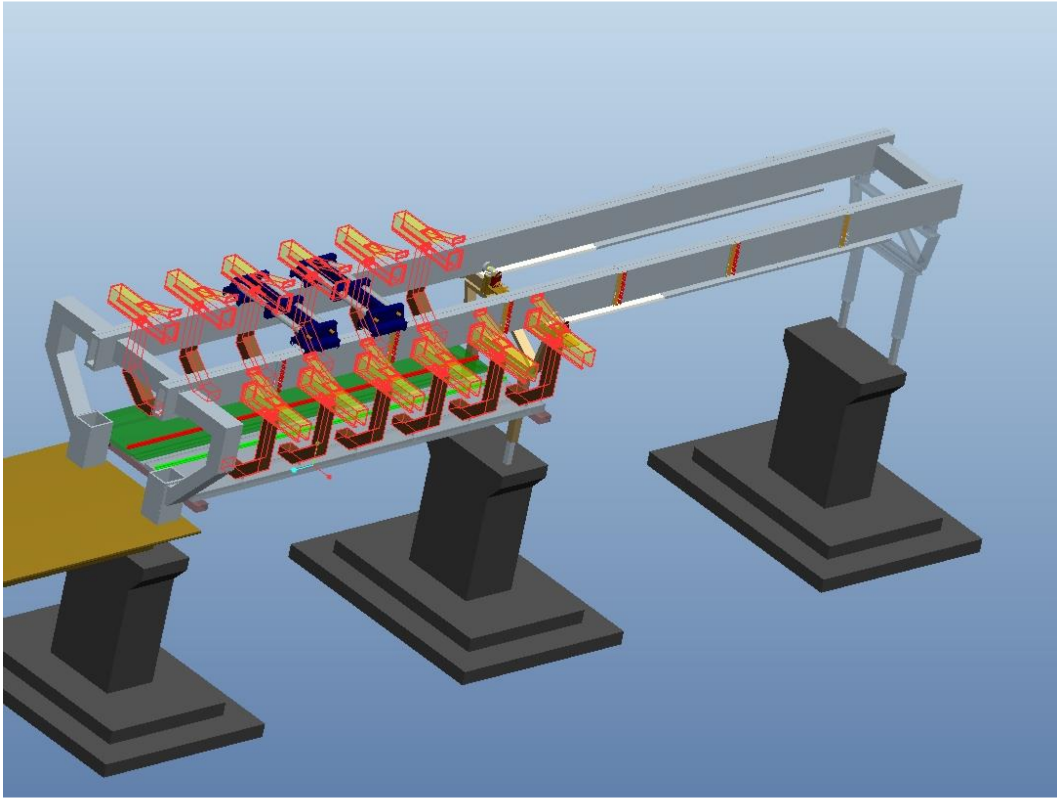

Figure 7. Redesigned Beam bridge machine with sliding beams

4. Conclusion

When target design comes into being, it might be in some less optimistic situations like fewer resources availability, less possibility of realization due to expensive resources, etc. This paper researches the way to add resource analysis into analogy design research based on analogy design as well as the '9-windows' tool in resource analysis, conclude the process of analogy design research based on resource analysis and seek to improve the success rate of analog design. We can find out that analog design through this way would have sufficient resource to use.

As for the improvement of this method, I do think a feedback is needed. And due to space limitations, we haven't discussed what shall we do if there are no appropriate resources in these systems expanded by the '9-windows' tool. Indeed, we can reuse the '9-windows' tool to super system, that is, treat the "super system" as current system to find more resources, etc.

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Paper ID: 62

Using representational system in neuro-linguistic programming with innovation process

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Abstract

Representational system is a postulated model from neuro-linguistic programming regarding how the human mind supposedly processes and stores information. Representational system can help people find internal requirement and communication. The innovation process makes every endeavour to find the best solution. TRIZ-based innovation technology is regarded today as the most comprehensive, systematically organized invention knowledge and creative thinking methodology and needs lots human mind process. In this study, we describe using representational system with TRIZ-based innovation process can increase creativity and communication quality.

Keywords: innovation process, NLP, Representational system.

1. Introduction

Innovation has an association with creative, which frequently implies unpredictable and erratic process. The premise of TRIZ is that the evolution of technological systems is not random, but is governed by certain laws. So, TRIZ exposes many tools to help this innovation process.

In (Silverstein et al.(2012)), A job to be done (JTBD) is a revolutionary concept that guides you toward innovation and helps you move beyond the norm of only improving current solutions. A JTBD is the higher purpose for which customers buy products, services, and solutions. A JTBD can be divided into functional aspects and emotional aspects. So, we can solve a problem through emotional aspects. TRIZ can help find ideal solution in function aspects. But, TRIZ does less job in emotional aspects.

Some tools about innovation are listed here. In (Silverstein et al.(2012)), Nine windows is a technique that helps you examine the innovation opportunity across the dimensions of time(past, current, future) and scale (supersystem, system, subsystem). Job scoping ensures that the innovation opportunity is effectively targeted at an actionable level. Provocation as movement is to create a shocking statement that is strong enough to move people out of their psychological inertia. Rapid Prototyping is to make a fast 3D model of the solution to explore its viability. However, in (Silverstein et al.(2012)) , the above are innovator's toolkit and more of less relation to a TJBD. A TJBD can be divided into functional aspects and emotional aspects. Function aspects can be explored by TRIZ, and emotional aspects can be done through NLP process.

2. TRIZ and NLP

TRIZ and neuro-linguistic programming (NLP) both aim to solve problems. TRIZ helps problems of products, and NLP helps problems of human mental process. TRIZ revealed many tools to focus on studying the patterns of change that created innovative patents. NLP studies and models the cognitive strategies of geniuses and then creates models of how they thought. In (Orloff M.,(2006), NLP supports free associative thinking and visualization and actualization of one's own experience when solving problems.

3. Representation system in NLP

Representation system is 5 input channels. Figure 1 shows the input from representation system can be filtered and become our sensory experience. Representation system is the element knowledge of NLP. Since, we represent information internally by way of pictures, sounds, feeling, smells and tastes. These sensed are our input channels. If we see a picture, its colors can affect our minds and feelings. In (Molden D. (2007)), submodalities are the special sensory qualities perceived by each of the senses. For examples, visual submodalities include colour, shape, movement, brightness, depth; auditory submodalities include volume, pitch, tempo; and kinaesthetic submodalities include pressure, temperature texture, and location. In (Bridoux D. and Mann D. (2002)), submodalities are inner sensor filters. If you see bright cloud, you can feel happy. If you see dark cloud, you might feel blue. This is an example that submodality affects your feeling and perception. In NLP, people take submodalities as operands to reframe their cognition. Table 1 is examples of submodiality distinctions.

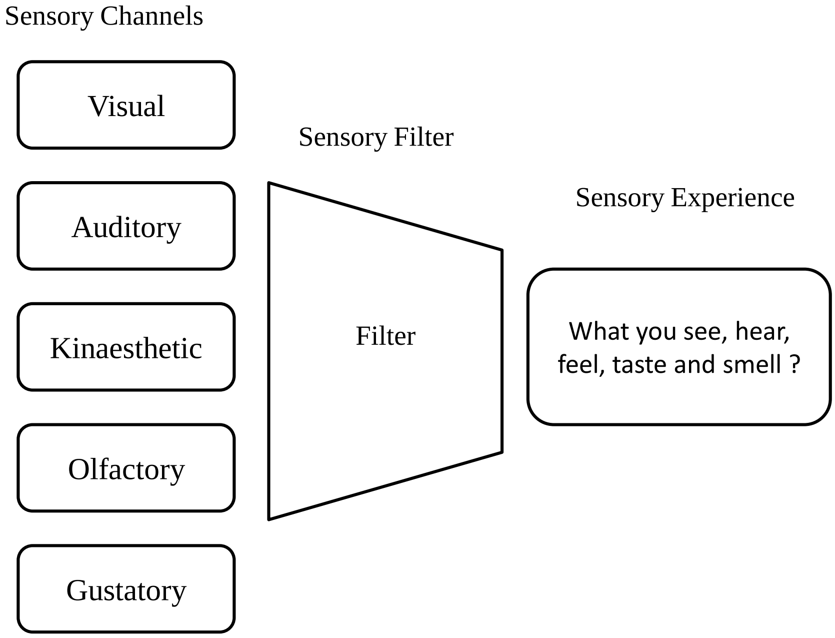

Figure 1 Representation system

Submodialities are similar to physical contradictions. Physical contradictions affect physical laws. However, submodialities affect our feeling and emotion. Both submodiclities and physical contradictions can be adjusted to get ideal solution on purpose.

Table 1 Examples of submodality distinctions

Visual	Auditory	Kinesthetic
brightness	pitch	pressure
size	tempo	location
color/black and white	volume	frequency
shape	rhythm	texture
location	timbre	temperature
distance	digital	intensity
contrast	duration	vibration
focus	clarity	
clarity	location	
frame/frameless	distance	

4. Applying Representation system in communication

Representation system is also communication channels. People use these 5 channels to process information in conscious awareness. As we age, people develop a strength in one channel and use this more often than the others. So, we can use the characteristic to help communicate each other during the innovation process. In a group innovation process, members often misunderstand others' words. People always delete, distort and generalize the information from others. (Molded D. and Hutchinson P. (2008)) suggests that whichever mode is used most often, this will be the mode in which you are able to communicate most effectively. Table 2 shows some examples of communicating with people of different channels mode. To visual communicator, we can emphasize on visual words, such as see, bright, and zoom. To auditory communicator, we can emphasize on auditory words, such as hear, sound, and music. To kinesthetic communicator, we can emphasize on kinesthetic words, such as feel, touch, and get. If we can not tell from which mode communicator is, we can use all the types of words in our conversation. By modifying just a small aspect of communication in this way, people can have a significant influence on people. And this aspect of communication can be used in innovation process.

Table 2 Communicating with people of different channels mode

Visual thinking mode	Auditory thinking mode	Kinesthetic thinking mode
Can you *see* what I mean? It's *bright* and *clear*. Let's *zoom in* on this.	I *hear* what you say? It *sounds* OK to me. It's *music* to my ears.	This just *feels* right. Let's keep in *touch*. I *get the hang* of this now.

4.1. Senario

A good motorcycle engineer can identify problems of engine. If his boss wants to give him some commands. After having issued commands, the boss needs some feedback. If the engineer is of visual thinking mode, the boss might ask him 'Is that clear?' If the engineer is of auditory thinking mode, the boss might ask him 'Do you hear me?' If the engineer is of kinesthetic thinking mode, the boss might ask him 'Do you get me?' Clear, hear and get, there 3 words consist with the engineer's favourite communication channel, and they are easily enter into the engineer's mind.

5. Applying Representation system in prototyping

Prototyping is to make a fast 3D model of the solution to explore its viability. According the revolutionary concept of A job to be done (JTBD) in (Silverstein et al.(2012)). The prototyping should be discussed in functional aspects and emotional aspects. Functional aspects goal can be achieved by TRIZ tools. However, emotional aspects can be calibrated by submodalities of representation system. Because we can alter submadalities in mind from prototyping, and observe how we feel internally. Do we feel better or worse? If we change the color, how we feel. If we add on the frame, how we feel. If we change the shape, how we feel. Representation system shows a way to calibrate people's emotion. In (Molden D., (2007b)), submodailties have a direct link with the intensity of people's experience and submodalities influence people's state.

6. Conclusion

Innovation process is a rich mind and communication work. Representation system can help people find people internal desires and help communicate. In this study, by applying representation system in innovation process can achieve the essential of A job to be done (JTBD) that outcome should satisfy with functional aspects and emotional aspects. Also, we use representation system to help communication. Submodalities in representation system help us calibrate our feeling from prototyping and find if the prototyping can suit for people's particular need.

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Paper ID: 64

Systematic Innovation Capabilities in Shipping: Validation of an established Innovation Process Model

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Abstract

In our paper, we present a theoretical framework aiming at fostering the formalization of shipping management methods used in distinct stages of the innovation process. We examine firm level, organizational and inter-organizational (maritime cluster or ecosystem level) aspects that promote systematic innovation in the shipping industry. We consider a number of management components, so as to examine in both an interpretative and a normative mode how shipping companies approach their systematic innovation related business behavior.

Keywords: shipping, dynamic capabilities, maritime cluster, market innovation, organizational intelligence, leadership, technical innovation, platform ecosystem.

1. Introduction

Based on the combined systematic innovation capabilities and innovation process model developed by Lawson and Samson (2001) and Ota et al (2013), we aim at validating and refining this generic, reference innovation process (IP) framework, while considering pertinent model elements, as relevant for shipping companies, drawing on theoretical arguments, observations and related research hypotheses.

Innovation studies in shipping interpret and systematize a number of main factors that apparently determine the success of shipping product/service innovations, market innovations, and innovations of the "production" processes (Jenssen and Randoy, 2002, 2006; Jenssen, 2003; Thanopoulou et al, 2010; Stig and Theotokas, 2014). These factors constitute our preliminary components to build a theoretically comprehensive, coherent and also empirically tested frame of analysis, at the firm level, as regards innovation in shipping.

Thus, overall we aim at (i) further developing and testing a refined and possibly applicable to a broader set of service industries IP model, which is based on management of both dynamic capabilities (DC) and IPs. The discussed model revisits and combines the model by Tidd et al. 2001, of routines existing in the innovation management process and the model by Davila et al (2006).

Also, (ii) we aim at proving a comprehensive systematic innovation capability model for shipping, in particular.

Against this background, shipping systematic innovation capability can be considered to have distinct, interlinked, also contextualized primary components, namely strategy and leadership, resourcing for innovation, organizational intelligence, organizational structure and systems, culture and behavior, and the management of technology. It is postulated that shipping organizations that explicitly develop and invest in these aspects of innovation capability, individually and in maritime clusters, may achieve sustainable innovation benefits, as the main source of their business and technology management strategies (Lawson and Samson, 2001). Successful shipping firms are observed to lever and organically integrate these elements in an effective manner. The systematic innovation capability of shipping companies constitutes a higher order construct that is manifested as a configuration of business activities leading to continuous, sustainable service, process and market innovation.

Based on the presented theoretical framework, we aim at formalizing the shipping management methods used in distinct stages of the examined IP model, towards further strengthening shipping companies' capability to formulate and implement their strategies for new services and markets, also processes, towards their sustainable operation. We examine firm level, organizational and inter-organizational (maritime cluster or ecosystem level) aspects that promote innovation in the shipping industry. We formulate a set of related hypotheses to be empirically tested via the respective, questionnaire tool for exploratory, qualitative (based on interviews) empirical survey.

In our paper, in section 2 we briefly provide the context and related analysis for innovation in shipping, whereas in section 3 we elaborate and situate the systematic capability approach in the shipping context. Our approach is proposed as exploratory based on literature review and consultation with shipping academic experts and shipping industry experts. We also provide a discussion and future directions for further theoretical development and empirical testing of the presented approach.

2. Innovation in Shipping: the context

In our analysis, we refer to innovation as "the reform of products, production processes, and operations, and organizational methods to bring about economic and quality benefits for companies, their customers and supply chain collaborators".

In the shipping context, innovation primarily accounts to both incremental also radical changes of the shipping service, namely the transportation of goods (or persons, however, passenger shipping is out of the scope of this paper), offered by shipping companies to their customers, which are shippers, freight forwards, and charterers. As an instance of service innovation we understand the provision of an improved service frequency of the vessels serving a trade route, or a combined joint shipping service based on a particular shipping companies' strategic alliance. Innovation in shipping services is typically enabled by interrelated advances (i.e. e-navigation technology, safety and security ship technology) and synergies at the respective maritime cluster level, which can be viewed to signify a shipping innovation ecosystem (Rubalcaba et al., 2012, Gallouj and Djellal, 2010).

A service-orientation, in the sense of a more customer (i.e. shipper) oriented management mindset is gradually observed to gain momentum, also a clear transition towards a strengthened supply chain and integrated multimodal transport oriented perception of the shipping service is witnessed.

Except service innovation, also market innovation is also observed and interpreted as important in the shipping sector, accounting to a shipping company's move to a new market, i.e. an established company in the container or tanker market entering the LNG market.

Process innovation is also important in the shipping sector; accounting to improvements of the shipping or ship operations based on information and communication technology, i.e. e-navigation, e-chartering, e-procurement, e-manning, port community systems for ship formalities clearance, voyage management systems etc. Process innovation also accounts to new financial management instruments for new investment management and governance approaches.

Organizational innovations are also interesting and relevant, accounting to new governance methods, i.e. public (publically traded) vs. family owned shipping companies' related organizational forms (Harlaftis, 1993). Also, network oriented and shipping ecosystem forms for digital shipping operations development and provision. Similarly, shipping ecosystem forms for naval technology-new ship technologies development, in collaboration with the main technology providers of the shipping ecosystem, i.e. shipbuilding, equipment manufacturers, electronics, IT and satellite communications providers.

The shipping industry is by its very nature functioning on an international basis, with shipping companies' fleets serving trade routes on a global scale, whereas office operations are typically being conducted from the main financial and trade centers of the world. Customers can be as widespread, also the main actors serving the overall maritime value chain can be similarly geographically (also from a cultural/nationality point of view) quite dispersed i.e. ship building, ship repair industry, ship supplies providers, charterers, banks, satellite communications providers, shipping software providers etc.

The sector is characterized by (i) a unique business operations specialization (i.e. chartering, technical management, safety and security management, rules and regulation compliance), also (ii) market segmentation (i.e. bulk, container, tanker, liquefied natural gas etc), and (iii) a distinct role played by international governing bodies, such as the International Maritime Organization (IMO) setting rules and regulations for the markets (labor, safety, environment protection, technical standards).

3. A Systematic Innovation Capability Framework

The model of systematic innovation capabilities, developed by Lawson and Samson (2001), and Ota et al (2013), is used as our foundation framework to be refined, and calibrated so as to constitute a reference innovation process model to support shipping managers and also maritime cluster organization managers to practice and evaluate their innovation management initiatives. We consider a number of management components, highlighted in Figure 1, so as to examine in both an interpretative and a normative mode how shipping companies approach their innovation related business behavior also how those elements are interlinked at the firm but also at the maritime innovation ecosystem level. A causality exploration view is in parallel pursued.

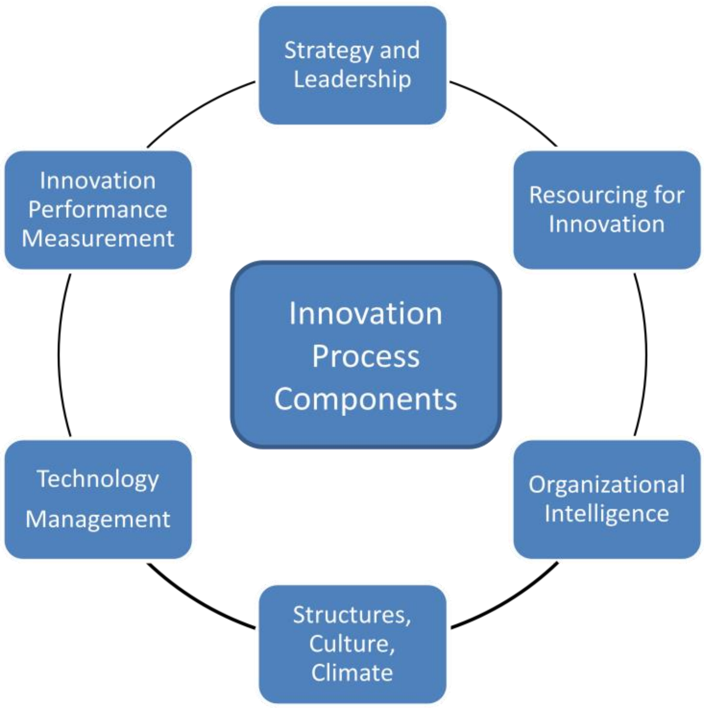

Figure 1. A Systematic Innovation Capability and Innovation Process Model

The innovation management theory includes numerous frameworks, models, also techniques; the presented model precisely constitutes an extended dynamic capabilities approach to generate a holistic model of innovation capability within the firm (Lawson and Samson, 2001, Ota et al, 2013). Furthermore, an "innovation process-IP" view is included, towards "understanding and formalizing the stages of each individual innovation activity as an organic and systematized sequence, within companies".

Tidd et al. (2001) discussed innovation activities from the perspective of process management, and divided the IPs within companies into five stages. Namely, they divided them into (i) the processing of signals, (ii) formulation of strategies, (iii) procurement of resources, (iv) implementation, and (v) learning and re-innovation, and considered them as the behavioral patterns that make the management of innovation successful.

Dynamic capabilities (DC) are a fundamental innovation concept proposed from the resource based view (RBV) analytical perspective in management and strategy theory. Teece et al. (2007), define DCs as the “ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments.” They also argue that the DC of companies is determined by the “three Ps” that include management and organizational processes, positions that are defined by relationships with technologies and customers, etc. and the paths representing the inertia of organizational behavior. DC is divided into the following components: (i) the capacity to sense and shape opportunities and threats; (ii) the capacity to seize opportunities; and (ii) the capacity to maintain competitiveness.

Innovation capability itself is not a separately identifiable construct. The systematic innovation capability is a higher order construct composed of reinforcing practices and processes within the firm and manifested in observable and also not immediately observable configurations of resources and capabilities, and harder to depict causality relationships of these enacted elements. These processes are a fundamental mechanism for stimulating, measuring and reinforcing innovation. The elements making up an innovation capability are grouped into five major elements. These elements have been built up from the literature on the management of innovation, as well as best practice models (Ota et al, 2013).

A reference model of systematic innovation capability serves the need for (re)usable and extensible models in order to facilitate analysis and construction of a multitude of generic or specialized by industry of firm type innovation frameworks. The following elements have been observed and theoretically defined to exist, in varying degrees, within innovative or high performing firms, also have been extensively, empirically tested in a number of sectors and national contexts. They are leadership and strategy, resourcing for innovation, organizational intelligence, organizational structure culture and climate, and the management of technology as well innovation performance measurement:

▪2.1 Leadership and Strategy

Innovation theory emphasizes the link between vision, strategy and innovation as important to effective innovation management. Strategy determines the configuration of resources, products, processes and systems that firms adopt to deal with the uncertainty existing in their environment, also the decisions about markets to enter or continue operating in.

In shipping, we may link superior performance with companies who broke the rules of their industry, with or without (new) technology, mainly through market and service innovation, also with process innovation, and became a dominant player. These companies were able to stimulate demand, expand existing markets and create new ones through accessible and competitive service offerings (Hamel, 1998; Kim and Mauborgne, 1999).

Leadership in shipping has been traditionally, also consistently linked to ship-owners entrepreneurial mentality and personality traits interrelated with national, cultural attributes (i.e. Greek ship-owners risk-taking mentality). Modern era leadership styles are observed as related to both traditional, family owned and public shipping companies' governance forms. Both autocratic and participative, team-based and collaborative leadership styles are observed, and recognized as success factors for high performing shipping companies, in a number of competitive markets, i.e. container shipping, tanker, or liner bulk markets. A firm excellence, or cost leadership orientation rather than innovation orientation of the shipping companies' leaders is also reflected in the leaders' value system.

Successfully formulating and implementing innovation strategy requires the support of key individuals in a shipping company, also at a maritime cluster-innovation ecosystem level, at various stages of the innovation process, to act as technological gatekeepers, business innovators or organizational sponsors (Tidd et al., 1997). Traditionally, the role has been played by ship owners, but also for public companies by members of the board of governance. Innovation champions, at the cluster level, inspiring figures in shipping associations or other important, leveraging individuals are also important in shipping.

Adoption of modern management approaches, namely corporate social responsibility and sustainable (environmentally friendly also) management except traditional ones such as quality management approaches, fosters scientific/professional strategic management in shipping, although not necessarily being consciously/explicitly innovation-oriented.

Hence, our premise (**H.1**) is that innovation in shipping entails a firm, insightful expression of the strategic direction. This may or may not necessarily be explicitly connected to innovation, but instead to excellence or sustainable, competitive operation. Leadership is a central parameter in strategy formulation and implementation, whereas champions of innovation initiatives are commonly active in important and interrelated roles, i.e. officers of technical departments, finance experts etc.

▪2.2 Resourcing for innovation

The ability to effectively orchestrate resources has long been recognized as critical to innovation success (Burgelman and Maidique, 1988). Effective resource management also contributes in increasing the number of new business initiatives.

Successful shipping organizations are observed to consistently be able to lever, combine and recombine *tangible resources* also *knowledge resources* into disparate markets, technologies and services. The ability to compete with new services and markets is "critically dependent on integrating advances in many other fields" (Porter et al., 1999). These advances evolve and are available at both the firm level, also at the maritime cluster/ maritime innovation ecosystem level, where shipping companies operate. As shipping firms successfully manage new ventures, not always recognized as innovation initiatives per se, they accumulate *experience and learning abilities*, supporting still further improvements, which actually enable them to sense and shape opportunities and threats.

In particular, innovative shipping organizations are able to lever, combine and recombine *financial resources* from disparate sources, through their access to global financial market networks. Innovative shipping firms employ a variety of funding channels to support their risk taking appetite and entrepreneurship. Shipping companies employ a number of alternative financial management processes, such as investment bank products or stock markets and specialized mechanisms such shipping derivatives trading or shipping freight contract or shipbuilding contracts trading. Effective financial management, also interpreted as process innovation per se, enables shipping companies to seize opportunities, and maintain competitiveness.

Hence, our premise (**H.2.a**) is that successful shipping companies effectively orchestrate and develop *tangible resources* (i.e. fleet, *financial resources*), also *knowledge resources* within the firm but also through their operation and close ties with their maritime network/cluster/ecosystem collaborators.

E-business has transformed the innovation process. Traditional uses of IT have often been aimed at operation and transaction automation, and optimization, accounting both to service and process innovations in shipping. E-maritime and e-navigation have drastically contributed in process innovation, diffusion of local or regional innovation globally, and create entirely new innovative practices and models (Metz, 1999).

E-business has also transformed knowledge management within shipping organizations and also at the maritime ecosystem level. New shipping services, new markets and process development have become an open, collaborative process taking place at the maritime ecosystem level, linking knowledge competencies worldwide.

Hence, another important premise (**H.2.b**) is that successful shipping companies effectively employ *e-business tools and practices to both optimize their operations* (i.e. e-maritime, e-navigation) but also better coordinate and *enable knowledge management* as a fundamental source of competitive strategic (innovation) advantage, within the firm but also through their operation and close ties with their maritime network/cluster/ecosystem collaborators.

▪2.3 Organizational Intelligence

Organizational intelligence has been defined as "the capability to process, interpret, encode, manipulate and access information in a purposeful, goal-directed manner, so it can increase its adaptive potential in the environment in which it operates" (Glynn, 1996). Since knowledge and ideas are primary inputs into the innovation process, intelligent firms can use this information to reduce the inherent uncertainty and ambiguity of innovative business operation. It allows them to identify new avenues for investigation and to more quickly eliminate unprofitable options. Saleh and Wang (1993) show that high-performing innovators proactively used environment scanning, technological forecasting and competitive analysis toward this goal.

In shipping companies we observe that organizational intelligence is primarily about *learning from customers and collaborators in the supply chain, and also learning about competitors*.

A strong appetite for continuous learning from customers and competitors along with privileged access to professional knowledge sources/actors of the maritime cluster, i.e. financial and market intelligence institutions is considered to enable high performing shipping companies to successfully innovate by timely entering new, lucrative markets. Furthermore, organization intelligence capabilities also allow thriving shipping companies to timely apply competitive technology management, as regards marine, green shipping, and digital shipping technology.

Burgelman and Maidique (1988) highlight the critical importance of understanding both competitors and markets to innovation management. This is attributed to a superior capability to generate, communicate and act on the most relevant, up-to-date information available about their environment. Shipping companies typically focus on their most demanding customers, in competitive also closed markets, and attempt to innovate to solve their problems thereby creating a service which is likely to create value for all transacting parties.

The process of generating, learning and applying knowledge about competitors' services, processes and strategies is also critical. Shipping competitor learning plays two significant roles: position diagnostic benchmarking and position advantage building (Day and Wensle, 1988; Dickson, 1992). A firm with superior competitor information can use this knowledge to apply its strengths against a rival's weakness, internalize competitors' strengths by imitation and improvement or discount the strength.

Hence, the respective premise (**H.3**) is that successful shipping companies consciously and effectively learn through a range of organizational intelligence mechanisms about their *customers and collaborators in the supply chain, and their competitors.*

▪2.4 Structures, Culture and Climate

Successful innovation requires an optimal overall formal organizational structure (Burgelman and Maidique, 1988). In shipping companies, *mixed mechanistic and organic organizational structures* are positively correlated with high performance.

As businesses grow there is a tendency to add layers, becoming more mechanistic and institutionalizing bureaucracy (Kanter, 1983). High performing shipping firms motivate and enable innovative behavior by creating permeable business boundaries, within limits. Shipping companies typically, actively support cross-departmental job rotation and practically implement rotation of jobs onboard and ashore enabling ideas generation and cross-fertilization.

Highly successful shipping firms implement reward systems fostering creative behavior, in terms of public recognition and financial bonuses for accountable, efficient but also proactive or innovation –oriented, entrepreneurial behavior in certain roles and positions, on board and ashore. Reward systems explicitly designed to empower employees at the individual or group level for incremental or radical innovation are rare in shipping companies' practices.

The appropriate *culture and climate* within the organization is also vitally important to innovation success. The components commonly identified as underlying the innovation boosting culture and climate are tolerance of ambiguity and failure, risk-taking mentality, empowered employees, favorable conditions for creativity and idea management, and communication.

In shipping companies, a strong organizational culture of "seamanship" and accountability prevails along with a mentality that values and emphasizes safety and security. A considerable differentiation of perceptions and values exists between individuals and roles ashore (managers, employees at shipping companies' offices-white collar positions) and seafarer positions and overall work environments onboard.

Thus, shipping companies may only partially cultivate a culture that praises tolerance for ambiguity, failure and encourage risk–taking. Shipping companies may have incorporated a systematic process for reviewing failed projects, (rarely perceived) as a valuable opportunity to learn and improve (Grady et al., 1993), but this is done only via quality management and standardization efforts, rather than an explicit innovation-orientated culture.

An open, innovative culture is primarily materialized by empowered employees; shipping companies are also observed to employ and support the professional development and well being of satisfied and empowered employees and managers, also seafarers, as a matter of their sustainable operation. This is not necessarily explicitly linked to a conscious innovation-oriented strategy but often to a competitive human resource management strategy. Liberalization of the labor market, as regards ship crews has an adverse impact for positions onboard. Main managerial positions, even though not directly associated with innovation management responsibilities, are commonly compliant with the above rules of state-of the art management philosophy.

Creativity may be viewed as the process of generating ideas that are formally cultivated though the innovation funnel, within a company. Shipping companies typically expect or "allow" creativity, in terms of divergent thinking, by senior management. New ideas, at the board level or through management roles in office hierarchy can be either (technology, market) knowledge-driven (how do we apply new knowledge?) or (maritime) vision-driven (this is our goal, what new knowledge do we need?).

Fostering communication within the company and its network of firms is necessary to achieve innovation. Communication facilitates knowledge sharing by combining the wide variety of experiences, building on others ideas and exploring issues relevant to innovation. Innovative firms reward cross-functional, cross-hierarchical, cross-cultural and cross-technological exchange of information and knowledge.

Shipping companies may foster to some extent various forms (formal, non-formal) communication as a conscious approach to foster innovation.

Hence, the respective premise (**H.4**) is that successful shipping companies do not cultivate deliberately an innovation–favoring culture and climate; rather a predominant, strong seafaring culture onboard and the white collar maritime culture may foster innovative behavior.

▪2.5 Management of technology

The management of technology is crucial to today's organizations. The shift towards ecosystem or platform based technical innovation management enables us to revisit the influence of external networks and its relationships with the corporate knowledge base and issues like intellectual property and technology oriented alliances and agreements. An emphasis is put on the management of technology within the company and innovation ecosystem, rather than research and development per se (Gawer and Cusumano, 2014; Fusfeld, 1995). A number of theories and tools have been developed that allow firms to assess their technological capabilities, needs and possibilities against overall business objectives (Bessant, 1994; Coombs, 1994). Innovative firms are able to link their core technology strategies, with innovation strategy and business strategy. This alignment generates a powerful mechanism for competitive advantage. Effective forecasting helps organizations to identify future developments in technologies, products and markets, generate more refined information, reorient the company to avoid threats or grasp new opportunities and to improve operational decision making (Burgelman and Maidique, 1988).

Naval engineering, green shipping, and digital shipping technology are *core technologies* for shipping, the development and adoption of which has constituted a critical factor for effective technical innovation management in shipping, both radical also incremental in contemporary shipping.

Shipping companies are observed (**H.5**) to follow to some extent formal methodologies that allow them to conduct scientific/professional technology forecasting and explicitly align core technology strategies, with innovation strategy and business strategy. Shipping companies are participating in technical innovation (platform) ecosystems.

▪2.6 Innovation Performance Measurement

Innovation measurement can be either implemented in terms of input measures of innovation (i.e. ratio of naval engineers/or environmentalists or electronics engineers employed in the shipping company), or innovation process intensity measurements or by innovation outputs in terms of direct outputs, such as new services developed, or profits from new offerings or the costs reduced by process innovations (Adams et al, 2006).

We consider as closely related the shipping performance measurement research tradition; it is based on a Key Performance Indicators (KPIs) oriented view, which can practically and effectively offer support in articulating innovation measurement aspects, addressing the operational, technical also financial, environmental, safety/security and employee/crew performance parameters. A detailed mapping of compound shipping management KPIs onto innovation related parameters can improve our understanding in shipping innovation performance.

Also with a strong e-analytics business process management approach gaining momentum in the shipping sector, we may also observe a data driven innovation performance measurement approach, in the near future (Kohler et al., 2013). However, currently

Shipping companies are observed (**H.6**) to moderately follow formal methodologies for business performance management, which are weakly, linked to innovation performance measurement.

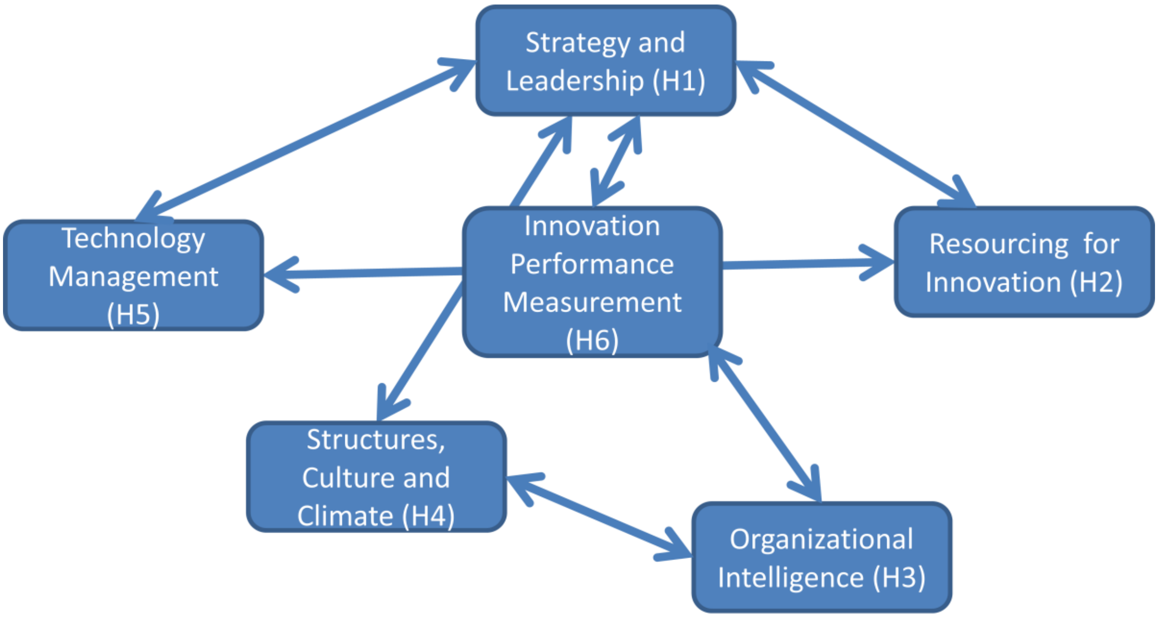

Figure 2. Hypothesis Formulation: towards a shipping systematic capability model development and testing

4. Discussion and Future Research

In our paper, we present results of a first approximation to construct and validate a systematic innovation capability model serving a structured innovation process in shipping companies.

We are firmly based on, explain and calibrate an established, combined systematic innovation capabilities and innovation process model, developed by Lawson and Samson (2001) and Ota et al (2013), whereas we also refer to important and relevant works on innovation in shipping. With our situated model, we aim at highlighting interesting variations of the role, relative importance and causal relationships between six main components of the systematic capability compound construct, namely leadership and strategy, resourcing for innovation, organizational intelligence, organizational structure, culture and climate, management of technology, and innovation performance measurement. We formulate a set of basic hypotheses, as also informed by consultation with shipping academic, as well market experts. We have devised and pilot tested a questionnaire, serving as a tool for qualitative case studies and possible quantitative empirical surveys in the shipping sector. The extensive and conclusive theoretical refinement and empirical testing of our framework is the immediate next step of our research.

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Mindful Insight for Systematic Innovation via Meditative Practices

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Abstract

Novelty is crucial in the innovative process. However, there are often roadblocks, or psychological inertia, hindering our minds from getting to that "Aha" moment of insight. TRIZ and other systematic innovation methodology have been created to break free from psychological inertia and facilitate the thought process of creative problem solving or creating innovative and novel ideas. In the past couple of decades, neuroscience has gained understanding of how the brain achieves insight. Neuroscience calls "the roadblock to the desired mental path" (Rock, 2009), impasse. When stuck at impasse, stopping oneself from thinking can inhibit distractions in the mind. Once the brain quiets down, internal cognitive awareness is activated and thus, there is more possibility of insight to occur. Furthermore, prior to the moment of insight, the brain unconsciously suppresses other brain activity to detect weak connections. Awareness of these new connections can spur innovative insights. Techniques and practices, similar to meditative practice, have been developed to increase insight. These techniques and practices train the mind to think openly and focused at the same time, which is in contraction of each other. The mind is also trained to be more alert to and more aware of capturing insights, as in mindfulness meditative practices, being more aware of the present moment and obtaining a quiet mind. Utilizing such practices into systematic innovation processes could train the mind to obtain mindful insight and prepare the mind prior to that "Eureka" or "Aha" moment!

Keywords: impasse, insight, meditative practice, mindfulness

1. Introduction

Advanced technology has pushed the world to enter the "Innovate, or Die" era, where innovation is highly appraised. Although innovation brings novelty and insight to the world, it is actually a gruesome process, in which there are many barriers, exterior (e.g., your boss, or your company) and interior (i.e., your mind, including your mental capacity, your attention span, mental distractions, personal views). Real innovation does not happen spontaneously; it is actually produced systematically. However, this process of insight is not obtained easily, nor is the whole process of gaining insight fully understood. In reality, there are often roadblocks, or psychological inertia, hindering our minds from getting to that "Aha" moment of insight. TRIZ and other systematic innovation methodology have been created to break free from psychological inertia and facilitate the thought process of creative problem solving or creating innovative and novel ideas. In the past couple of decades, neuroscience has shed some light on how the brain works and how it achieves insight.

2. How the brain works and why it is so hard to be productive

In this era of high productivity, not only are we expected to process more information, but also process it in a less amount of time. Fast-paced companies need good observation and decision-making capabilities, even sensemaking capabilities are to be trained as skills, rather than just being part of a company's process or structure (Breuer and Gebauer, 2011). However, the mind has limited capacity and resources. Rock describes conscious thinking as a "precious resource to conserve" (2009, p.18). Therefore, when the mind is overwhelmed by using up a lot of mental capacity, its ability to process accurately will decline, more when you are multi-tasking, in which most of us do during the innovative thinking process.

As the ability to process more weakens, it will heavily influence the mind when it comes to producing novelty ideas, which is crucial to the innovation thinking process. Rock (2009) discusses the impact of doing too much and overloading the mind. If the mind is to be more productive, there are three solutions for this dilemma: 1) embed repetitive or routine tasks, 2) assigning mental tasks in best possible order, also called queuing, and 3) split your attention, by doing certain tasks at a certain time. Since the mind has limited capacity to work, Rock advices prioritize mental task to avoid doing high-energy-consuming tasks simultaneously, writing out all ideas instead of holding them in (it will wear down the brain faster), and to only focus on one conscious task at a time to save mental energy.

▪2.1 Distractions and Impasse

Even if the brain focuses on one thing at a time, it gets distracted easily because it has to deal with both external and internal distractions constantly. They keep the brain from staying focused on the mental task at hand, because the brain is wired to be attentive and notice novel things that get our attention. External distractions are any distractions from the outside world, from an instant message to people walking by, and internal distractions are any that from the mind, like reminiscing a past memory, or mind wandering. Distractions have a negative influence on the brain, because they deplete the performance of the brain's prefrontal cortex, the area that turns on when the brain tries to inhibit a distraction. Inhibition of distractions is an essential skill for focusing. However, the process of inhibition is high-energy consuming and often requires catching the impulse when it occurs, in between 0.3 seconds after the brain signal emerges. The window of opportunity for inhibition is 0.2 seconds before the momentum happens. The practice of inhibition stops unwanted patterns from developing early on, before they take over and distract the mind, by disconnecting a soon-to-become neural link. Once a neural connection is made, the neurons fire off whenever, the same connection is made. By practice of inhibition, unwanted neural connections won't fire off. Nevertheless, each time you inhibit something, your ability to inhibit again decreases (Rock, 2009).

Another issue the brain faces is when it gets stuck solving a certain problem or hits a roadblock trying to come up with a solution, which is called impasse in neuroscience. Impasse is anything that is keeping your mind off the "desired mental path", or your brain trying to make a neural connection but can't make any links (Rock, 2009). Schooler et al. (1993) and Knoblich et al. (1999) defines impasse as "the state when the subject does not know what to do next." This experience is similar to when a writer suffers from writer's block, trying to get something out of the mind, but can't. During an innovative thinking process, experiencing impasse will inhibit productive output. Therefore, true innovation requires averting past this impasse experience. Knoblich et al. (1999) investigated how past experience is misleading, what is known as the impasse experience. Rock (2009) describes Stellan Ohlsson's work on the impasse experience, explaining that when people face new problems, they apply strategies that worked in the past. If the situation is similar to prior experience, the strategy will work, but if it is under a new circumstance, then the knowledge from the prior experience will actually impede a better solution from appearing. This incorrect strategy, meaning the strategy from successful prior experience doesn't work under this new situation, will be the cause of impasse. This phenomenon is similar to, in TRIZ methodology, what is known as psychological inertia (PI). Kowalick's (1998) understanding of PI is of the following:

"The psychological meaning of the word "inertia" implies an indisposition to change - a certain "stuckness" due to human programming. It represents the inevitability of behaving in a certain way - the way that has been indelibly inscribed somewhere in the brain. It also represents the impossibility - as long as a person is guided by his habits - of ever behaving in a better way."

"Psychological Inertia (PI) represents the many barriers to personal creativity and problem-solving ability, barriers that have as their roots "the way that I am used to doing it." In solving a problem, it is the inner, automatic voice of PI whispering "You are not allowed to do that!" Or, "Tradition demands that it be done this way!" Or even, "You have been given the information, and the information is true.""

This state of when the mindset is stuck in a certain state and one's ability to "think outside of the box," or think innovatively, is hindered is what is describe as an impasse experience. Knoblich et al. (1999) notes of Ohlsson's past work on how one's prior experience influences the brain's ability to produce a working solution and becomes the root of impasse. However, when the representation of the problem is altered, the state of impasse can be broken. Impasse can be broken because when the problem is represented differently, it activates a different area of long-term memory of the brain, even triggering an area dormant but obtaining relevant knowledge of the new situation. By generating new neural connections, or forming stronger weak links, the mind can reroute its current neural path. Systematic innovation techniques are aimed to break free of this state of impasse, or having an impasse experience. Therefore, to "think outside of the box" is simply "changing the representation of the problem", which much of TRIZ methodology is based on.

▪2.2 Zone of Peak Performance and Flow experience

There are several methods that neuroscientists use to measure levels of arousal, or brain activity happening in the brain; however, the most common two ways are: electroencephalogram (EEG), which measures levels of electrical activity in the brain, and functional magnetic resonance imagery (fMRI), which measures blood oxygenation changes of activated regions (Fink et al, 2009; Kounios and

Beeman, 2009; Rock, 2009; Jung-Beeman, Collier, and Kounios, 2008; Kounios et al., 2006). By measuring the brain's activity, neuroscientist can study brain activity in different regions, when one region becomes busier than others and how the brain shifts brain activity.

For the brain to work at its best, there must be a certain level of arousal (a physiological and psychological state of being awake or reactive to stimuli, Wikipedia), not too much or too less. Too much and the prefrontal cortex overloads and is stressed out; too less and the brain doesn't focus. When there is too much activity seen in the prefrontal cortex, it causes over-arousal. There are two strategies to decrease levels of arousal, (1) reduce the amount and pace of the information received, or (2) activate other regions of the brain to deactivate the prefrontal cortex. When there is too less brain activity, or under-arousal, there are two ways to increase arousal: (1) the quickest way is to by increasing adrenaline levels to stimulate alertness and attention, or (2) visualization of fear is another way to stimulate the same response (Rock, 2009).

Psychologists Robert Yerkes and John Dodson studied the relationship between arousal and performance in 1908 (Wikipedia). The Yerkes-Dodson law is based on when physiological or mental arousal increases, performance increases as well, but after a certain point of performance, the level of arousal becomes too high, causing performance to decrease. The flow of arousal and performance is presented as an inverted U-shaped curve. Rock (2009) calls the peak of the inverted U, the zone of peak performance. Figure 1 shows Rock's version of the inverted U.

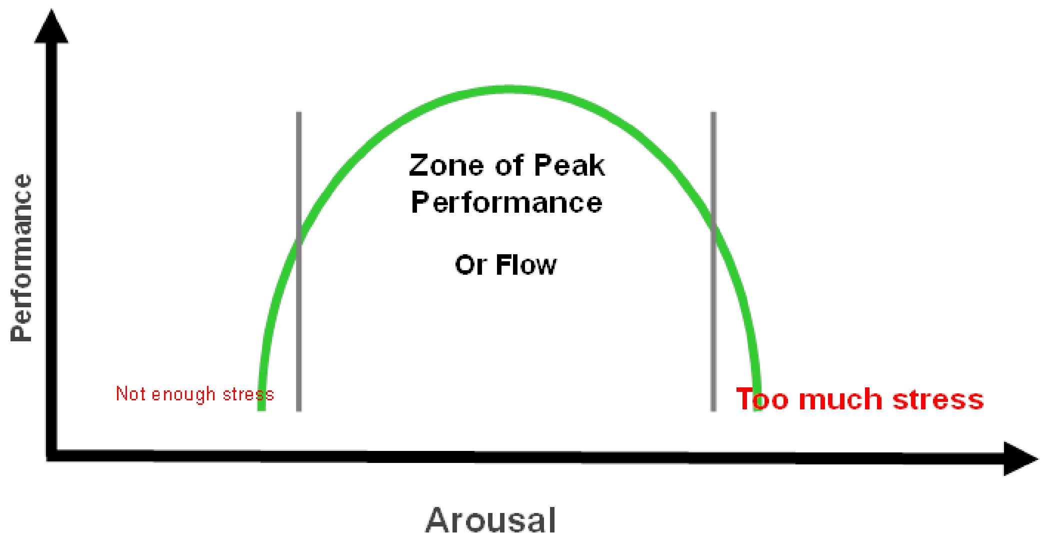

Figure 1. The Inverted U (Zone of Peak Performance).

The zone of peak performance needs the right amount of arousal, just like in Csikszentmihalyi's flow theory, where if the task is too challenging or lacks challenge and creates boredom, the person cannot have optimal experience and there is no "flow" happening. Csikszentmihalyi's work of flow was based on investigating intrinsic motivation of people of different interest and studied their positive psychology. The theory for flow was based on the results of these studies. Nakamura and Csikszentmihalyi (2011) state that for flow to happen, its proximal conditions are: (1) the perceived challenge must exceed their existing skills, but must be equipped with enough skills to complete the task at hand, and (2) there must be clear proximal goals and instant feedback of progress. They also noted the characteristics of optimal experience being:

(1) intense and focused concentration on what one is doing in the present moment,
(2) merging of action and awareness,
(3) loss of reflective self-consciousness (i.e., loss of awareness of oneself as a social factor)
(4) a sense that one can control one's actions; that is, a sense that one can in principle deal with the situation because one knows how to respond to what happens next,
(5) distortion of temporal experience (typically, a sense that time has passed faster than normal)
(6) experience of the activity as intrinsically rewarding, such that often the end goal is just an excuse for the process

(Nakamura and Csikszentmihalyi, 2011, p.90)

Therefore, being "in flow" is when the brain is functioning at its best with the right amount of arousal. However, Nakamura and Csikszentmihalyi (2011) and Rock (2009) explain that each person's flow, or zone of peak performance, is individual. Hence, although everyone will experience the same characteristics "in flow", each individual will have a different level of arousal, or have different levels of peak performances, or even perform different under different tasks. Consequently, getting the brain at just right amount of arousal is quite a complicated task, even more so when there is more stress trying to produce a novel solution from a newly encountered problem.

3. The neuroscience of insight

For creative problem-solving, it is crucial to generate innovative solutions, or produce a novel idea. Ideas come from insight. An insight is the act of recombining knowledge in a whole new way (Rock, 2009). However, how does the mind construct insight? What is the process of insight? In the past few years, neuroscience has shed some light on how the brain achieves insight by analyzing brain activity in different regions as participants perform mental tasks (Kounios and Beeman, 2009; Jung-Beeman, Collier, and Kounios, 2008; Kounios et al., 2006). Rock (2009) stated that Beeman's work originated in examining how people solve cognitive problems; in consequence, led to interest of the insight experience. Later, in 2004, Beeman and his colleagues' goal was to understand the whole insight experience, by examining what happens before, during and after the insight experience (Kounios and Beeman, 2009; Jung-Beeman, Collier, and Kounios, 2008; Kounios et al., 2006). Kounios and Beeman (2009), Jung-Beeman, Collier, and Kounios (2008), Kounios et al. (2006) studied the neuroscience of insight and the following is their work and results.

▪3.1 The "Aha" moment

The "Aha" moment is defined as the insight gained by "a sudden solution to a long-vexing problem, sudden recognition of a new idea, or sudden understanding of a complicated situation" (Jung-

Beeman, Collier, and Kounios, 2008, p.1). They are the result of reconstructing or reorganizing the components of a situation or problem (Kounios and Beeman, 2009). Kounios and Beeman (2009, p. 210) lists why insight is important:

(1) It is a form of cognition that occurs in a number of domains.
(2) It occurs when a solution is computed unconsciously and later emerges into awareness suddenly, which is in contrast with the deliberate, conscious search strategies that have been the focus of most research on problem solving.
(3) It involves a conceptual reorganization that results in a new, nonobvious interpretation, often identified as creativity.
(4) It can result in important innovations.

Kounios and Beeman (2009), Jung-Beeman, Collier, and Kounios (2008), Kounios et al. (2006) had participants solve *compound remote-associate problems*, which were word puzzles, containing three words (the example given was *pine, crab,* and *sauce*), and the goal was to come up with a solution word (for this set of words, it would be *apple*) that could be combined with each word to produce a common phrase or word (here, the common words or phrases would be *pineapple, a crab apple, and applesauce*). Rock (2009) mentions their research showed these participants will try to logically solve the problem, using one idea after another until one fits, 40% of the time; however, 60% of the time, an insight experience occurs. Although Kounios and Beeman (2009) and Jung-Beeman, Collier, and Kounios (2008) notes that attempting to observe the brain for sudden insights actually presented several challenges, such as imaging of the brain and other brain regions activating memory as well, their research discovered a fascinating phenomenon.

▪3.2 The incubation period and the calm before the "Aha" moment

Rock (2009) explains, from Beeman's research, that just before the insight occurs, some regions in the brain shuts down, like "a car going into idle," allowing weak activation to appear, "hinting at the solution somewhere in the brain (p.80)." Kounios et al. (2006) states in their results:

"The fMRI signal changed in several brain areas during the preparation interval. Most areas showed decreasing signal during preparation as neural activity returned to baseline. A few areas showed increased signal, indicating increasing neural activity during "rest." This increase was strongest in anterior-cingulate cortex (ACC). Small regions within posterior-cingulate cortex (PCC) and bilateral posterior middle/superior-temporal gyri (M/STG) also showed slightly increasing or sustained activity during preparation." (p.886)

"Thus, in the context of problem solving, the activity observed in ACC prior to insight may reflect increased readiness to monitor for competing responses, and to apply cognitive control mechanisms as needed to (A) suppress extraneous thoughts; (B) initially select prepotent solution spaces or strategies and, if these prove ineffective, (C) subsequently shift attention to a nonprepotent solution or strategy. Such shifts are characteristic of insight." (p.887)

These two statements of results show that before an insight experience occurs, brain activity quiets down in some regions, letting insight to pop up, or allowing weak, but relevant, neural links to surface, by "suppressing extraneous thoughts" and letting the mind process unconsciously. This is why sometimes insight happens in odd places, like taking a shower. Figure 2 (retrieved from http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0020097) represents the insight experience. It shows how the moment of insight appears, when alpha brain waves (subconscious) calm down, and gamma brain waves (insight) suddenly spikes up. That moment of exchange brain waves is the spark of insight, or the “Aha!” moment.

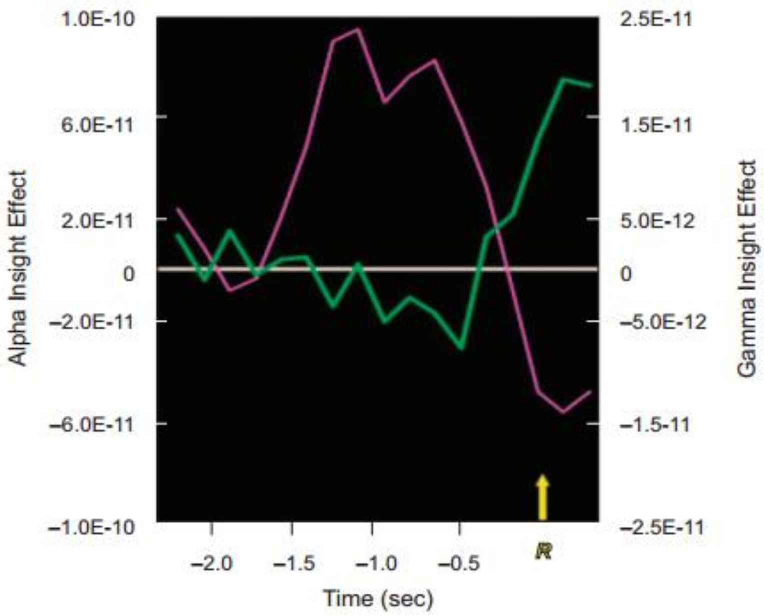

Figure 2. The Insight Experience.

(Source: Jung-Beeman M, Bowden EM, Haberman J, Frymiare JL, et al. (2004) Neural Activity When People Solve Verbal Problems with Insight. PLoS Biol 2(4): e97. doi:10.1371/journal.pbio.0020097, Retrieved from http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0020097)

In addition, Fink et al. (2009) analyzed the participants as they worked on four verbal tasks which needed to generate creative ideas. The study investigated the brain activity of the participants during creative thinking through EEG and fMRI. The results were (p. 734):

“The EEG study revealed that the generation of original ideas was associated with alpha synchronization in frontal brain regions and with a diffuse and widespread pattern of alpha synchronization over parietal cortical regions. The fMRI study revealed that task performance was associated with strong activation in frontal regions of the left hemisphere. In addition, we found task-specific effects in parietotemporal brain. The findings suggest that EEG alpha had synchronization during creative thinking can be interpreted as a sign of active cognitive processes rather than cortical idling.”

4. Mindfulness Insight for Systematic Innovation

Innovation is often seen as a breakthrough. True innovation doesn’t happen spontaneously; it is often accomplished with repeated methodology and systematically (website). Nonetheless, insight is perceived as essential to creativity and associated to generating creative ideas (Jung-Beeman, Collier, and Kounios, 2008). In previous sections of understanding how the mind works, it is best for the mind to be focused on one mental task and away from distractions for the brain to work effectively. Therefore, training the mind to be focused and attentive is crucial to producing insight. Furthermore, exercising the mind to calm down and letting insight to appear prepares the brain for “Aha!” moments.

The basis of meditative practices, such as mindfulness training, is to become focused and alert, attentive and aware of presence, similar to the settings prior to the "Aha!" moment.

▪4.1 Mindfulness Research

Mindfulness found its roots in the pursuit of determining the causes of suffering and ways to relieve from it throughout human history (Siegel, Germer, and Olendzki, 2008). Mindfulness comes from the Pali word, *sati*, meaning *awareness*, *attention*, and *remembering* (Siegel, Germer, and Olendzki, 2008). In western culture, mindfulness research is often used as a practice in psychotherapies for stress management (Grossman, 2010; Kristeller, 2006), general therapeutic mindfulness practice (Siegel, Germer, and Olendzki, 2008) and healthcare settings, including mental health (Hirst, 2003). Richards (2010) investigated the relationship between self-care, mindfulness and well-being in mental health professionals, and results indicated that mindfulness (not self-awareness) is a significant mediator of self-care importance and well-being, but not of self-care frequency and well-being. Mindfulness has also been used in education, teaching students to become focused, attentive, aware, and alert (Moore, 1992). Recently, mindfulness is being trained in organizations, too. Breuer and Gebauer (2011) used two strategic approaches to create a mindfulness environment in facing situations of uncertainty: Future Research (FR) as a methodology to visualize the future for future developments and High Reliability Organizing (HRO) as an approach to promote collective mindfulness and inhibit undesirable events. Their results showed that: "(1) inquiry on positive and negative deviance from expectations strengthens mindfulness for innovation and inspires change, (2) new collective practices and structures combine both approaches to foster innovation, and (3) cultivating operational reliability and excellence in innovation within one move may lead to a new sensitivity to innovation (p.17)." Ramiller and Swanson (2009) write of mindfulness routines for IT innovation, by combining mindfulness, a state of alertness, freshness, and flexibility of the mind, with routine, a state of schemas, consistency and reproducibility in thinking. Vago and Silbersweig (2012) views mindfulness as a "state, trait, process, type of meditation and intervention that has proven to be beneficial across a diverse group of psychological disorders as well as for general stress reduction" (p.1).

Recently, mindfulness research is in search of understanding if it promotes insight. Ren et al. (2011) investigated whether meditation can promote insightful problem-solving by maintaining the mind in a mindful and alert conscious state. Their evidence showed that participants that practiced meditation practices solved more previously unsolved problems, indicating direct evidence of meditation promoting insight. Their findings suggested that the increased insight ability was obtained by maintaining a more alert and mindful state of consciousness through meditation. However, when the participants were more relaxed during meditation or control cognitive task interval, they achieved less insight later. From previous section on how the brain works, this seems to be due the arousal level being low; hence, performance was low. Therefore, in the study of Ren et al. (2011), meditation heightened insight by sustaining the mind in an alert and mindful state, as to a passive type of relaxation (e.g. sleep) which doesn't need any mental effort.

▪4.2 Mindfulness Meditation

There are different forms of meditation: (1) concentrative meditation, (2) mindfulness meditation, also known as insight meditation (Kristeller, 2007), and (3) lovingkindness meditation (Siegel, Germer, and Olendzki, 2008). Concentrative meditation (the Pali translation is *samantha bhavana*) uses a focal object to train the mind on one focused object, like breathing or a mantra (Siegel, Germer, and Olendzki, 2008). Mindfulness meditation cultivates "moment-to-moment, nonjudgmental awareness of one's present experience (Kristeller, 2007, p. 395)", which is important because it is in contrast to an "undisciplined mind", which is filled with "habituation, mindlessness, laxity, and scattered attention" (Weick and Putman, 2006, p. 277). Grossman (2010) defines mindfulness as "awareness and attentiveness to immediate experience" (p.88). Whereas lovingkindness meditation (the Pali word *metta*) enhances the emotional quality associated with mindfulness and can be in a form of concentration meditation (Siegel, Germer, and Olendzki, 2008). Raffone, Tagini, and Srinivasan (2010) classified meditation into two main styles: (1) Focused Attention (FA) Meditation, similar to concentration meditation with the regulative skills of monitoring the focus of attention, detecting distraction, disengaging attention from the source of distraction, and redirecting or refocusing on the object and includes Transcendental Meditation (TM), which centers on the repetition of mantras, and (2) Open Monitoring (OM) Meditation, similar to insight meditation with nonjudgmental awareness of sensory, cognitive, and affective fields of experiencing the present moment, and involving high-order meta-awareness skills of understanding ongoing mental process.

There are three formats of mindfulness meditation: (1) everyday mindfulness, (2) formal meditation practice, and (3) retreat practice (Siegel, Germer, and Olendzki, 2008). Every day insight meditation focuses on developing careful and nonjudgmental attention, by starting from "observing the natural sequence of changing experience, such as breathing, body sensation, through the five senses, thoughts and feelings, etc. (Kornfield, 1979, p. 42)". The components of mindfulness meditation are: (1) attention regulation, (2) body awareness, (3) emotion regulation, including a) reappraisal and b) exposure, extinction, and reconsolidation, and (4) change in perspective on the self (Holzel et al, 2011).

Sternberg (2000) argues mindfulness can be a cognitive ability, a personal trait, and cognitive style. The most reminiscent ability are attention and concentration abilities; other abilities include openness to novelty, alertness to distinction, sensitivity to different contexts, awareness of multiple perspectives, and orientation in the present (Sternberg, 2000). Langer and Moldoveanu (2000) discuss how mindlessness, the direct opposite of mindfulness, is a social issue and is the direct cause of human error in complex situations, of prejudice and stereotyping, even boredom and malaise is conveyed by mindlessness. Mindfulness and mindlessness distinction fits into Carroll's cognitive styles (Sternberg, 2000, p.22):

(1) Field independence (perceives things independently of their backgrounds) versus field dependence (perceives things dependently upon their backgrounds);
(2) Scan stimuli extensively versus scan stimuli intensively;
(3) Broad inclusiveness in categorizing versus narrow exclusiveness in categorizing;

(4) Cognitive complexity (structures the world in a complex way) versus simplicity (structures the world in a simple way);
(5) Reflexivity (one thinks carefully before one acts) versus impulsivity (one who acts impulsively);
(6) Leveling (tends to blur similar memories) versus sharpening (remember things as very distinct and as less similar than they actually are);
(7) Constricted versus flexible control;
(8) Tolerance for incongruous or unrealistic experiences

▪4.3 The ARIA model for Mindful Insight

Rock (2009) spent over ten years in developing techniques and practices to increase insight based on neuroscience research. The result was a framework modeling the stages of insight, the ARIA (Awareness, Reflection, Insight, and Action) model, which also includes practical techniques to enhance insight. The *Awareness* stage focuses lightly on an impasse, being aware of the problem. However, by minimizing the activity in the prefrontal cortex through quieting the mind of distractions or other thoughts and not focusing too hard, the mind can simplify the problem as much as possible. This stage is similar to the stage of turning your specific problem into a general problem in TRIZ problem-solving methodology. The *Reflection* stage reflects on the thinking process, and not the content of the thoughts, as you hold the impasse in mind. When impasse is seen at a high level, not too detailed, and it activates right hemisphere brain regions which are important for insight, and when the mind is in a dreamy state, it allows loose connections to form as ideas flow in. An insight will appear once the mind realizes none of the previous strategies are working. The *Insight* stage happens when the burst of gamma brain waves flow in, right after the alpha waves calm down as the brain goes quiet. The *Action* stage is harnessing the energy once an insight emerges.

5. Conclusion

Although innovation brings novelty and insight to the world, it is actually a gruesome process, in which there are many barriers, exterior (your boss, or your company) and interior (your mind). Real innovation does not happen spontaneously; it is produced systematically. However, the process of insight is not obtained easily. If you want to learn how to “think outside the box”, first, don’t overload your brain. Second, learn to be focused and attentive with the task at hand. This way your brain can work effectively. Rock (2009) mentions the brain process for insights: “activating a quieter stage and generating greater cognitive awareness and control (p.84).” Mindfulness trains the mind for awareness of being aware, which consists of the presence of attention and concentration in the current moment (Hirst, 2003). The mind needs to be trained to acquire attention and focus, because attention and concentration is like a muscle that can be obtained through repetitious workout (Goleman, 2013). With concentration practices, mental hindrances and interferences can be ignored, which leads to a calmer, focused mind, and with concentration and mindfulness, the mind can control attention (Weick and

Putman, 2006). In addition, meditation can promote insightful problem-solving by maintaining the mind in a mindful and alert conscious state (Ren et al, 2011).

Furthermore, the brain calms right before an insight occurs, switching from alpha brain waves to gamma waves, and that crossover is the spark of insight, the “Aha!” moment (Kounios and Beeman, 2009; Jung-Beeman, Collier, and Kounios, 2008; Kounios et al., 2006). Mindfulness meditation can train the mind to let go of distractions (shutting down certain brain regions) and seek for new connection (connecting a weak, but relevant link) (Rock, 2009), because when we are actively engaged in the present, the mind can notice new things and is sensitive to context (Hirst, 2003). Mindfulness is a systematic mental training practice that “develops meta-awareness (self-awareness), an ability to effectively modulate one’s behavior (self-regulation), and a positive relationship between self and other that transcends self-focused needs and increases prosocial characteristics (self-transcendence) (Vago and Silbersweig, 2012, p.1-30).” Langer and Moldoveana (2000) call mindfulness as “a process of drawing novel distinctions” (p.1), leading to: “(1) a greater sensitivity to one’s environment, (2) more openness to new information, (3) the creation of new categories for structuring perception, and (4) enhanced awareness of multiple perceptives in problem solving” (p.2). All of these characteristics are needed in systematic innovations thinking.

However, there are some common misunderstandings about mindfulness: (1) Mindfulness is not having a blank mind; (2) Mindfulness is not becoming emotionless; (3) Mindfulness is not withdrawing from life; (4) Mindfulness is not seeking bliss; and (5) Mindfulness is not escaping pain (Siegel, Germer, and Olendzki, 2008, p. 9-10). Every day mindfulness practice aims to develop an understanding of how the process of experience takes place through careful observation (Korfield, 1979). Nevertheless, we not only want a mindful brain, we also want a mindful body, relieved of stress. Meditative practices train the mind and body to being at ease when innovating. Being mindful, individuals “have a choice in what phenomena to attend to and how they act” (Hirst, 2003, p.359). Therefore, mindfulness not only promotes mental health, but also raises awareness of choice of action. Moreover, a recent study (Baas, Nevicka, and Velden, 2014) demonstrated that between mindfulness and creativity, obtaining observation skills are key to creativity (via website). Hence, mindfulness meditation practices that acquire attention and awareness skills promote observation skills needed to enhance mindful insight for systematic innovation.

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TOP-TRIZ, Method for Innovation, Applications, Implementation

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Abstract

TOP-TRIZ is a result of three decades of development of TRIZ by Zinovy Royzen, a TRIZ Master. The objectives of TOP-TRIZ development are the increasing the effectiveness and completeness of both problem formulation and problem solving while making the method more user friendlier, easier to learn and apply. Another objective is to maximize utilization of the recourses in order to develop the most ideal solutions. TOP-TRIZ includes further development of problem formulation and problem modeling, development of Standard Solutions into Standard Techniques, further development of ARIZ and Technology Forecasting. TOP-TRIZ has integrated its methods into a universal and user friendly system for innovation. The power of TOP-TRIZ has been proven by solving many difficult problems. A set of courses provides the learners of TOP-TRIZ with different level of practical experience sufficient to achieve outstanding results.

Classical TRIZ

Genrich S. Altshuller, the creator of the Theory of Inventive Problem Solving, stopped development of TRIZ Methods to solve technical problems in 1985. His last version of TRIZ known as Classical TRIZ. It includes the following methods.

- Substance-Field Analysis
- 76 Standard Solutions
- Algorithm for Inventive Problem Solving (ARIZ)
- Laws of Evolution of Technical Systems

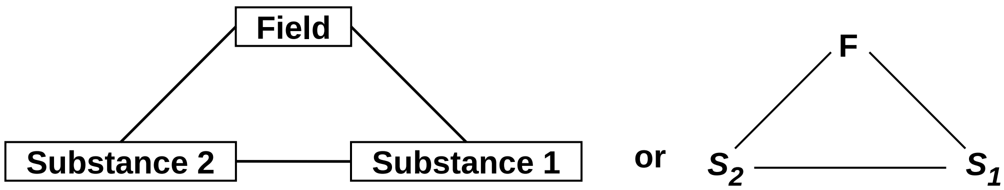
Some people include also 40 Inventive Principles and Contradiction Matrix, the earliest version of TRIZ, even though Altshuller did not mention Inventive Principles in his last technical book titled *To Catch an Idea*.

The most typical question the users, especially beginners, have is what is the problem and how to identify the right TRIZ method to solve it.

Classical Substance-Field Models

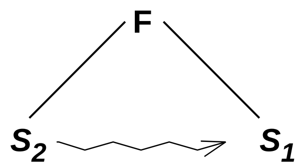
Altshuller’s Substance-Field model of the simplest system is composed of three elements — the two substances and a field between them.

Substance-Field Models of the Simplest Useful System



S_1	The object.
S_2	The tool.
F (Field)	Energy or force.

Substance-Field Model of the Simplest System Having a Harmful Action



S_1	The object.
S_2	The tool.
F (Field)	Harmful energy or force.

Substance-Field Models describe models of the systems rather than functions. When used for Function Modeling, the Substance-Field models do not provide products or results of the functions.

Tool-Object-Product (TOP) Function Modeling

According to Tool-Object-Product (TOP) Modeling, the complete model of a function has four elements. It has the tool of the function (or the function provider), the object of the function (or recipient of the action of the tool), the action of the tool at the object, and one more component — the product of the function. The action is described by one arrow, which simplifies the model.

TOP Model of a Useful Function

$$T \xrightarrow{F} O \Rightarrow U.P.$$

O	The object of the useful action
T	The tool of the useful action
F (Field)	Energy or force, or description of the useful action
U.P.	A useful product.

- An adequate useful action. $\longrightarrow$
  The value of the useful product meets its requirements.

- An insufficient action. $\dashrightarrow$
  The value of the useful product is below of its requirements.

TOP Model of an Absent Useful Function

There is an object. It is desired to obtain a useful product, however, there is neither the tool nor the useful action.

$\boldsymbol{O \Rightarrow U.P.}$

O The object of an absent useful function.
U.P. The desired useful product.

TOP Model of an Absent Useful Function

There is an object and the tool. It is desired to obtain a useful product, however, the action is absent or insufficient.

$\boldsymbol{T \dashrightarrow O \Rightarrow U.P.}$

O The object of an absent or insufficient useful function.
T The tool of an absent or insufficient useful function.
U.P. The desired useful product.

TOP Model of a Harmful Function

$\boldsymbol{T \overset{F}{\leadsto} O \Rightarrow H.P.}$

H.P. A harmful (unwanted) product or products.
O The object the harmful action.
F (Field) Energy or force, or description of the harmful action.
T The tool or immediate source of the harmful action.

A harmful action is decreased or eliminated.

TOP Model of an Unknown Harmful Function

$\boldsymbol{\overset{?}{\leadsto} O \Rightarrow H.P.}$

O The object of the harmful action.
H.P. A harmful (unwanted) product or products.

TOP Model of a Conflict

Very often a useful action also causes an unwanted effect, or an attempt to improve a function leads to deterioration in another function of the system. Conflicts are the most difficult type of problem in innovation. TOP-TRIZ offers models to describe any type of conflict.

Conflicting Actions of the Tool on the Same Object

$$T \begin{array}{c} \xrightarrow{F_u} \\ \underset{F_h}{\rightsquigarrow} \end{array} O \begin{array}{l} \Rightarrow U.P. \\ \Rightarrow H.P. \end{array}$$

Conflicting Actions of the Tool on Different Objects

$$T \begin{array}{l} \xrightarrow{F_u} O_1 \Rightarrow U.P. \\ \underset{F_h}{\rightsquigarrow} O_2 \Rightarrow H.P. \end{array}$$

Modeling a function by describing all four components — the tool, the object, the action, and the product — improves understanding of both the function and the best ways for its improvement.

Advantages of TOP Function Modeling:

- **Universal Model of a Function**
  Neither the tool of the function nor the object of the function has to be a substance as it is required in Substance-Field Model. In TOP-TRIZ Model, an object is anything we want to modify. It can be a field. TOP Function Modeling allows you to model any function in any system. It is a more generic way to model a function than Substance-Field Modeling.

- **Complete Description of a Function**
  Desired and unwanted products of the functions of a modeled system improve understanding of the system and simplify analysis of the system resources.

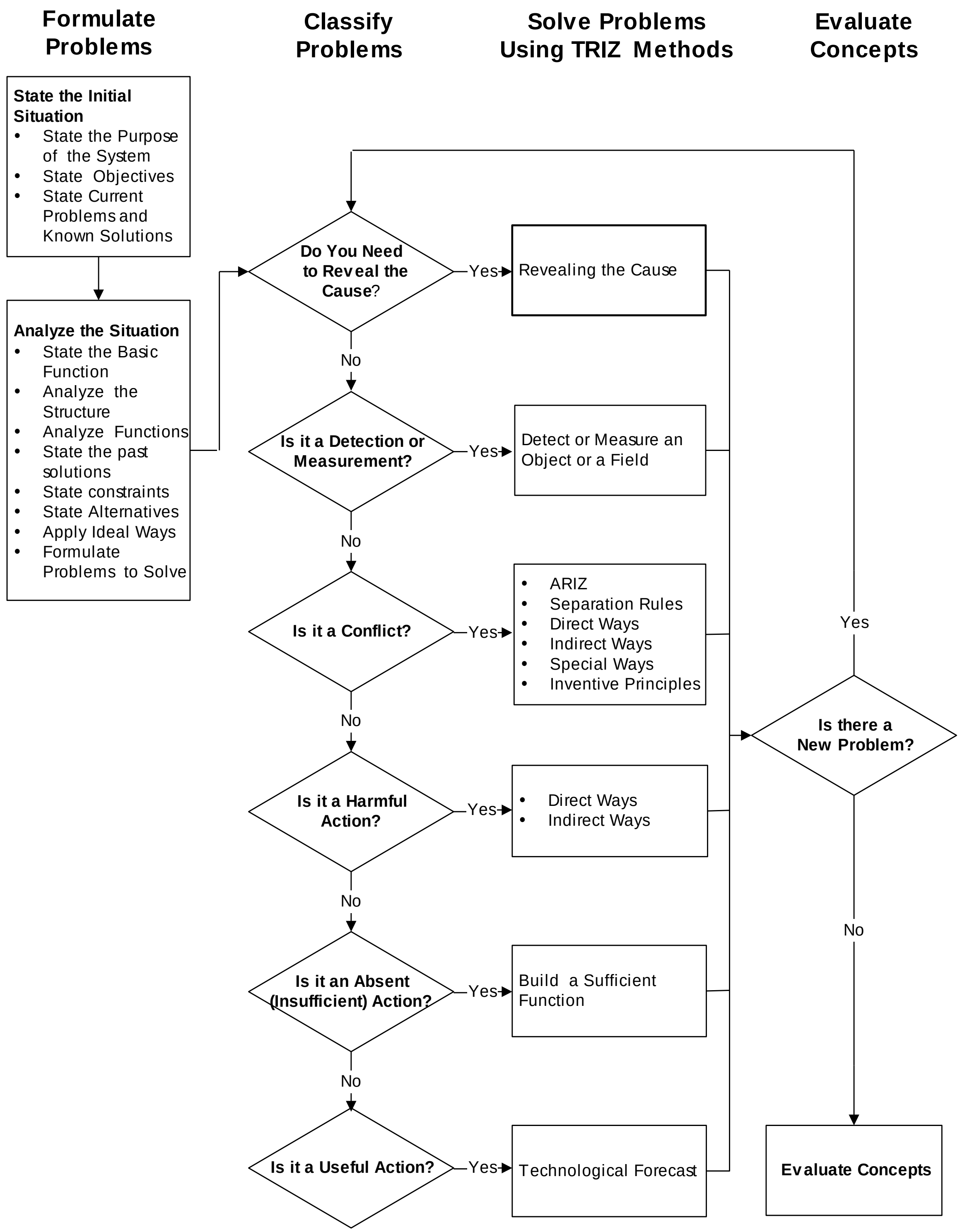
- **Link Between Functions**
  Introducing the product of a function into its model provides a very convenient and understandable link between functions. For example, a product of the first function can be a tool or an object of a subsequent function.

  The link between functions is important in understanding not only a desired performance of a product, but also the chain of unwanted functions. Links between functions simplify cause-effect analysis and improve the process of revealing the cause of a current or potential failure of a product.

- **Increasing Effectiveness of Function Analysis**
  TOP-Function Modeling is supported by templates to guide you in modeling any type of functions and in describing the performance of your system, its interaction with its supersystem and environment by a number of functions.

- **Problem Classification**
  Any single function or a conflict can be considered separately and classified according to TOP-TRIZ Flow Chart. Function modeling helps you to understand the system's performance, state the set of problems to consider, classify the problems, and determine the TRIZ Methods to be applied according to the TOP-TRIZ Flow Chart.

  TOP-TRIZ Flow Chart



TOP-TRIZ Problem Formulation

TOP-TRIZ Problem Formulation is a universal approach to analyze any situation needing an improvement. It includes TOP-TRIZ Function Analysis of the current problems of the project, known solutions to these problems and their disadvantages, analysis of the history of the problem and constraints. It includes analysis of the alternatives of the system and Ideal Ways.

Ideal Ways is an analytical method made up of the ideal directions for improving the situation. For example, if a component of the system is involved in a disadvantage, Ideal Way 1 suggests two ways to get rid of the component by eliminating its function. Ideal Way 2 suggests two ways to get rid of the component by its substitution. Ideal Way 3 guides you to make the component itself eliminate its disadvantage.

TOP-TRIZ problem formulation guides you to develop an exhaustive set of problems associated with your system and its need for an innovative solution.

TOP-TRIZ Problem Solving

TOP-TRIZ Flow Chart classifies problems into six classes and offers corresponding problem solving methods for each class of problems. The methods include Standard Techniques and Conflict Solving algorithm (TOP-ARIZ). TOP-TRIZ problem solving methods guides you to develop an exhaustive set of innovative solutions. It also aims to maximize utilization of the resources of the system, its supersystem and environment to make the best solutions inexpensive.

Standard Techniques

TRIZ Standard Techniques is a further improvement of Altshuller's Standard Solutions. Some Rules were reformulated, some new rule were added. Some Standards were integrated, so the total number of the Standards was reduced.

Reclassification of the Standards helps to develop the most simple and user friendly Flow Chart.

Standard Techniques are step-by-step guides for applying generic solutions to your problem and developing specific solutions by utilizing the resources.

A Standard Solution comprises a rule and an example. Each Standard Technique includes also a step-by-step approach to apply the rule to your problem. For example, Standard to eliminate a harmful action by introduction of a substance-insulator became more than a page-long guide how to do it and where to look for this substance-insulator.

As a result of such development, Standard Techniques became both more effective and easier to apply methods than Standard Techniques. In addition, general problem solving techniques like Standard Techniques to Build a Sufficient Function and for Harmful Function elimination are used also for revealing the causes of the failure, reducing the number of methods to learn and shortening the time of training.

Conflict Solving Algorithm (TOP- ARIZ)
TOP-ARIZ is further development of Altshuller's ARIZ. Integration of TRIZ Methods allowed reducing the number of steps in ARIZ and improving its effectiveness. The steps were redesigned and each step received a template.

Initial function analysis of a system has improved identification of the right conflicts. TOP function modeling improves understanding of the conflict, its opposite versions, the function of X-resource and its product. One of the most difficult steps in ARIZ – formulation of the physical contradiction — is simplified significantly. Techniques for Physical Contradiction Separation are reformulated, supplied with templates and an additional technique was added.

As a result, most difficult problems with contradictions involved can be routinely solved while minimizing product changes and costs.

The Process of TOP-TRIZ Problem Solving

TOP-TRIZ Flow Chart guides you from the very beginning of the process. In general, problem formulation results in an exhaustive set of problems. Selecting one problem at a time, the user classifies the problem according the TOP-TRIZ Flow Chart and identifies the methods to apply. Each method could help to develop a number of concepts. However, it very seldom, any of the concepts could be implemented right away. In most cases, any concept could bring at least one or two new or subsequent problems.

Subsequent Problems
No matter what class of the original problem is, the most common subsequent problems are the following.

- A concept while solving the first problem causes deterioration of a feature or a function. So, it is a conflict.
- A concept requires to modify a resource or to derive what is needed to solve the first problem out of an available resource. This class of problems is an absent action.
- A new action has to be performed in a certain time. This class of problems is detection or measurement.

In the worst situation, a concept might cause all three new problems together.

A subsequent problem is not the reason to reject a concept. TOP-TRIZ Flow Chart guides you to classify a new problem and apply the corresponding methods. And again, a number of concepts could be developed to solve this new problem. And again, the best concept might bring their own new problems. And again, new problems have to be classified according to TOP-TRIZ Flow Chart. And so on, until there are no more new problems needing innovative solutions.

In addition, there is one more type of subsequent problems which is ignored in many cases by not TOP-TRIZ users. The fact is that no matter how your new concept is good, there are always next steps according to technology forecasting. These steps could be to be discovered by a problem solver right away. However, many users consider technology forecasting as a tool for rood mapping of innovation and, therefore, do not apply while working on a single problem loosing an opportunity to enhance the best concepts.

TOP-TRIZ methodology guides you in your project to formulate an exhaustive set of problems associated with your system, the current problem and your objectives.
Then, TOP-TRIZ guides you to develop an exhaustive set of the best solutions.
This approach helps you not only select the most ideal solution for implementing. Having the exhaustive set of the commercially applicable solutions is the basis for a reliable patent protection of your business.

TOP-TRIZ methodology provides advantages in systematic innovation in order to develop better products and processes at a lower cost and in less time while being user friendly.

- Helps develop breakthrough concepts and ideas
- Helps to solve six classis of problems including contradictions
- Leads to maximize the resources in order to develop better products at a lower cost
- less number of people involved and less time needed to develop an innovative solution to a problem
- Estimation of time for each step and the whole process
- Increases efficiency and effectiveness of creative work
- Develops the winning concepts faster
- Helps pursue competitive advantage

Elegant and valuable solutions to your most difficult design and manufacturing problems can be obtained much faster. The right solution at right time can potentially save hundreds of man-hours, millions of dollars, and accelerate a project by days, months, even years.

Teaching TOP-TRIZ

The complete program includes three 40-hour courses.

1. Designing and Manufacturing Better Products faster Using TRIZ. It is my basic course. It is a 40-hour course and can be conducted as five-day course.
2. Advanced Practice TRIZ Course. It is an entirely practice course (21 cases) and can be conducted as a five-day course or remotely via WebEx, 2 hours a week.
3. TRIZ Practitioner Course. It is also an entirely practice course (21 cases) and can be conducted as a five-day course or remotely via WebEx, 2 hours a week.

The Program of Designing and Manufacturing Better Products Faster Using TRIZ

- Basic concepts of TRIZ
- Analysis of a system and problem formulation

- Solving a class of problems called *Insufficient Function*
- Solving a class of problems called *Conflict*
  - Algorithm for Conflict Solving
  - Five techniques for Physical Contradiction Separation
  - Special Ways to introduce new resources without causing subsequent problems
  - 40 Inventive Principles and Contradiction Matrix
- Solving a class of problems called *Harmful or Unwanted Function*
- Solving a class of problems called *Measurement*
- Solving a class of problems called *Revealing the Cause of a Failure*
- Technology Forecasting
- Concept evaluation
- Combined application of TRIZ Methods
- Solving problems brought by participants.

Advanced Courses

The objective of the advanced courses is to help TRIZ users in gaining advanced level experience in applying TRIZ and confidence in working on their real-life problems and facilitation of TRIZ facilitation of teams.

The TOP-TRIZ courses provide the learners with practical experience sufficient to achieve outstanding results. For example, Peter R. Menge, Ph. D., Senior Scientist at Saint-Gobain Crystals wrote me the following.

“I have taken many professional development training courses over my career in science and engineering. I found the Basic TRIZ and Advanced Practice TRIZ courses to be the most useful, the most stimulating, and the most satisfying of these trainings. Although I have only been applying the techniques and algorithms for a few months, I have been able to find new solutions to chronic manufacturing problems in our plant. The process can be used on low tech and high tech levels. I have used the method from simply helping to take cost out of a manufacturing process to developing intellectual property based on new solid state physics. Two features of TRIZ that I really find to be especially valuable are:

1) The functional analysis process forces you understand what the problem really is on a fundamental level.

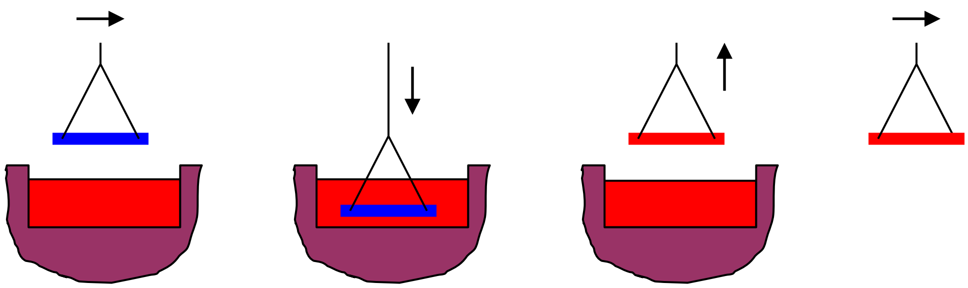
2) The TOP-TRIZ algorithm is complete. You can’t miss what the general solutions are. You can be confident that if a solution to your challenge exists, you will find it."

TOP-TRIZ Applications

Case 1. Plating Steel Rods and Pipes with Aluminum

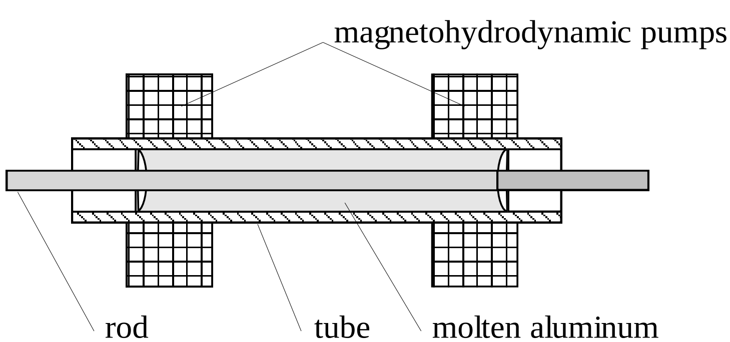
Background of the problem

An old system for plating steel rods and pipes with aluminum included a well in the ground of a shop filled with molten aluminum at 700-740° C and a conveyer moving steel pipes and rods. Preheated pipes and rods were submersed into molten aluminum for a short period of time and then removed with a coat of aluminum which protects steel pipes and rods against corrosion.



Old process of plating steel rods and pipes with aluminum

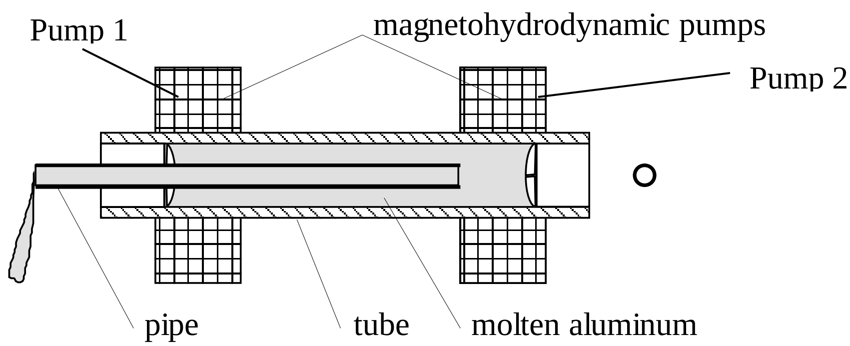
A new system for plating steel rods and pipe with aluminum was developed in order to increase the rate of production. The new system includes a tube and two pumps utilizing the magnetohydrodynamic (MHD) phenomenon. When a magnetic field and an electric current intersect in a liquid, their repulsive interaction propels the liquid in a direction perpendicular to both the field and the current. The pumps keep molten aluminum in the tube, and a rod passing through the tube is plated with aluminum.



Plating steel rods

The test of the new system was a success for plating rods. Strait line motion of the rods increased productivity of the process. In addition, the new system removed excess of aluminum, decreased loss of aluminum due to oxidation, decreased energy loss and improved the shop environment. However, there was a problem with plating pipes. High temperature (700-740° C) molten aluminum was pumped out of the tube through the pipe inserted in the tube.

The cause of the failure was understood. A steel (ferromagnetic) pipe does not allow a magnetic field to pass through it, thus there are no forces to keep molten aluminum inside.



Plating steel pipes

The pipes have to be plated outside and inside. After working on the problem for a half a year without a result, the team requested help.

Initial Situation

1. The purpose of the system is *to plate steel pipes with aluminum.*
2. The objective of the project *is to eliminate leakage of aluminum from pipes.*
3. Current problem. *Aluminum leaks from a pipe going through the tube*
4. State known solutions. State advantages and disadvantages of known solutions.

   A. Collecting aluminum escaping from the pipe and returning it back to the system. This solution complicates the system.

   B. Sealing the pipes for plating the outside surface and different methods of plating the inside of the pipes.
   This solution requires another piece of equipment to plate pipes inside.

Analyze the Situation

1. The basic function of the system is to plate steel pipes with aluminum.
2. Describe the structure:

The system includes:

MHD Pump 1
MHD Pump 2
Tube
Molten Aluminum
Heater
Feeding mechanism
Steel pipe

The Supersystem

Laboratory (Shop)

The Environment

Air

3. Analyze functions and formulate problems.

TOP Function Modeling

Pump 2 pumps molten aluminum out from the pipe.

Pump 2 —***Pumps***→ ***Aluminum Inside*** ⇒ ***Aluminum (H.P.) Outside***

The harmful function is caused by disabling the pump 1 to hold aluminum.

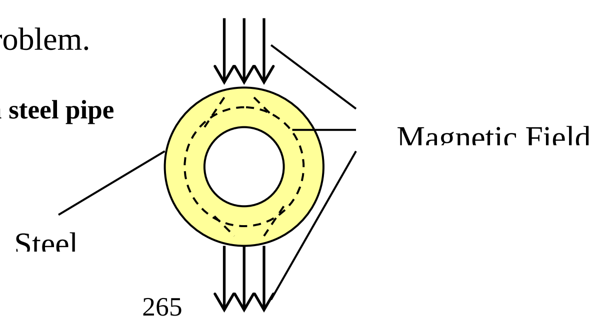
Pump 1 - - - - - - - -→ ***Aluminum Inside*** ⇒ ***Aluminum (H.P.) Outside***

Pump 1 is unable to hold aluminum because a steel pipe blocks magnetic field.

Steel Pipe —***Blocks***→ ***Magnetic Field*** ⇒ ***Magnetic Field (H.P.) Blocked***

This is the root cause of the problem.

There is no magnetic field inside a steel pipe

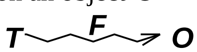
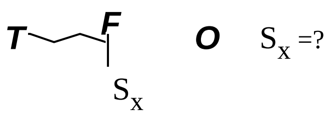
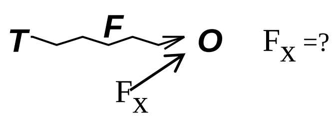
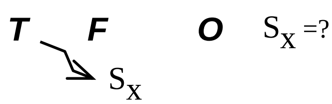
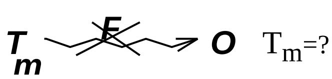
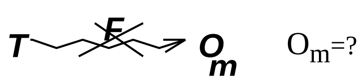
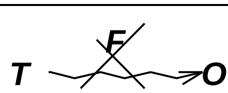


It is a harmful function and according to TOP-TRIZ Flow Chart we need to Standard Techniques for Harmful Action Elimination comprising Direct Ways and Indirect Ways.

Steel Pipe ⟿ ***Magnetic Field*** ⇒ ***Magnetic Field (H.P.) Blocked***

Tool (T) Object (O)

Direct Ways

Problem ➡ Solution	Description
There is a harmful action on an object O → Eliminate the harmful action 	
	Insulate O from the harmful action by a substance-insulator S_x.
	Counteract the harmful action with the opposing field F_X.
	Protect O from the harmful action by a safety substance S_X which attracts the harmful action on itself.
	Modify the tool (source) of the harmful action T to turn off the harmful action.
	Modify O to be non sensitive to the harmful action.
	Alter the amount of the zone of the harmful action, its duration or both to decrease the harmful action or eliminate it completely.

Concept

There is a need to modify the Pipe (Tool) to make it stop blocking the magnetic field.

New Problem

Steel Pipe ⇒ ***Steel Pipe***

It is an absent action and according to TOP-TRIZ Flow Chart we need Build a Sufficient Function.

Problem: → **Solution according to Rule 1:**

Steel Pipe $\Rightarrow$ ***Steel Pipe*** ***Tx*** $\xrightarrow{Fx}$ ***Steel Pipe*** $\Rightarrow$ ***Steel Pipe Modified***

$\boldsymbol{F_x}$ **=?**

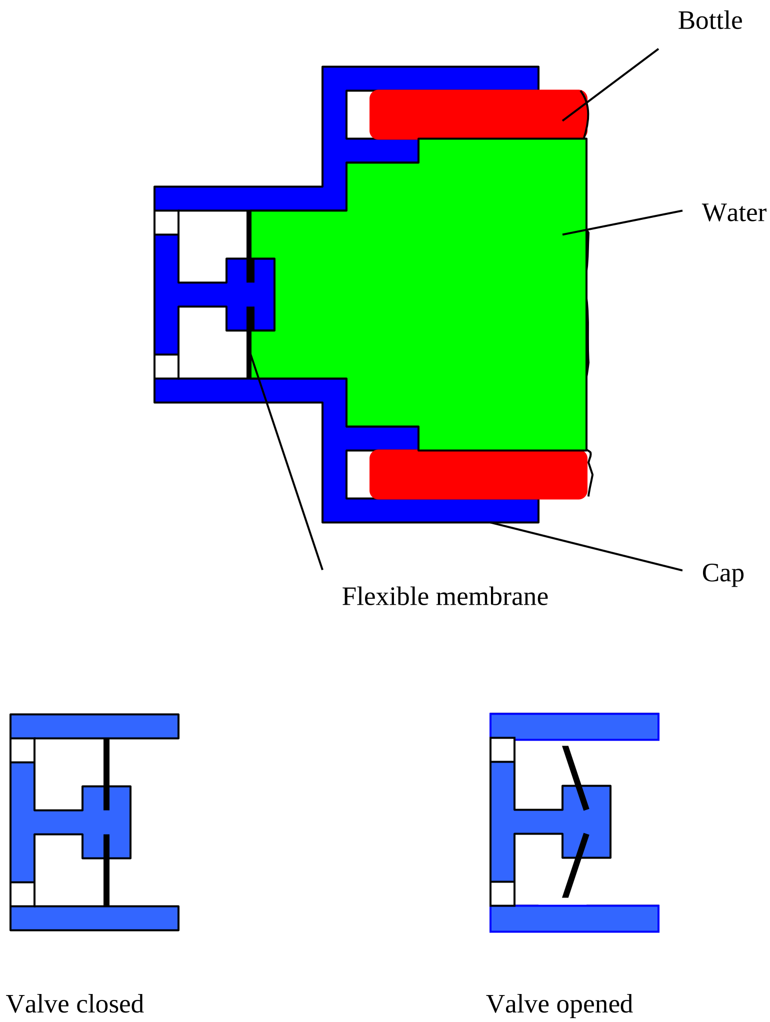
Identify the field F_x. It may be:

- Mechanical fields
- Thermal fields.
- Chemical reaction.
- Electric current.
- Magnetic field.
- Electromagnetic fields.

It was recommended to heat pipes over Curie point of steel which is 770° C.

Case 2. Water Bottle Cap Problem

A water bottle cap which avoid the need for manual positioning of the valve and which permits dispensing water by application of suction, should open easily at suction pressures less than -0.38 psi. The problem is that under normal use, sometimes internal container water pressure can be greater than 0.38 psi, and thus the valve can leak water. Also, water has to be released by squeezing the bottle with pressure applied to the valve not less than, for example, 1 psi. After working on the problem for a year without a result, the team turned to TOP-TRIZ.



Water bottle cap with a flexible membrane

Initial Situation

1. The purpose of the system is to seal water in the bottle and release water by sucking.

2. The objective of the project is to design a closure that meets the following requirements.
   - One hand bottle use
   - Opening the valve by sucking with ΔP not more than 0.38 psi
   - Dispensing water by squeezing the bottle.
   - No leakage

3. Current problem. Valve designed for easy opening by sucking leaks under normal conditions of use.

4. State known solutions. State advantages and disadvantages of known solutions.

   - Push to open valve. Eliminates leakage. It takes two hands to operate.

   - Twist to open valve. Eliminates leakage. It takes two hands to operate.

   - "Stiff " Valve. Eliminates leakage. It does not open by sucking.

Analyze the Situation

1. **The basic function of the system is to seal and dispense water.**

2. **Describe the system, supersystem and environment.**

   The system:

   Cap

   - Case
   - Stem
   - Valve

   Water Bottle

   Water

   Air in the bottle

   The supersystem:

   Customer

   The environment:

   Air

   Outside Forces

3. Analyze functions and formulate problems.

The Current Problem (Problem 1)

Water leaks through the cap under normal conditions of use because ΔP applied across the valve could be more than 0.38 psi.

Model of the harmful function.

Lets
Valve ⇝ ***Water*** ⇒ ***Water***
Open ***Inside*** ***Outside (leakage)***

Problem 2.

The Problem 1 is caused because the Valve is opened.
Model of the harmful function.

Pressures
Water ⇝ ***Valve*** ⇒ ***Valve***
Pressurized ***Closed*** ***Opened***

The harmful function is caused because water in the bottle is pressurized by an outside force. However, the valve was designed to be opened when 0.38 psi applied across it.
The open valve causes leakage of water.

The useful functions of the valve are to open and to seal water.

1. The function of the valve is to open water.

Model of the function.

Lets
Valve ⟶ ***Water*** ⇒ ***Water***
Open ***Inside*** ***Outside (dispensed)***

In order to perform the function there is a need to apply suction with $\Delta P=0.38\ psi$.

2. The function of the valve is to seal water.
Model of the function.

Seals
Valve ------> ***Water P*** ⇒ ***Water P***
Closed ***Sealed (does not leak)***

It is also possible to say that the function of the valve is to press the wall in order to seal water.

Valve (*Closed*) --*Presses*--> *Wall* ⇒ *Wall* (*Pressed*)

The function is insufficient. The valve is flexible in order to open it easily. A known solution is to make it "stiffer."

List of Problems

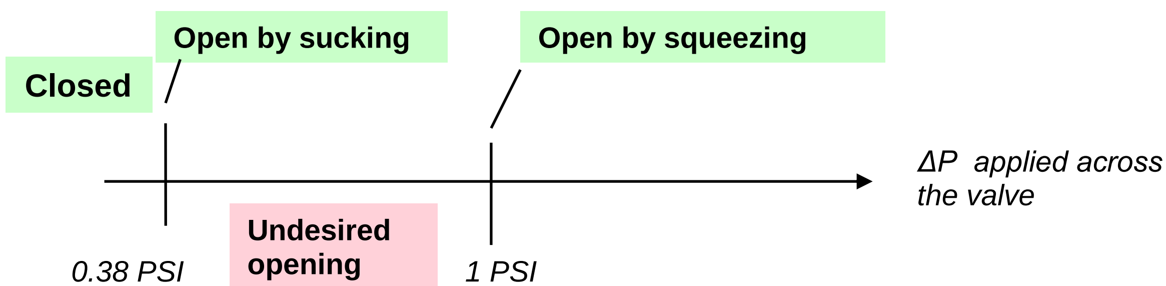
Problem 1.

Valve (*Open*) ~~*Lets*~~> *Water* (*Inside*) ⇒ *Water* (*Outside (leakage)*)

Problem 2.

Water (*Pressurized*) ~~> *Valve* (*Closed*) ⇒ *Valve* (*Opened*)

Problem 2 is the preferred problem to start.



Known Solution

A "stiff" valve eliminates leakage by sealing water; however, water will be sealed even when suction is applied.

Problem 3. **Conflict**

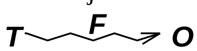
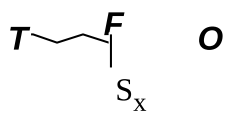
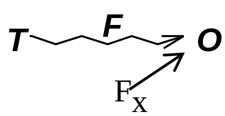
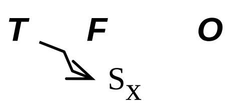
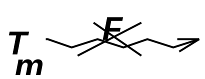
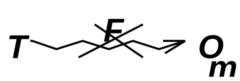
Valve (*Stiff*) → *Water (Pressurized)* ⇒ *Water (Pressurized)* (*Sealed*)

Valve (*Stiff*) ~~> *Water* ⇒ *Water* (*Sealed*)

Problem 2

Water Pressurized $\rightsquigarrow$ ***Valve Closed*** $\Rightarrow$ ***Valve Opened***

Direct Ways

Problem ➡ Solution	Description
Problem: There is a harmful action on an object O Solution: Eliminate the harmful action 	Description
 S_X =?	Insulate O from the harmful action by a substance-insulator S_X.
 F_X =?	Counteract the harmful action with the opposing field F_X.
 S_X =?	Protect O from the harmful action by a safety substance S_X which attracts the harmful action on itself.
 T_m=?	Modify the tool (source) of the harmful action T to turn off the harmful action.
 O_m=?	Modify O to be non sensitive to the harmful action. *A stiff valve.* *Problem 3.* *A stiff valve will not be opened by sucking.*
	Alter the amount of the zone of the harmful action, its duration or both to decrease the harmful action or eliminate it completely. *In order to reduce total amount of the harmful action we need to decrease the area of the valve exposed to water.* *Problem 4. A smaller area of the valve exposed to water will not be sufficient to open the valve by sucking.*

According to Direct Ways, there are two solutions to Problem 2.

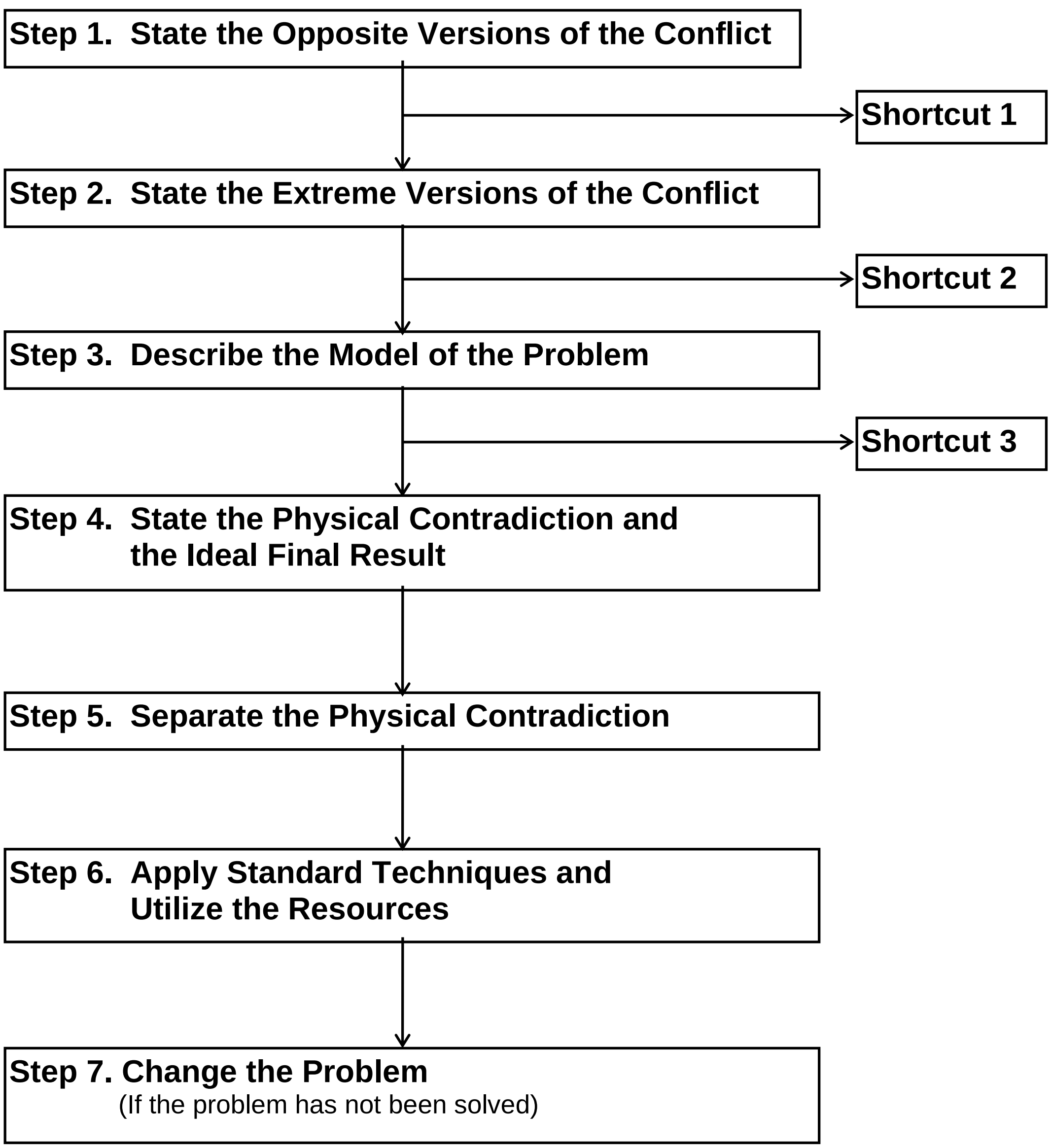
A. A stiff valve. This solution causes a new problem. A stiff valve will not be opened by sucking.

B. A smaller area of the valve is exposed to water. This solution causes a new problem. The valve will not be opened by sucking.

An attempt to solve this problem improves understanding of the physics involved.

Problem 3. Conflict

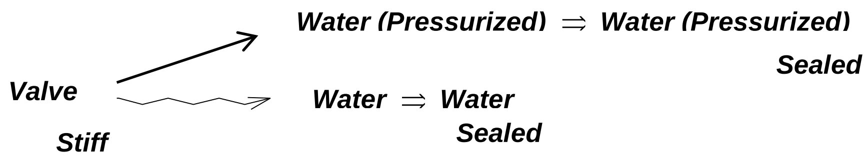
TOP-ARIZ Flow Chart



Algorithm for Inventive Problem Solving

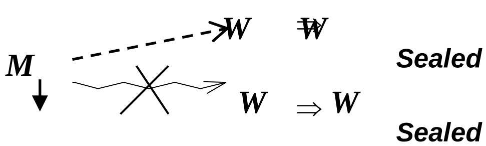
Step 1. State the Opposite Versions of the Conflict

- The system for sealing and dispensing water includes a ~~valve~~ ***Membrane***, water and pressurized water.
  Model of the conflict.

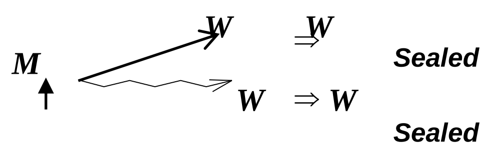


- **State the Opposite Versions of the Conflict**

Conflict 1.
In order to dispense water by sucking
the membrane has to be flexible
but it does not seal pressurized water.



Conflict 2.
In order to seal pressurized water
the membrane has to be stiff
but it will not dispense water by sucking.



- A minimum alteration of the system has to provide dispensing water by sucking and sealing pressurized water without any complication or deterioration of the system or anything else.

- Shortcut 1. Separate Preliminary Physical Contradiction 1.
  The membrane has to be flexible and stiff.

  1. Separation in Space
  2. Separation in Time
  3. Separation Between the Components
  4. Separation Between the Components and the Set of the Components
  5. Separation Between Parameters

Separate the Physical Contradiction
The valve has to be flexible to be opened by sucking and has to be stiff in order to prevent its opening by pressurized water.

Separation in Space

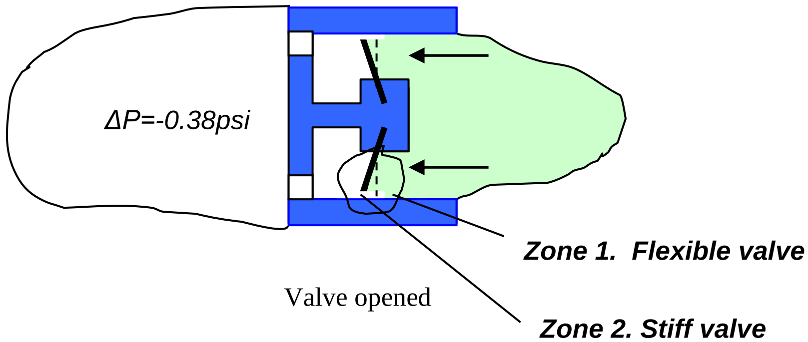
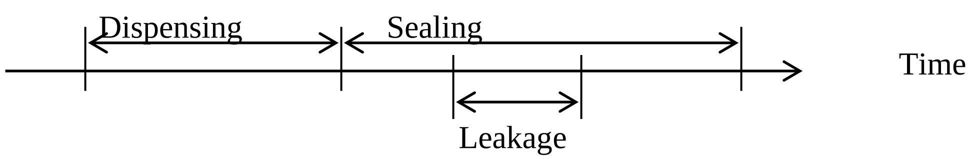


Figure 11: Water bottle cap

Separation in Time



Separation Between the Components

Two valves. Existing valve has to be flexible. A new valve has to be stiff.

Separation Between the Components and the Set of the Components

Both valves are flexible. The system of the flexible valves is stiff.

Separation Between Parameters

Opening of the valve depends on the force applied to the valve.

$$F = \Delta P \times Area$$

Another way to analyze the situation is the following.

Sucking Air-Water $\xrightarrow{\textbf{\textit{Pressures}}}$ ***Valve*** $\Rightarrow$ ***Valve Opened***

Air-Pressurized Water $\overset{\textbf{\textit{Pressures}}}{\rightsquigarrow}$ ***Valve*** $\Rightarrow$ ***Valve Opened***

The valve is opened when ΔP =0.38 psi applied across it. Even though the tools of the functions are different, the ΔP is the same.

From this point of view the following conflict can be stated.

$$\underset{\textbf{\textit{0.38 psi}}}{\Delta P} \begin{array}{l} \longrightarrow \\ \rightsquigarrow \end{array} \textbf{\textit{Valve}} \begin{array}{l} \Rightarrow \textbf{\textit{Valve Opened (for dispensing)}} \\ \Rightarrow \textbf{\textit{Valve Opened (leakage)}} \end{array}$$

TOP-ARIZ

Step 1. State the Opposite Versions of the Conflict

- The system for sealing and dispensing water includes a ~~valve~~ ***Membrane*** and the pressure across the valve.

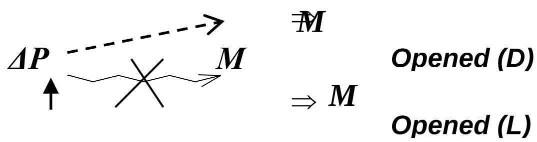
- Model of the conflict.

$$\underset{\textbf{\textit{0.38 psi}}}{\Delta P} \begin{array}{l} \longrightarrow \\ \rightsquigarrow \end{array} \textbf{\textit{Membrane}} \Rightarrow \textbf{\textit{Membrane}} \begin{array}{l} \textbf{\textit{Opened (for dispensing)}} \\ \textbf{\textit{Opened (leakage)}} \end{array}$$

- **State the Opposite Versions of the Conflict**

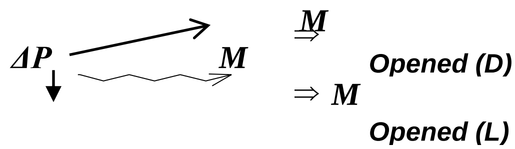
Conflict 1.

In order to eliminate opening of the membrane (leakage) the ΔP across the membrane has to be increased, but the membrane will not be opened by sucking.



Conflict 2.

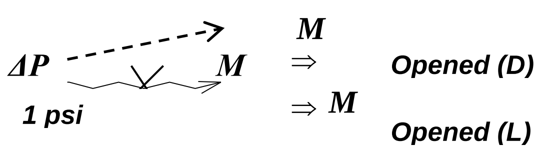
In order to open the membrane by sucking the ΔP across the membrane has to be decreased, but the membrane will be opened by pressurized water (leakage).



Step 2. State the Extreme Versions of the Conflict

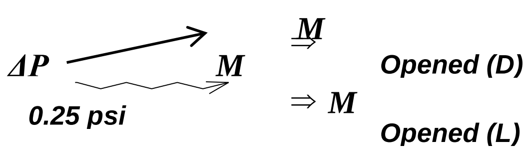
Extreme Conflict 1.

If the ΔP across the membrane is 1 psi in order to eliminate opening of the membrane (leakage) completely, the membrane will not be opened by sucking.



Extreme Conflict 2.

If the ΔP across the membrane is less 0.25 psi in order to open the membrane by sucking easily, the membrane will be opened by pressurized water (leakage).

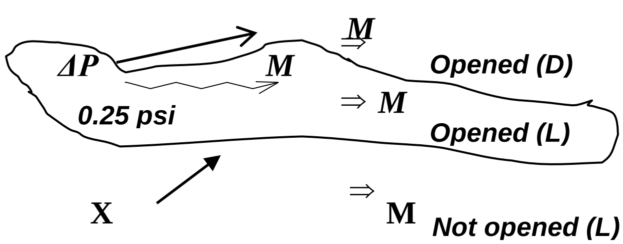


Step 3. Describe the Model of the Problem

- Conflict 2 is better for the basic function of the system.
- It is necessary to identify an *X*-resource:

X-resource has to eliminate opening of the membrane by pressurized water (leakage).

X-resource must not deteriorate easiness of opening the membrane by sucking.



Step 4. State the Physical Contradiction and the Ideal Final Result

- **Define Macro Level Physical Contradiction.**

  In order to eliminate opening of the membrane by pressurized water (leakage), the membrane has to have no opening force **and** the membrane has to have an opening force in order to be opened by sucking.

  .

- **State the Ideal Final Result**

  During the operating time, the zone of the conflict itself has to provide *membrane with an opening force and no opening force.*

Step 5. Separate the Physical Contradiction

Separation in Space

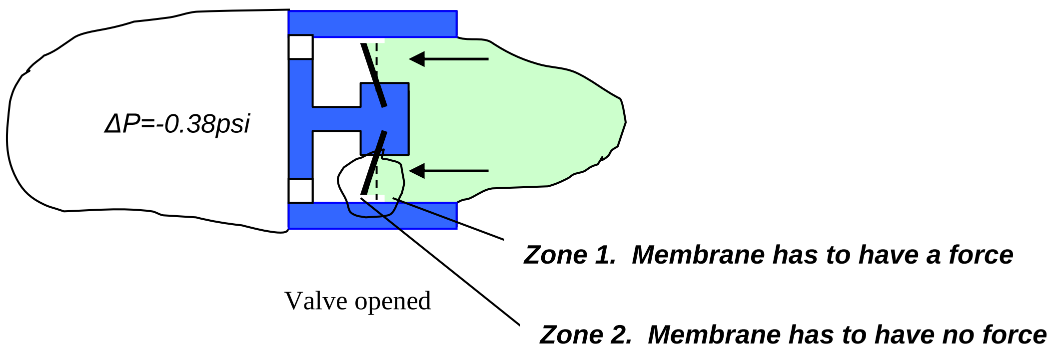
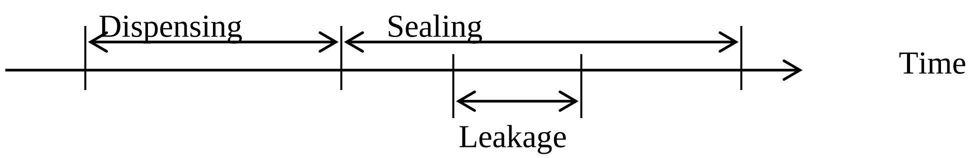


Figure 12: Water bottle cap

Separation in Time



Separation Between Parameters

Opening of the membrane depends on the force applied to the valve.

$$F = \Delta P \times Area$$

In order to have opening force and no opening force having the same ΔP across the valve when sucking and when water pressurized, area of the valve exposed to pressurized water has to be smaller than the area of the valve exposed to suction.
“It is clear that through the application of TRIZ we were able to generate more concepts in two days than the contracted inventors were able to accomplish in over a year. Also

the concepts and approaches we developed with your help are founded in sound engineering principles."
Larry Smeyak

US006832706B2

(12) **United States Patent**
Hearld et al.

(10) **Patent No.:** **US 6,832,706 B2**
(45) **Date of Patent:** **Dec. 21, 2004**

(54) **DISPENSING CLOSURE**

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(73) Assignee: **Alcoa Closure Systems International**, Crawfordsville, IN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 46 days.

(21) Appl. No.: **10/340,319**

(22) Filed: **Jan. 10, 2003**

(65) **Prior Publication Data**

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(51) **Int. Cl.**7 .... **B65D 25/40**
(52) **U.S. Cl.** **222/494**; 222/482
(58) **Field of Search** 222/212, 481.5, 222/482, 494, 153.14, 556, 545; 137/852, 854

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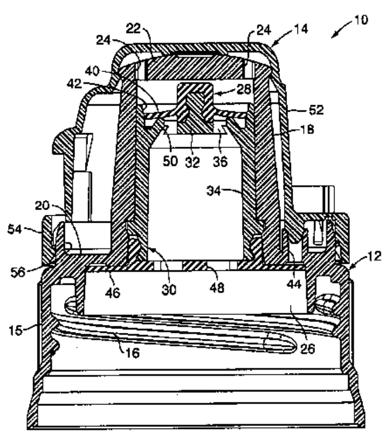
(57) **ABSTRACT**

A dispensing closure assembly includes an outer closure body having an upper tubular portion which can function as a mouthpiece for users. The closure assembly includes a flexible valve member mounted within the tubular portion of the closure body for dispensing of liquids or like contents by either the application of suction by a consumer, or by squeezing the associated container. By the provision of a liquid seal lip which coacts with an inside surface of the flexible valve member, the closure assembly can be configured to facilitate convenient use by consumers, while avoiding undesirable leakage attendant to normal handling during use.

16 Claims, 11 Drawing Sheets



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I would like to thank the Alcoa CSI team Involved in the project: Mark Powell, Larry Smeyak, Ramesh Kamath, David Babcock, Nassan Najdawi and Coy Hearld.

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TRIZ Identification of Solution Models by Function-Attribute Characteristics Using Mathematical Measures

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Abstract

So far, TRIZ has based on logical reasoning for identification of Solution Models. The identification of relevant solution models has been highly relying on individual expert's experience and is highly subjective. This research proposes a couple sets of mathematical ways to identify TRIZ solution models based on some classification schemes or similarity measures. The use of mathematical methods allows the users to quickly and objectively obtaining models of solution to a problem with priority without reliance on TRIZ expert knowledge and experiences.

In this paper, relevant trends identification using similarity measures is used as an example. In identifying relevant trend solutions, the attribute characteristics of the problem are compared against the attribute characteristics of certain earlier stage of a trend first. If they match, certain ensuing stages of the same trend can imply model of solutions if jumping into that stage can provide functions needed to solve the subject problem. By encoding the 'knowledge' embedded in the trends, a piece of software is written to identify the relevant trends for problem solving quickly and objectively without needing to rely on expert experience and knowledge. K-fold validity verification was used to verify the effectiveness of this method. The results shows that the 8 best solutions proposed by the proposed similarity measure achieved 92% of problem solving capability and is significantly better than the 5% problem solving rate by 8 randomly selected trends. If 10 best solutions are used, the problem solving capability is 100%. Contributions of this research include: 1) providing a framework to open up a new area for research to used mathematical methods for TRIZ problem solving. This is favorable for elevating TRIZ for scientific recognitions; 2) establishing an effective computer-aided innovation system to automatically and objectively identify relevant trends for problem solving; 3) integrating the enhanced classical trends and Darrel Mann's trends into a more comprehensive set of 52 trends for broader use.

Keywords: TRIZ, Systematic Innovation, Similarity, Classification, Model of Solutions, Trends.

1. Research Purpose

Currently, the most difficult aspect of using evolutionary trends involves the reliance on the judgment and experiences of experts in determining which evolutionary trends are related to problems. These processes are time-consuming and flawed. Thus, based on an integration of the classic Gen3 and Darrell Mann evolutionary trends in the theory of inventive problem solving (TRIZ), this study replaced the need for expert judgment and experience by calculating the similarities in attribute functions using mathematical tools constructed using new evolutionary trends. This quickly and objectively provided users with relevant trigger solutions to evolutionary trends without relying on experts and human comparison of individual evolutionary trends.

2. Relevant Literature

2.1 Evolutionary Trend

Trends of Engineering System Evolution was first proposed by Altshuller (1984) in the laws of development of technical systems, which was further studied and organized by his students and other scholars. It is a crucial TRIZ tool and a trend-determining tool in classical TRIZ. The content comprised 11 main evolutionary trends and 25 subtrends (Fig. 1). Every evolutionary trend in classical TRIZ is interconnected and involves a full structural diagram on its relationship within the evolutionary trend.

Mann (2002) proposed 37 evolutionary trends and distinguished them into three dimensions, which comprise space, time, and interface. In this study, only relevant technological evolutionary trends were investigated, and two evolutionary trends related to sales were excluded: sales evolution and customer purchases after viewing a product. In addition, four evolutionary trends that were repeatedly listed were excluded: mono-bi-poly (similar), mono-bi-poly (various), mono-bi-poly (increasing difference), and boundary breakdown. Thus, 52 trends were compiled in this study, including the aforementioned classical TRIZ trends and 31 of Mann's technological evolutionary trends.

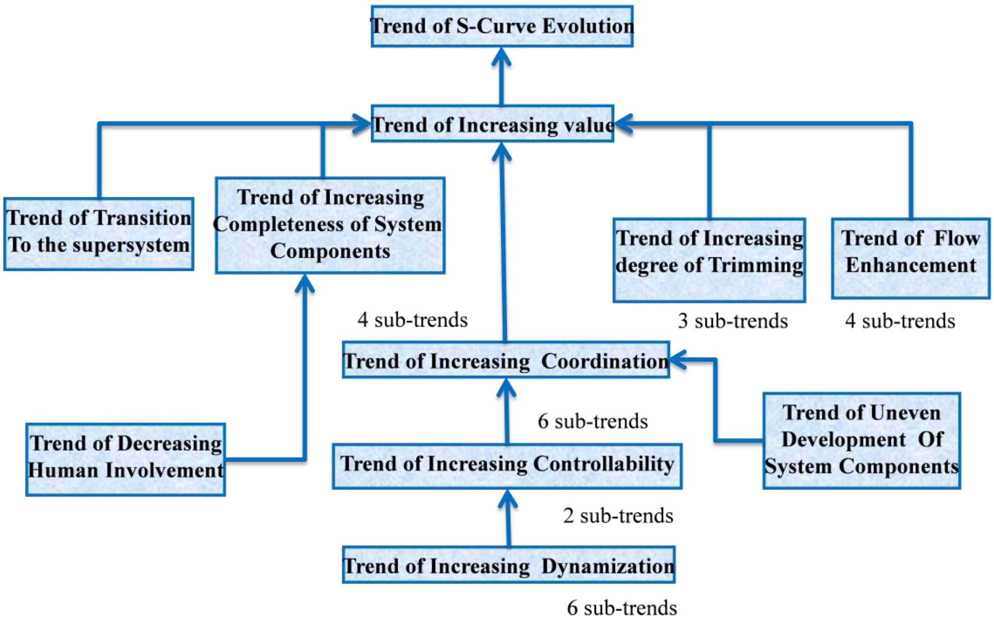

Figure 1. Structural diagram of the relationships of the evolutionary trends

2.2 Similarity Comparison

Dunn and Everitt (1982) listed a binary variable paired observation contingency table (shown in Table 1) by using a two-by-two matrix to express its concept. A matrix variable that equals to one represents that an observed value exhibits the defined characteristics; a matrix variable that equals to zero represents that the observed value does not exhibit the defined characteristics. Among the variables, *a* represents the number of attributes in which observed values *i* and *j* are equal to one and that these two consist of the defined characteristics, which results in successful positive matches; *b* represents the number of attributes in which observed values *i* and *j* are respectively (0, 1), which represents that *i* does not exhibit the defined characteristics and thus pairings are unsuccessful; *c* and *b* have identical concepts and represent the number of attributes in which observed values *i* and *j* are respectively (1, 0), which represents that *j* does not exhibit the defined characteristics; lastly, *d* represents the number of attributes in which *i* and *j* are both zero, which means that neither exhibit these attributes, thereby resulting in negative matches.

Table 1. Paired observation contingency table

i / j	1(Presence)	0(Absence)	Sum

1(Presence)	a	b	a+b
0(Absence)	c	d	c+d
Sum	a+c	b+d	a+b+c+d

Numerous similarity measurement methods exist (Choi et al., 2010; Donald et al., 1989; and Meyer et al., 2004). Ten measurements with their respective computational methods are listed as follows:

$$S_{JACCARD} = \frac{a}{a+b+c} \quad (1)$$

$$S_{Dice} = \frac{2a}{2a+b+c} \quad (2)$$

$$S_{Anderberg} = \frac{a}{a+2(b+c)} \quad (3)$$

$$S_{RUSSELL\&RAO} = \frac{a}{a+b+c+d} \quad (4)$$

$$S_{SOKAL\&MICHENER} = \frac{a+d}{a+b+c+d} \quad (5)$$

$$S_{PEARSON\&HERON-I} = \frac{ad-bc}{\sqrt{(a+b)(a+c)(d+b)(d+c)}} \quad (6)$$

$$S_{OCHIAI} = \frac{a}{\sqrt{(a+b)(a+c)}} \quad (7)$$

$$S_{OCHIAI-\text{II}} = \frac{ad}{\sqrt{(a+b)(a+c)(d+b)(d+c)}} \quad (8)$$

$$S_{YULEQ} = \frac{ad-bc}{ad+bc} \quad (9)$$

$$S_{ROGER\&TANIMOTO} = \frac{a+d}{a+2(b+c)+d} \quad (10)$$

*S represents similarity and the respective subscripts indicate the scholars who proposed each similarity equation.

Through the analysis performed in this study as well as experiments conducted by several graduate students, an improved Dice computational method was adopted, which is presented in Section 3.3.

3. Research Method

This study is primarily based on a new integrated evolutionary trend to construct a computerized mathematical problem-solving tool and enable users to identify relevant evolutionary trends. To generate a convenient mathematical method for identifying solution models, characteristic expressions for the problem, solution model, and trend characteristics must be standardized. The following shows the standardized methods for array expression:

3.1 Problem Characteristics Array and Problem Solution Array

Problem solution characteristics arrays (PSCAs) are primarily used for expressing problem characteristics until the solution characteristics required for resolution are obtained. A PSCA can be divided into two parts. The first part is the problem characteristics array (PCA). The function of this array is to determine the basic core characteristics of problems. The second part is the solution array (SA), which is primarily used for expressing the methods of resolution adopted for problems. An entire case expression can be presented using the PCA and SA, which enables the rapid retrieval of key content when searching for patents and knowledge and accumulating past experiences and knowledge as a database for solving new problems.

However, based on various solving tools, the corresponding characteristics of PCA can be divided into several stages, which are listed as follows:

1) PCA based on parameter conflicts: This stage primarily describes problems in terms of combinations of parameter conflicts. Specifically, the improvement of certain parameters leads to the deterioration of other parameters. This is the attribute perspective. The format for this stage is shown in Fig. 2:

	PCA taking parameters conflict as basis							
Case No.	improved parameters				worsen parameters			
	1(+)	2 (+)	….	m (+)	1 (-)	2 (-)	…	m(-)

i								

Figure 2. PCA diagram based on parameter conflicts

2) PCA based on characteristics and functions: This stage (shown in Fig. 3) is primarily used for describing the initial attributes presented by problems. Consequently, this stage is composed of an attribute array and function array in which the functions are divided into the targeted functions and those that change attributes.

	PCA taking attribute and function as basis											
Case No.	Attribute array				Function array							
	1	2	….	P	1	2	….	P	1	2	….	Q
i												

Figure 3. PCA diagram based on attributes and functions

3) PCA based on the Su-field model: This stage (shown in Fig. 4) primarily describes problems using Su-field relationships and comprises a Su-field array and constraint array. The structure of this PCA is as follows:

	PCA taking Su-field model as basis				
Case No.	Su-field Array				Constraint array
	Tool	Target	Field	Interaction	
i					Nine different solving problem constraints

Figure 4. PCA diagram based on the Su-field model

SA is an array expression for trigger solutions in which TRIZ solution tools can be adopted to present the solving conditions of problems, which generally consists several methods of expression: 40 principles of invention, 51 evolutionary trends, and 76 or 78 standard solutions.

This study investigated technological evolutionary trends as an example; thus, the solution array was expressed using only 51 evolutionary trend stages. Figure 5 shows the method of expression used for SA in this study in which $S_{T,i}$ represents the similarity of stage *i* of trend *T*. An $S_{T,i}$ equal to one represents that trend *T* stage *i* can be used as the possible solution to a problem. Contrarily, when $S_{T,i}$ is equal to zero, trend *T* stage *i* cannot be used as the possible solution to a problem.

Trend1				Trend2			...	TrendT				...	Trend51			
$S_{1,1}$	$S_{1,2}$	$S_{1,3}$	…	$S_{2,1}$	$S_{2,2}$	…	…	$S_{T,1}$	…	$S_{T,i}$	…	…	$S_{51,1}$	$S_{51,2}$	$S_{51,3}$	…

Figure 5. The SA diagram used in this study

3.2 The Trend Characteristic Array

Each stage in the evolutionary trend consists of its corresponding attribute and function characteristics; therefore, these stages can be expressed using trend characteristic arrays (TCAs). In addition, the array contents are identical to that of the basic case array, which is based on attribute functions: The first part is attribute array and the second part is function array, which includes change attributes (indirect functions) and direct functions. However, the major difference is that TCAs do not comprise solution arrays because the trend stage itself is a type of solution (Fig. 6). The evolutionary trend itself is a type of case, which can be first included into the case database for the solution process before collecting past cases.

TCA												
Trend Mth	Attribute array				Function array							
	1	2	….	P	1	2	….	P	1	2	….	Q
1 stage												
2 stage												
…												
Nth stage												

Relative attribute
Change attribute (Indirect function)
Direct function

Figure 6. The TCA

3.3 Mathematical Solving Tools

This study proposed two relevant mathematical concepts. The first part is the concept of classification. Problem models of the TRIZ problem-solving tool that correspond to the solution model belong to the same type of classification. In the second part, problems and cases are individually filtered at similar levels based on a past case solution database to obtain problem solutions. Descriptions for the two methods are as follows:

1) The concept of problem solution classification

After the problems become standardized as PCAs, each solution model can independently determine whether the solutions are problem-relevant solutions or problem-irrelevant solutions toward current PCAs. The classification model can then be coordinated with past solution cases during training to obtain the combined effect of all cases, determine appropriate parameter values as a classification engine, and classify the problem-solving model of the TRIZ problem-solving tool. Thus, each problem-solving model can be trained as classifiers. When new problems are generated, they can be input into the classifier to obtain classified outputs, determine whether the solution model belongs to the trigger solution of such problem, and proceed to classifications determining whether the solutions are relevant to the problem.

Numerous classification methods exist. Theoretically, any classification method capable of the bisection method can be used to construct this classification engine. Methods such as artificial neural network, support vector machine, or the Mahalanobis-Taguchi System are some of the examples; any of these classification methods in coordination with training sets can be used for finding SAs for their corresponding problems, replacing past expert knowledge, and rapidly classifying solution models by using computerized systems, thereby providing robustness in the solutions obtained. Using artificial neural network as an example (Fig. 7), each parameter involved must first be determined when establishing the classification engine; thus, past solution cases (PCAs and SAs) can be used for training for obtaining the suitable configuration of parameter combinations. When problems are queued for solution model classification, corresponding problem characteristic functions are input as nodal points to confirm the solution case and obtain the corresponding principle of invention, trend stage, or standard solution.

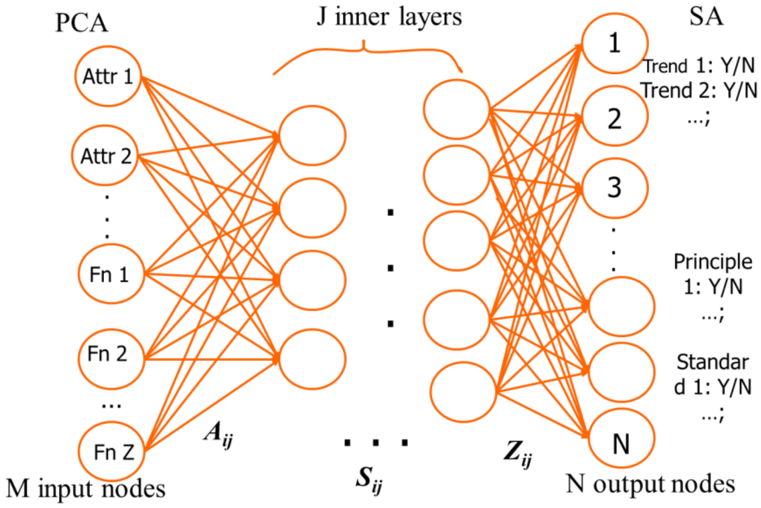

Figure 7. The concept of the artificial neural network application in this study

2) The concept of problem solution similarity

The concept of *similar problems have similar solution models* was assumed as a basis. Using past solution cases in which PCA and SA were used as a database, problems can be described using the form of PCA when encountering new problems to be solved. Such a description is then individually compared with cases in the case database and deduced using the example cases to calculate similarities between the problem model and past solution cases. Identical problems typically have identical characteristics; numerous common characteristics between problems and past cases represent that these problems have high degrees of similarity with the example cases. Thus, the reference solution case models can be used as trigger solutions. Simple matching coefficients, Jaccard's similarity coefficient, and Dice's coefficient are common similarity comparison methods.

This method was adopted in this study to compare the similarities of attributes and functions related to evolutionary trends. The main theoretical basis is that identical types of problems consist of identical attributes and functions. If a case database with a known solution is used as the training set, similarities between the PCA of a problem to be solved and that of the solved problem in the database can be compared. All qualified SAs are output or sorted (in descending order) according to degrees of similarity to provide the recommended priorities and output the first few most similar SAs for solution reference.

Regardless of adopting the classification or similarity comparison concept, specific solutions to the problem can be obtained by referring to corresponding problem models to solution models (see Fig. 8).

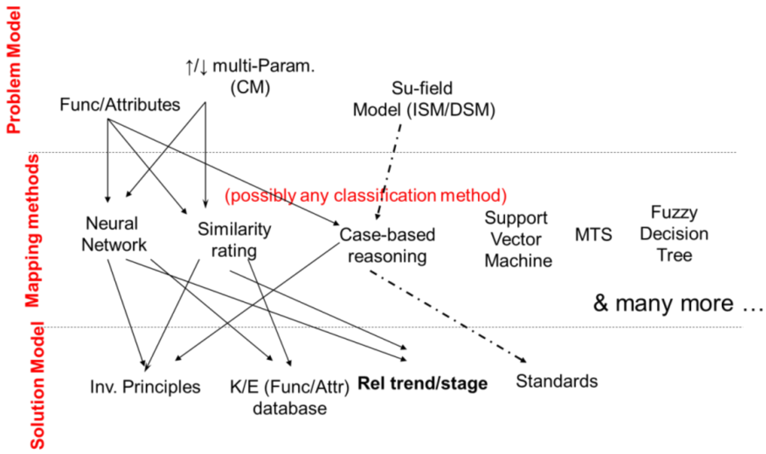

Figure 8. Problem model mapped to a solution array

3.4 Similarity Comparison of Evolutionary Trends

Identical problems must have identical function attributes to apply similarity comparison methods in engineering evolutionary trends. Problems and evolutionary trends that consist of numerous common function attributes represent high degrees of similarity and indicate that the problems are suitable for such evolutionary trends. Hence, the basic function attributes of the problems can correspond to the function attributes of the evolutionary trends to ultimately determine the corresponding solution. The overall solution model is shown in Fig. 9.

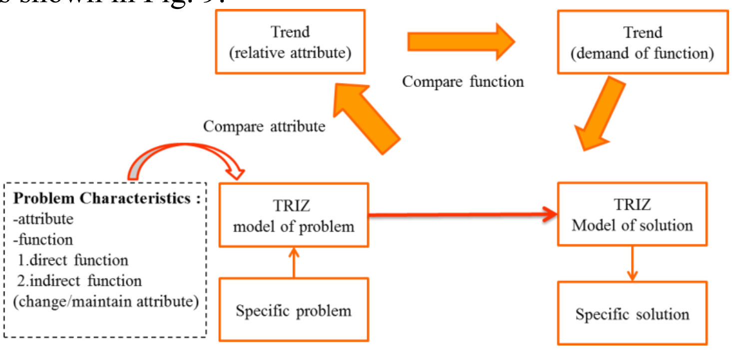

Figure 9. Process illustration of the evolutionary trend solution model

To further complete the overall evolutionary trend, two major evolutionary trends were integrated in this study: Gen3 and Darrell Mann's evolutionary trends. The result was an engineering system-related technological evolutionary trend:

1) Mono-bi-poly (increasing difference) → Source: Gen3/Mann (G/M)
2) Increasing differentiation between main functions → Source: G
3) Deeper integration → Source: G
4) Increased similar integrated systems → Source: G/M
5) Increased various integrated systems → Source: G/M
6) Trend of increasing the completeness of system components → Source: G
7) Stage of coordination → Source: G
8) Smart materials → Source: M
9) Webs and fibers → Source: M
10) Action coordination → Source: M
11) Rhythm coordination → Source: M

12) Coordinating shapes (use as checklist) → Source: G
13) Coordinating rhythms (2) (use as checklist) → Source: G
14) Coordinating materials (use as checklist) → Source: G
15) Coordinating actions (2) (use as checklist) → Source: G
16) Parameters of coordination (use as checklist) → Source: G
17) Device trimming & process trimming → Source: G/M
18) Reducing number of energy conversion → Source: M
19) Increasing conductivity of the flow (use as checklist) → Source: M
20) Improving flow utilization (use as checklist) → Source: G
21) Reducing the conductivity of the harmful/incidental flow (use as checklist) → Source: G
22) Reducing the impact of the harmful flows (use as checklist) → Source: G
23) Reducing human involvement → Source: G/M
24) Increasing asymmetry → Source: M
25) Boundary breakdown → Source: M
26) Geometric evolution (linear) → Source: M
27) Geometric evolution (volumetric) → Source: M
28) Degrees of freedom → Source: M
29) Increasing level of control → Source: G
30) Increasing number of controllable states → Source: G
31) Decreasing density → Source: M
32) Controllability → Source: M
33) Trends of uneven development of system components → Source: G
34) Nesting (down) → Source: M
35) Nesting (up) → Source: M
36) Substance dynamization → Source: G/M
37) Composition dynamization → Source: G
38) Nonlinearities → Source: G/M
39) Single-level to multilevel → Source: G
40) Function dynamization → Source: G/M
41) Field dynamization (use as checklist) → Source: G
42) Space segmentation → Source: M
43) Surface segmentation → Source: M
44) Object segmentation → Source: M
45) Evolution from macro- to nanoscale → Source: M
46) Increasing use of senses → Source: M
47) Increasing use of color → Source: M
48) Increasing transparency → Source: M
49) Reducing damping → Source: M
50) Design point → Source: M
51) Design methodology → Source: M

However, based on the integrated results of the Gen3 and Darrell Mann's evolutionary trends, these evolutionary trends can be further divided into two types: One type has an apparent sequence in the evolutionary stages whereas the other type does not. Therefore, problems can be individually compared to evolutionary trends after being standardized to PCAs. If the attribute array of a certain problem is similar to that of the M^{th} trend and N^{th} stage and the M^{th} trend is an apparent sequential evolutionary stage, then these problems can be considered similar. With these conditions, a current problem can be identified to further determine the functions required for a problem. If the functions provided by the next stage of this trend are identical, then this trend can be a reference solution to a problem (Fig. 10).

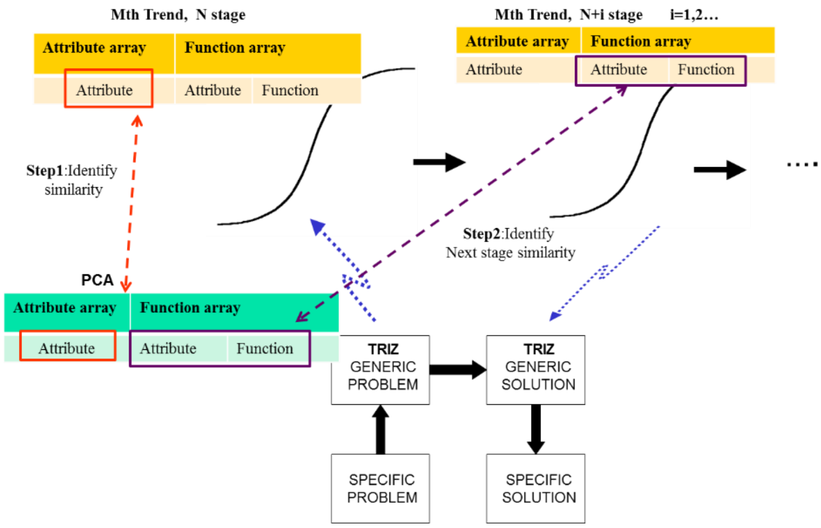

Figure 10. Case comparison with apparent sequence in evolutionary stages

By contrast, if the attribute array of a problem is similar to that of the M^{th} trend and N^{th} stage and the M^{th} trend does not have an apparent sequence in evolutionary stages, then function arrays from the $(M-1)^{th}$ and $(M+1)^{th}$ trend stage can be used for comparison to determine the suitable evolutionary stage as the trigger solution to a problem. This concept is shown in Fig. 11.

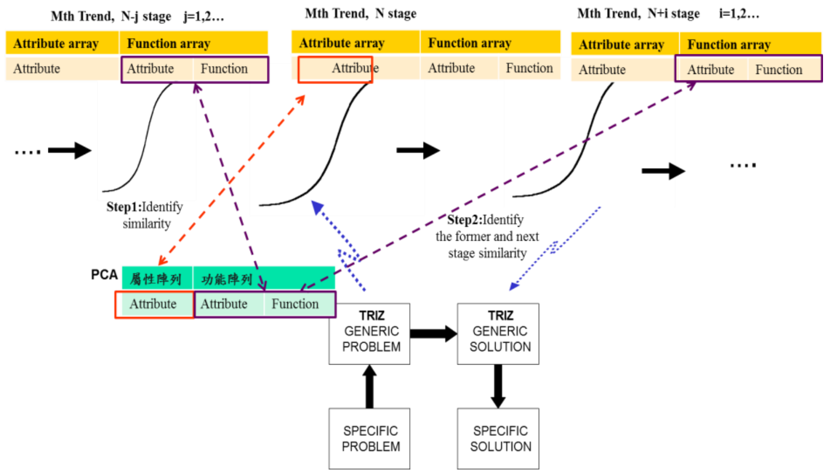

Figure 11. Case comparison without apparent sequence in evolutionary stages

On this simple basis, comparisons between problem characteristic arrays and evolutionary trend stages or past solution cases in the evolutionary trends during this study were mostly zero-to-zero, which represents that neither the problems nor evolutionary trends have used this attribute or function. One-to-one conditions represent that both the problems and evolutionary trends are involved in such attributes or functions. However, one-to-one conditions are more crucial than zero-to-zero conditions necessitating that weights larger than one be given. By contrast, zero-to-zero conditions are of lesser concern than one-to-one conditions. For practical considerations, the aforementioned similarity calculation methods were modified, as shown in Eqs. 11–12. Similarity coefficients were used to distinguish the evolutionary trends that match the problems to be solved and to further determine the stages to which these problems belong as well as directions of future development. This eventually determines the trigger solutions, which were ultimately converted to specific solutions. The overall concept and steps for establishing the mathematical tools are described as follows:

Steps for establishing the mathematical tool:

Step 1: Collecting cases and establishing the case database

During the process of matching solution models, their similarities must be compared. Currently, in addition to the existing trend attribute function characteristics of the 51 evolutionary trends, additional cases must be included to each trend to increase the reliability of problem–evolutionary trend comparisons.

Step 2: Define the PCA

The purpose of this step is to clearly define the function attributes of the overall problem and fill the PCA into function attributes of the problem. When the problem to be solved used relevant function attributes, a value of one is filled in the function attribute field of the problem; when the problem to be solved did not use relevant function attributes, a value of zero is used.

Step 3: Similarity calculations

The similarity concept proposed in this study calculates the function attributes of problems and evolutionary trends. Binary variables are typically calculated using Jaccard's similarity coefficient and Dice's coefficient methods. However, despite using Dice's weighted (1-1) pairs, the weighting values provided did not effectively determine the trigger solutions to the problems in this study; consequently, increasing the (1-1) weighting values may be required. Additionally, this study investigated whether to consider conditions in which both fields are zero. Accordingly, this study developed a modified similarity model in which the function attribute similarities were calculated as follows:

Attribute similarity calculation:

$$^{A}Sim = \frac{^{A}\alpha\, ^{A}a + \, ^{A}\beta\, ^{A}d}{^{A}\alpha\, ^{A}a + \, ^{A}b + \, ^{A}c + \, ^{A}\beta\, ^{A}d} \qquad (11)$$

$0 \leq \, ^{A}Sim \leq 1; ^{A}\alpha, \, ^{A}\beta$ are weighting values

Symbol descriptions:

1) ^{A}Sim represents the similarity coefficient of the attributes between the problem to be solved and the j^{th} stage of the i^{th} evolutionary trend of the new evolutionary trend.
2) ^{A}a represents the number of attributes used by the problem to be solved and the j^{th} stage of the i^{th} evolutionary trend.
3) $^{A}b + \, ^{A}c$ represents the number of attributes individually used by the problem to be solved and the j^{th} stage of the i^{th} evolutionary trend.
4) ^{A}d represents the number of attributes not used by the problem to be solved and the j^{th} stage of the i^{th} evolutionary trend.

Function similarity calculation:

$$^{F}Sim = \frac{^{F}\alpha\, ^{F}a + \, ^{F}\beta\, ^{F}d}{^{F}\alpha\, ^{F}a + \, ^{F}b + \, ^{F}c + \, ^{F}\beta\, ^{F}d} \qquad (12)$$

$0 \leq \, ^{F}Sim \leq 1; \, ^{F}\alpha, \, ^{F}\beta$ are weighing values

Symbol descriptions:

1) ^{F}Sim represents the similarity coefficient of the functions between the problem to be solved and the

j^{th} stage of the i^{th} evolutionary trend.

2) ${}^{F}a$ represents the number of functions used by the problem to be solved and the j^{th} stage of the i^{th} evolutionary trend.
3) ${}^{F}b + {}^{F}c$ represents the number of functions individually used by the problem to be solved and the j^{th} stage of the i^{th} evolutionary trend.
4) ${}^{F}d$ represents the number of functions not used by the problem to be solved and the j^{th} stage of the i^{th} evolutionary trend.

The aforementioned descriptions showed the similarity calculation method for function attributes. The overall process for problem comparison is shown in Fig. 12. However, the similarities of the problem to be solved can be primarily compared to the two parts in the evolutionary trend itself and past solution cases. The first part is the similarity comparison of the evolutionary trend itself. Each trend is a type of trigger solution and thus has no solution array. The second part compares past solution cases with the problem to be solved. All past cases have defined solution arrays; problem stages and solution stages are clearly identified. Accordingly, the two parts of similarity comparison slightly vary. The similarity comparison processes of these two parts are separately introduced as follows:

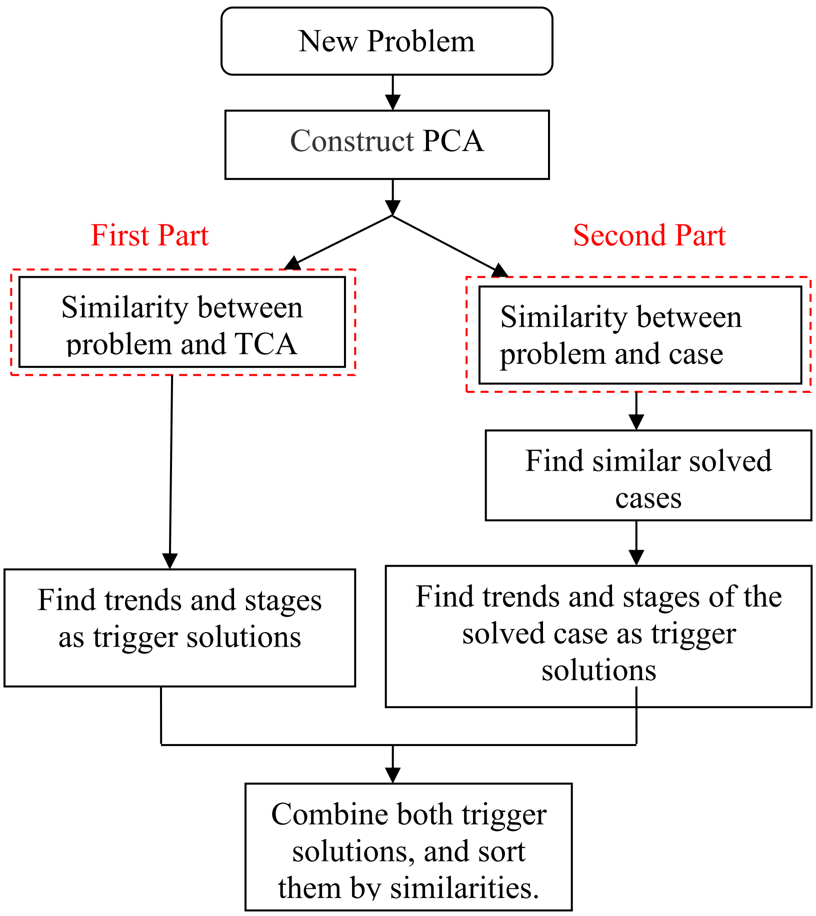

Figure 12. Overall process of similarity comparison

1) First part of Fig. 12: Similarity comparison process for the PCA to be solved and evolutionary trends

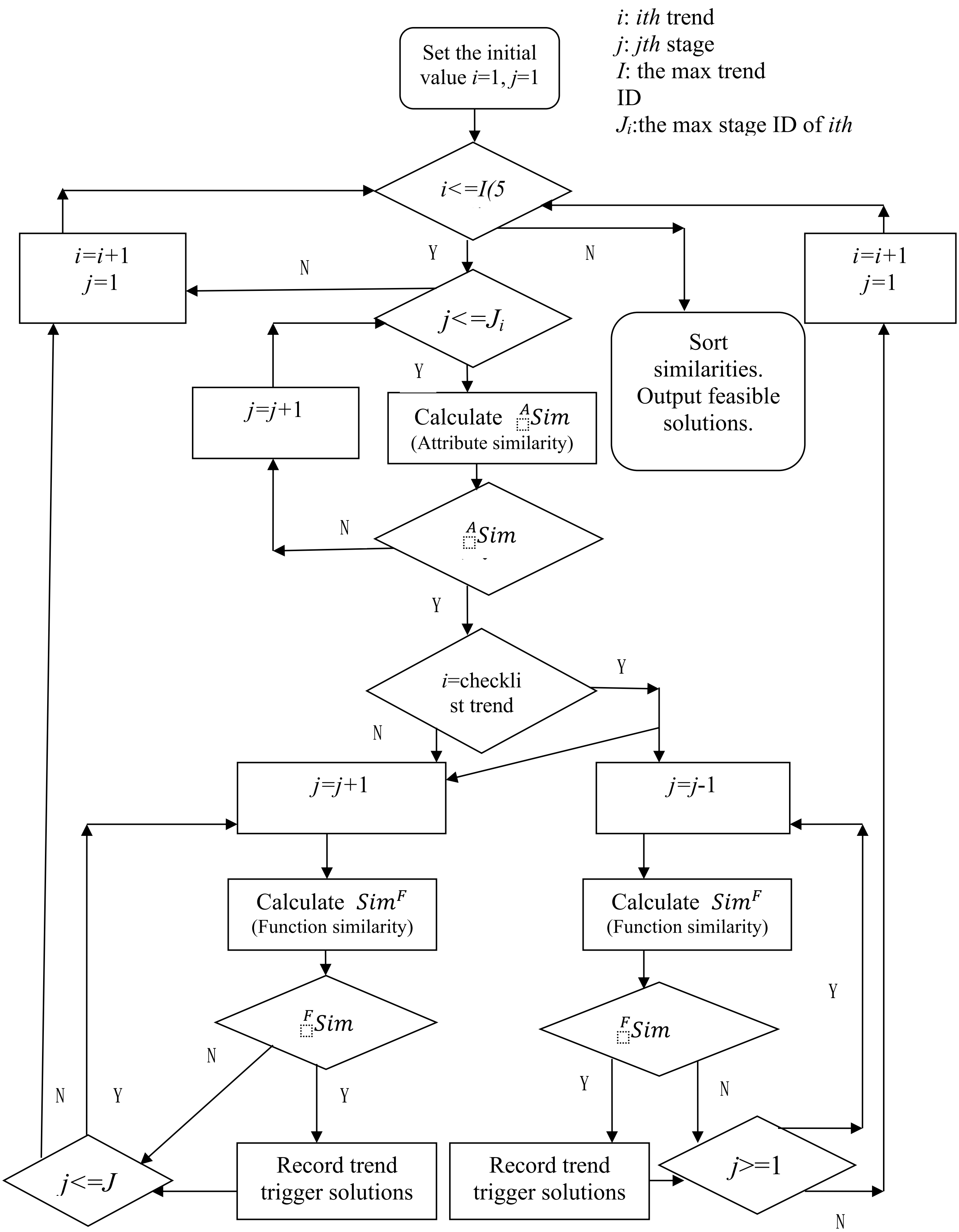

Figure 13. Similarity comparison process for the evolutionary trends and PCA

Step 1: Set initial values

Set $i = 1$ and $j = 1$ represents calculating the attribute and function similarities from the first stage of the first evolutionary trend.

Step 2: Determine whether $i <= I(51)$

The expression $I(51)$ represents that the model currently consists of 51 trends. During attribute and function similarity calculations, whether a trend is less than or equal to the maximum number of trends must first be determined. When test results shows that the trend i is less than the maximum number of trends, calculation continues. By contrast, the trend i that is equal to the maximum number of trends represents that all trends have completed similarity calculations. Thus, overqualified trends can be sorted and previous k feasible trigger solutions or all solutions are output.

Step 3: Determine whether $j <= J_i$

The variable J_i represents the number of stages in trend i; an A j value greater than J_i represents that all stages have completed similarity calculations. The calculation must proceed to the next trend, reset j to one, and begin from the first stage of the proceeding trend. If $j <= J_i$, the trend has not completed all stages of calculations and calculation on the attribute and function similarities of this trend can proceed.

Step 4: Calculate ${}^{A}Sim$

The expression ${}^{A}Sim$ represents attribute similarities between a problem and an evolutionary trend and is calculated using Eq. 11.

Step 5: Determine whether ${}^{A}Sim >= L_A$

The symbol L_A is a qualification for attribute similarity. During the similarity calculations of each problem and trend, the similarities must be greater than a certain level to serve as the trigger solution to the problem. If ${}^{A}Sim$ qualifies, calculations proceed to Step 6, otherwise $j = j + 1$ and calculations proceed to the next stage of the trend and return to Step 3.

Step 6: Determine whether i = checklist trend and calculate ${}^{F}Sim$

A checklist trend represents that this trend belongs to a trend without an apparent sequence in evolutionary stages. The variable ${}^{F}Sim$ represents the function similarity of the problem and evolutionary trend (Eq. 12). If trend i = checklist trend, trend i stage j may proceed to stage $j - 1$ to calculate ${}^{F}Sim$ in the past stage and proceed to stage $j + 1$ to calculate ${}^{F}Sim$ in the next stage; if trend i does not equal to checklist trend, calculations then only proceed to determine ${}^{F}Sim$ in the next stage ($j + 1$).

Step 7: Determine whether ${}^{F}Sim >= L_F$

The variable L_F is the qualification for function similarity. If the function similarity is larger than the qualification standard, trend stage records are used as trigger solutions to the problems, otherwise j must be reevaluated to check whether $j < J_i$. If $j < J_i$, calculations may proceed to the next stage ($j + 1$) to determine ${}^{F}Sim$ or the next trend ($i + 1$) and return to Step 2.

Step 8: Repeat the aforementioned process

When similarity calculations for all evolutionary trends are completed, the similarities of all feasible trigger solutions can be sorted (in descending order) followed by outputting the past k (decided by the solver) number of feasible trigger solutions or all trigger solutions greater than the qualifying standard as trigger solutions for the problem. Lastly, trigger solutions are converted to specific solutions to the problem.

2) Second part of Fig. 12: Similarity comparison process for PCA to be solved and past solution cases

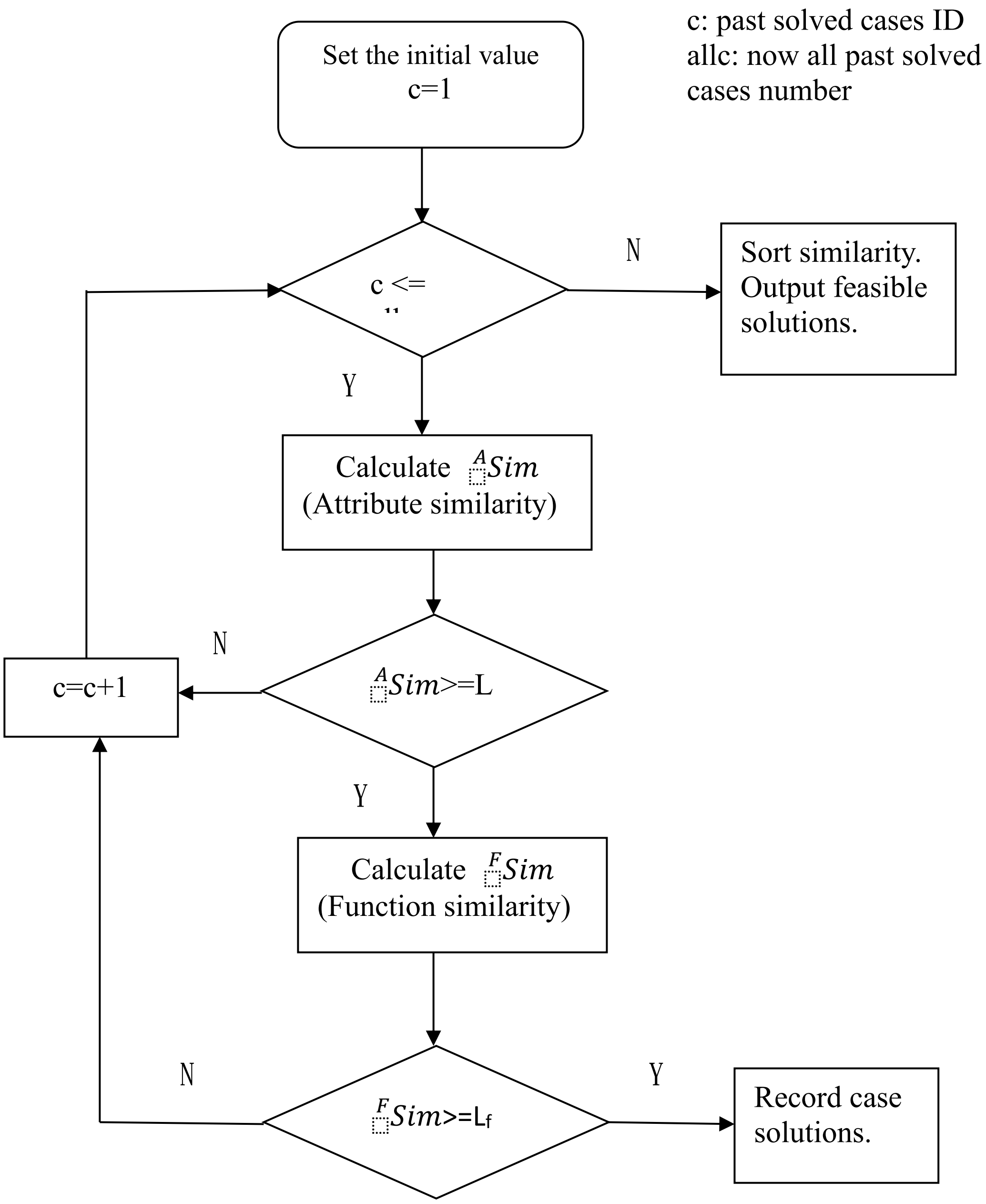

Figure 14. Similarity comparison process for PCA to be solved and past solution cases

Step 1: Setting initial values

Set c = 1, which represents calculating attributes and function similarities from the first case number.

Step 2: Determine whether $c <= allc$

The variable *allc* represents the total number of all past solution cases. Duly, when calculating attribute and function similarities, *c* must be checked to see if it is less than or equal to the current total number of cases. If the case number is less than the total case number, calculations proceed to Step 3. By contrast, if the case number is equal to the total case number, similarity calculations for all cases have been completed. Thus, this test can be combined with the similarity comparison process between the evolutionary trend itself and the PCA and sort their corresponding trigger solutions that are greater than the qualifying standard. Moreover, the initial k number of feasible trigger solutions or all solutions can be output.

Step 3: Calculate ${}^{A}Sim$ and determine whether it is greater than L_A

The expression ${}^{A}Sim$ represents the attribute similarity between PCA and past case examples (Eq. 11). The variable L_A represents the qualification for attribute similarities. Similarities between the problem and past cases must be greater than a certain level to serve as a problem's trigger solution. Thus, the similarity must be verified to observe whether it is greater than the attribute qualification value. If the similarity is greater than the qualification value, calculations proceed to Step 4, otherwise $c = c + 1$ and calculations proceed to the next case number and return to Step 2.

Step 4: Calculate ${}^{F}Sim$ and determine whether it is greater than L_F

The expression ${}^{F}Sim$ represents the function similarity between PCA and past cases (Eq. 12); L_F represents the qualification for function similarities. If the similarity is greater than the qualification value, the case solution record can serve as the trigger solution to the problem, otherwise $c = c + 1$ and calculations proceed to the next case number and return to Step 2.

Step 5: Repeat the aforementioned steps

If the similarity calculations for all past solution cases have been completed, similarity comparison results from the evolutionary trends itself can be combined to sort (in descending order) all the feasible trigger solutions for past solution cases and the problem and output the initial k number (decided by the solver) of feasible trigger solutions or all trigger solutions greater than the qualifying standard as the trigger solutions to the problem. Lastly, trigger solutions are converted to specific solutions to the problem.

3.5 Setting Similarity Parameters

Similarity comparison processes consist of setting numerous unknown parameters. Each type of parameter combination substantially influences the solution model output. The Taguchi method was used in coordination on parameter setting to objectively obtain the optimal parameter combinations. The calculations target maximizing the case solution hit rate. Design function properties were compared with paired weighting and function attribute qualification parameters were combined to provide an objective and efficient parameter setting:

The study process is as follows:

1) Setting factor standards for a total of six factor parameters, which comprise (1-1) weighting ${}^{A}\alpha$ and (0-0) weight ${}^{A}\beta$ from the attribute similarity equation, Eq. 11, and (1-1) weighting ${}^{F}\alpha$ and (0-0) weight ${}^{F}\beta$ from the function similarity equation, Eq. 12.
2) Determine whether factor standards satisfy conditions without considering (0-0) to prevent considering a (0-0) pairing caused by setting a standard that is too low.
3) Proceed to conducting a Taguchi experiment after confirming the appropriate factor standards. The target is to optimize case solution hit rates and determine the optimal parameter combinations.
4) Lastly, the following table was produced based on experiments:

Factor	Attribute qualification	Function qualification	Attribute(1-1) weighting	Attribute(0-0) weighting	Function(1-1) weighting	Function(0-0) weighting
Parameter value	0.6	0.7	6	0	8	0.2

4. Software Construction

A simple operating interface for the mathematical problem solving tool in this study was constructed using the Matlab graphic user interface. The primary purpose was to enable users to rapidly search for new evolutionary trend solutions from a variety of new evolutionary trends through the aid of this software.

However, a case database must first be constructed for conducting mathematical comparisons before writing the software. The case database was primarily based on cases on the evolutionary trends as well as past solution cases, the attribute property characteristics of which were further expressed. The first half of the case database consisted of cases from the evolutionary trends itself; the second half of the database expressed past solution cases.

4.1 Inputting the Problem

The interface window shown in Fig. 15 appears after opening the executable file. The PCA of the evolutionary trend were primarily based on attribute and function stages. Thus, the first array in the interface is the attribute array; problems matching the attribute characteristics were marked with the value 1 and the problems not matching the attribute characteristics were marked with the value 0. The second array showed changed or maintained attribute arrays (indirect functions) in the function stage. If the attribute of the problem was to be changed or maintained, it was marked with 1; if the attribute of the problem was not to be changed or maintained, it was marked with 0. Lastly, the third array is the function array (direct function). The method of expression was identical to the aforementioned methods: targeted functions were marked by 1; nontargeted functioned were marked by 0.

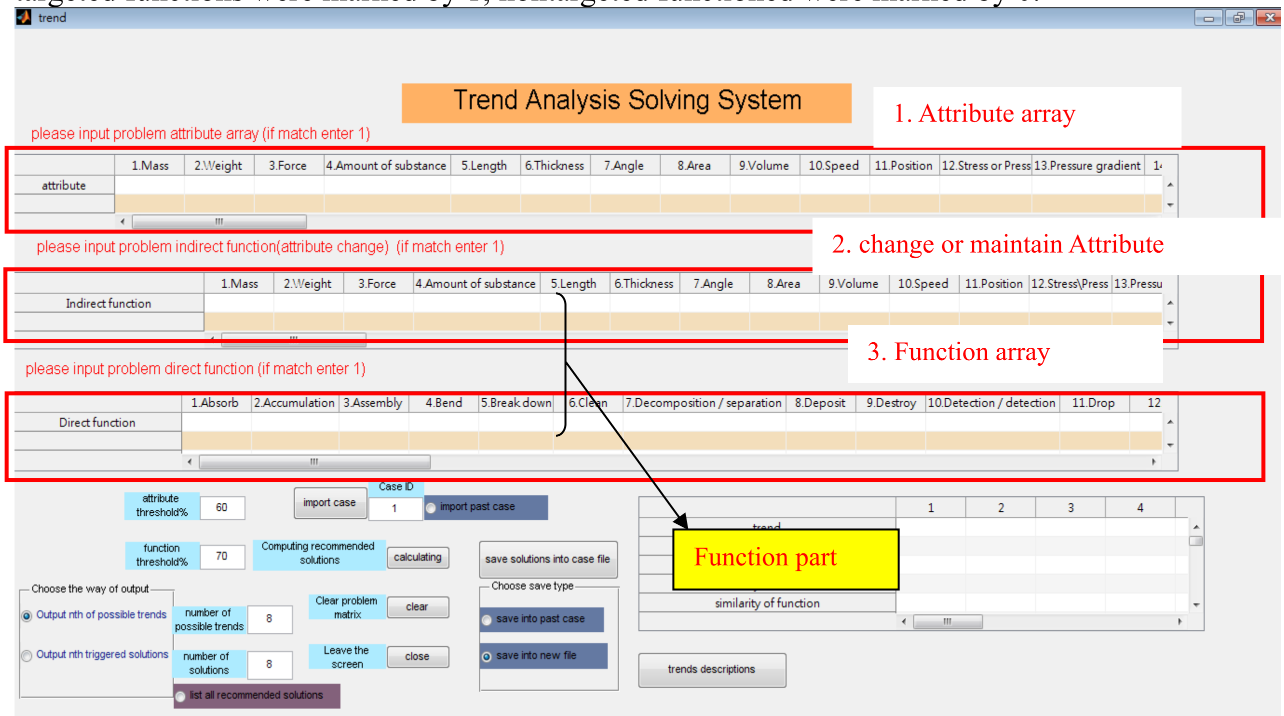

Figure 15. Input window of the software interface

However, if reading the PCA of past cases is desired, users can access past cases using the case database *case.xlsm*. The user must select the *import case* button on the software interface as shown in Fig. 16 and enter the desired case number on the side. After opening the case.xlsm file and clicking on the *select past case PCA* button, the software automatically assesses the PCA of the selected case and closes after the file has been read.

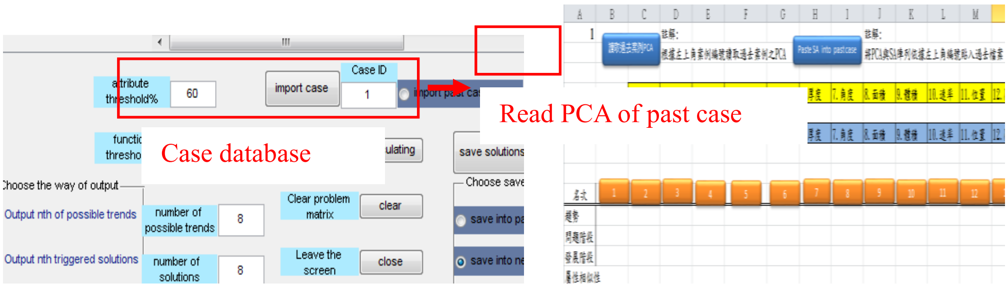

Figure 16. Accessing the case database

In addition, users can also write the case PCA in a case and have it assessed by the software through opening the case database. Upon completing the PCA, users can click the *finish* button, during which Excel automatically enters zero values for unrelated attributes and functions to simplify software assessment (shown in Fig. 17). Moreover, during the PCA construction process, input mistakes or deletions in the cases can be modified by clicking the *clear* button to delete the PCA contents.

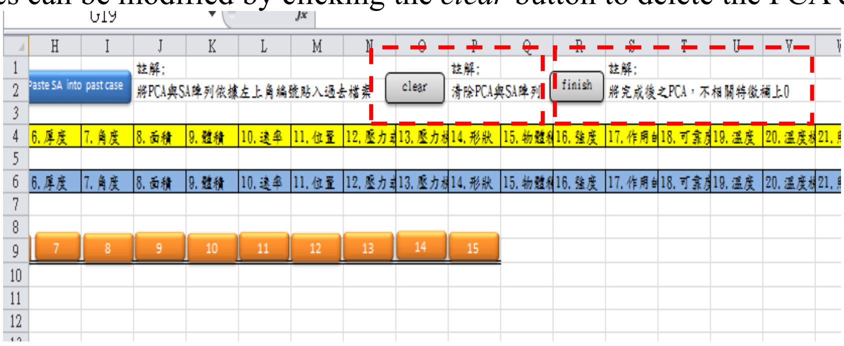

Figure 17. Writing PCA in the case database

4.2 Outputting Solution Database

After the PCAs of the problems to be solved are entered into the software, the similarities between the PCAs and example cases in the database can be further compared. Before conducting similarity calculations, users can manually enter attribute (1) and function (2) qualifying values and the number of output trend solutions (3). However, only two types of output methods can be selected. The first type is the desired number of output trends; thus, trigger solutions with multiple stages in the same trend is possible for reference. The second type of output method is the desired number of output trigger solutions. Therefore, the number of output trends may be limited. However, the number of output trend solutions is generally recommended for the first eight trends with the highest similarities. In this system, the evolutionary trends currently consist of 51 trends. Outputting the trigger solutions of eight evolutionary trends represents outputting the foremost 15.4% trigger solutions with the optimal trends, but users can also manually modify the parameter values.

After inputting appropriate parameters, the user can click the *computing-recommended solutions* button to proceed to similarity calculations (Fig. 18).

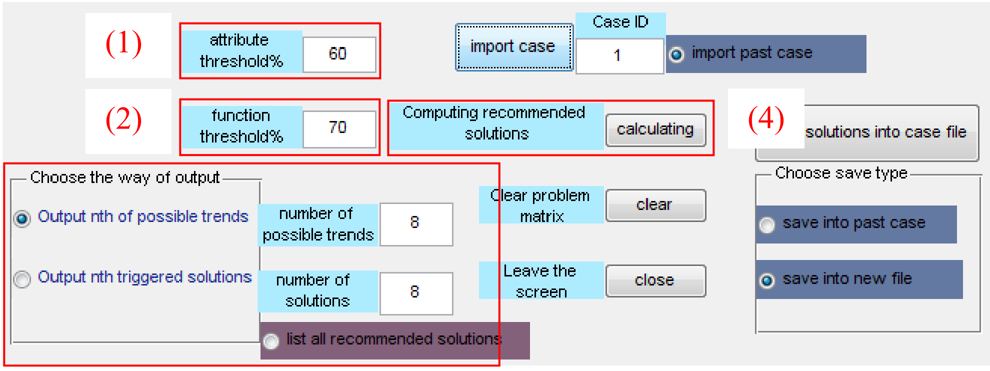

Figure 18. Input parameters on the user interface

After clicking on the computing-recommended solutions button, the software automatically outputs the possible trigger solutions. The user can also convert the provided trigger solutions into specific solutions corresponding to the problem (Fig. 19). However, if outputting all feasible trigger solutions greater than the qualifying value is preferred, the user can click on the *list all recommended solutions* button to provide users all the possible trigger solutions.

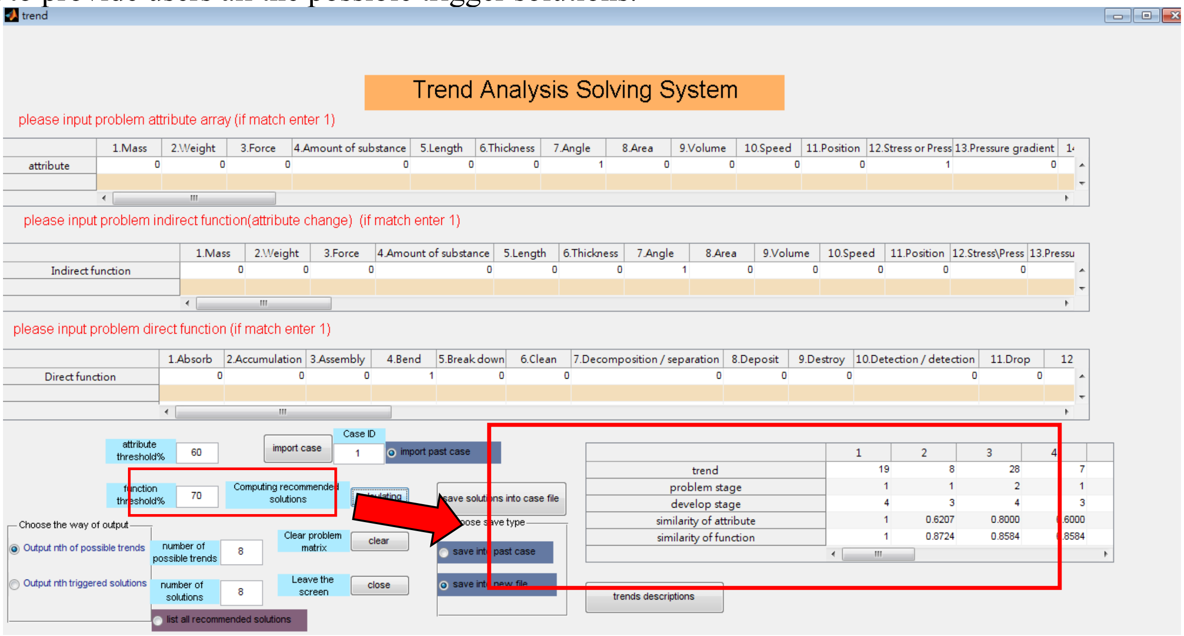

Figure 19. Feasible trigger solution output

To record the case-solving process and benefit case-file archives, a saving option was also made available for user. Users can select one of the two saving options beside the *save solutions into case file* button. The first option is to output the resulting solution records from the software to the case database case.xlsm so that the user does not have to rerun the software when rechecking the trigger solutions of a case example. The complete output is shown in Fig. 20. If this case example is a case from the past case database, the user can click on the *paste SA into past case* button and then the case is directly pasted on the original case file. This option provides the user an extremely convenient method for updating cases. Additionally, the rank numbers of SA trigger solutions can also be directly selected, which automatically links trigger solutions to their corresponding problems and development stages associated to a specific trend. The problem stage is marked in blue and the development stage is marked in yellow to render user checks convenient (Fig. 21). The other method also enables independently saving a new case file (Fig. 22). After selecting this method, the user is reminded to input an appropriate file name after which the software automatically saves this file.

Figure 20. Complete output of the case database

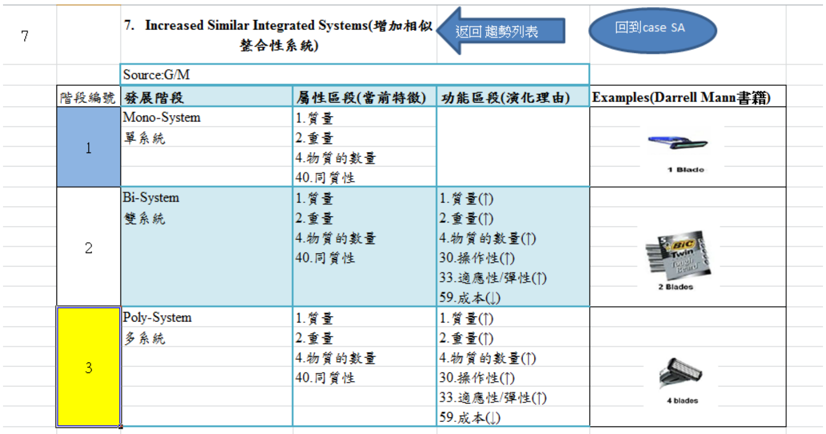

Figure 21. Contents of the SA trigger solution

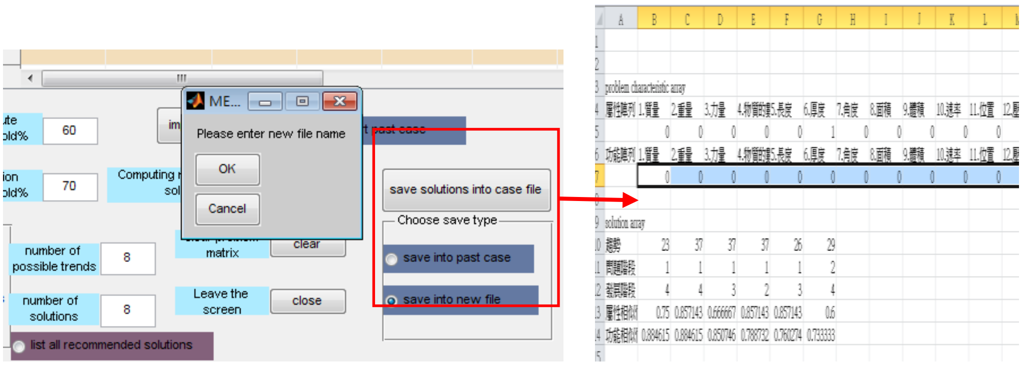

Figure 22. Saving the output trigger solution in a new file

However, trigger solutions that are output by the software are only expressed in evolutionary trend numbers in the software interface which often renders users unable to immediately recognize the evolutionary trend. In these situations, the user can select the *trend descriptions* button to conveniently obtain relevant content regarding an evolutionary trend. As shown in Fig. 23, a list of all evolutionary trends appears immediately after the user clicks the trend descriptions button. The user can then click on the *detailed descriptions* button to display the information regarding a specific trend. Moreover, examples were also provided beside the contents of evolutionary trends. To return to the main listing display, an arrow was provided beside the trend contents to automatically return to the display of evolutionary trend listing (Fig. 24).

Figure 23. List of evolutionary trends

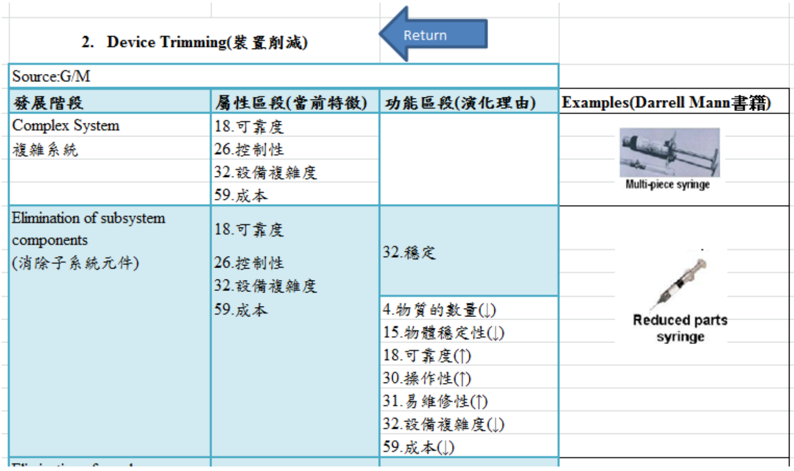

Figure 24. Evolutionary trend contents

Based on the new evolutionary trends, a simple operating interface was established in this study. Then, recommended evolutionary trend solutions were obtained through the verification of case examples, which are discussed in Chapter 5.

5. Case Verification

Based on evolutionary trends, the similarities of the problem and case database were compared to determine the possible trigger solutions to the problem. Through applying k-fold cross-validation and designing engineering evolutionary trend surveys, the method of similarity comparison was verified.

5.1 K-Fold Cross-Validation

To increase the reliability of the problem-solving process, the k-fold cross-validation method was adopted in this study to determine whether the case database comparison still reached the original solution capability of the case example, thereby confirming the robustness of the case database. In 124 case examples, a 4-fold cross-validation in test groups of Ki (i = 1,…, 4) was adopted. Thus, each test group consisted of 31 cases in which each case was trained and tested. The best, worst, and random output trigger solutions were used to determine whether these solutions hit original case solutions.

	k_fold(1)	k_fold(2)	k_fold(3)	k_fold(4)	overall average
Positive	0.935484	0.870968	0.903226	1	0.927419355
Negative	0	0.032258	0	0	0.008064516
Random	0	0.032258	0.129032	0.064516	0.056451613

Table 2. The overall performance obtained from k-fold cross-validation (on hitting the original solutions)

The four sets of test results showed the hit rates of positive, negative, and random trigger solutions, and these results can be further integrated. As shown in Table 2, the case solution hit rates for positive trigger solutions reached over 90%; by contrast, the case solution hit rates for negative trigger solutions were extremely low, and case solution hit rates for random trigger solutions were less than 10%. Yet, to clearly determine the significant differences between positive, negative, and random trigger solutions, hypothesis testing was applied to the results in Table 2:

1) Output methods of the eight best and random similarity trigger solutions

$$H_0: \mu_{8\_best} <= \mu_{8\_random}$$
$$H_1: \mu_{8\_best} > \mu_{8\_random}$$

Output results from the Minitab software:

Two-sample *t* test and confidence interval: Eight best and eight random solutions

Two-sample *t* test for the eight best vs. eight random solutions

	N	Mean	StDev	SEM
Eight best	4	0.9274	0.0551	0.028
Eight random	4	0.0565	0.0551	0.028

Difference = μ_{8_best} - μ_{8_random}
Estimate for difference: 0.870968
95% lower bound for difference: 0.795271
t test of difference = 0 (vs. >): *t* value = 22.36
p = .000
DF = 6

The analysis results showed that $p = .000 < \alpha = .05$; therefore, H_0 was rejected in this study, which verified that the case solution similarity hit rate of the eight best trigger solutions were statistically higher than that of the randomly selected trigger solutions. This demonstrates the effectiveness of the similarity comparison method applied in this study.

2) Output method of the eight best and worst similarity trigger solutions

$$H_0: \mu_{8\_best} <= \mu_{8\_worst}$$
$$H_1: \mu_{8\_best} > \mu_{8\_worst}$$

Output results from the Minitab software:

Two-sample *t* test and confidence interval: Eight best and eight worst solutions

Two-sample *t* test for the eight best vs. eight worst solutions

N	Mean	StDev	SEM

Eight best	4	0.9274	0.0551	0.028
Eight worst	4	0.0081	0.0161	0.0081

Difference = μ_{8_best} - μ_{8_worst}
Estimate for difference: 0.919355
95% lower bound for difference: 0.851809
t test of difference = 0 (vs. >): *t* value = 32.03
p = .000
DF = 3

The results showed that when α = .05, *p* = .000, thus *p* < α, which represents that H_0 was rejected. This proved that the case solution similarity hit rate of the eight best trigger solutions were statistically higher than that of the eight worst trigger solutions.

3) Summary
The results from a one-tailed *t* test showed that regardless of the eight trigger solutions of random selections or worst similarities, neither output methods were significantly superior in problem solving performance to the eight trigger solutions of the highest similarities. Hence, the solving power of the eight trigger solutions of the highest similarities was superior to the outputs of other methods.

5.2 Survey of engineering evolutionary trends

A survey of engineering evolutionary trends was designed based on software output. Each survey consisted of various cases and individually provided eight trigger solutions of the highest (positive) and lowest (negative) similarities and random selections as a reference for survey participants. The results were then used to determine whether the provided trigger solutions can be converted to specific solutions to the problems and that this mathematical method was substantially effective.

Therefore, the positive, negative, and randomly selected trigger solutions of all the cases were statistically analyzed by averaging the number of specific solutions successfully converted to calculate the proportion of problems solved. The results are presented in Table 3. Table 3 shows that the solving power of the eight trigger solutions of the highest similarities was approximately 52%, which represents that more than half of the trigger solutions output by the software can be converted into specific solutions. However, only 18% of the randomly selected trigger solutions can be converted into specific solutions to the corresponding problems and only approximately 10% of the trigger solutions of the lowest similarities can be used to solve the corresponding problems. Thus, this result verified that positively output trigger solutions have comparatively superior solving power.

Table 3. Survey verification results

	Positive solving effect	Negative solving effect	Random solving effect
Proportion of specific solutions converted	0.5261	0.1079	0.1869

Verification result:

Based on the two verification methods of k-fold cross-validation and engineering evolutionary trend surveys, the effects of the proposed method in this study were obtained (Table 4).

Table 4. Verification results

Total number of cases	Average output trigger solution	Proportion of specific solutions (the first eight)	Case hit rate
124	14.34	0.5261	0.927

The eight trigger solutions of the highest similarities were generally used as ideas for problem solving in this study. Thus, after verification using 4-fold cross validation, a case hit rate of approximately 93% was obtained. However, to investigate the influence of output trend trigger solutions on case solution hit rates, additional sensitivity analysis is required to adjust the output number of trend trigger solutions. The resulting change in case solution hit rates was then used to determine the influence on succeeding problem-solving processes. Table 5 shows the case solution hit rates for two, four, six, eight, nine, and 10 trend trigger solutions. Outputting only two trend trigger solutions certainly caused comparatively lower case solution hit rates. However, an increase to nine trend trigger solutions substantially increased case solution hit rates and almost entirely hit the case solution. When the number of trend trigger solutions increased to 10, these trigger solutions matched case solutions at a 100% hit rate.

Number of output trend trigger solutions	k_fold(1)	k_fold(2)	k_fold(3)	k_fold(4)	overall average
2	0.741935	0.645161	0.677419	0.806452	0.717742
4	0.774194	0.774194	0.741935	0.935484	0.806452
6	0.83871	0.806452	0.83871	0.967742	0.862903
8	0.935484	0.870968	0.903226	1	0.927419
9	0.967742	1	1	1	0.991935
10	1	1	1	1	1

Table 5. Results of changing the number of trend trigger solutions

Based on Table 5, the results of the sensitivity analysis are shown in Fig. 26. The number of trend trigger solutions is positively correlated with case solution hit rates. Thus, the number of output trend trigger solutions substantially influenced case solution hit rates regardless of increasing or decreasing the number of output trend trigger solutions. Outputting the ten most similar trend trigger solutions certainly resulted in comparatively superior problem solving power.

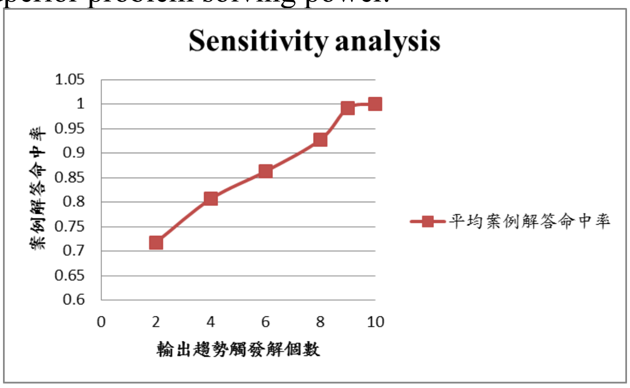

Figure 26. Sensitivity analysis on the number of trigger solutions

6. Conclusion

Integrated new evolutionary trends were used as an example in this study. A mathematical solution model was constructed through similarity comparison to ultimately obtain the corresponding trend solutions and convert them into feasible solutions. However, engineering evolutionary trend surveys also showed that the proportion of specific solutions converted from trigger solutions were substantially higher in the eight most similar trigger solutions than in those with lesser similarities. Thus, this comparison method was certainly effective for problem solving. The overall contributions of this study are as follows:

1) A past solution case database was constructed to enhance the robustness of problem–database comparisons.
2) PCAs and SAs were developed to standardize problems and simplify mathematical calculations.
3) Common attributes and functions were organized and gathered as a reference for expressing PCAs and SAs and continuing further research development.
4) Gen3 and Darrell Mann's evolutionary trends were integrated along with similar trends in which the corresponding evolutionary stages were completely defined to complement the deficiencies in both evolutionary trends. Eleven main trends from Gen3 were further developed into 17 main trends in this study.
5) A standardized function attribute table for new evolutionary trends was established; an evolutionary cause for the new overall evolutionary trend was ultimately defined.
6) A mathematical similarity concept was used to enable objective and rapid searches for the most probable trend and stage of the trigger solutions to prevent being extremely reliant on expert opinions.
7) Optimized methods were applied to determine similarity parameter settings.
8) A computer-aided trend identification system was constructed to prevent laborious manual comparison processes and automatically and rapidly identify feasible solutions to the provided problems.

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Application of Lean and TRIZ Methodologies in the Maintenance Service of a Food Company

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Abstract

Industrial maintenance is becoming more important in business. Current requirements force managers to seek new forms of organization, using techniques and methodologies that are commonly used in the management of other functional areas of business.

Improvement of the maintenance department of a company in the food sector was established as the main goal of the study. The analysis of existing maintenance activities in the company was performed with the use of certain Lean and TRIZ methodology techniques.

From the point of view of Lean Thinking, some waste have been identified both in factory production as well in the maintenance service. Solutions to reduce or eliminate the identified waste were proposed. The solutions have emerged through the application of the main TRIZ techniques together with various Lean methodology analytical tools and maintenance recent theories: 5 S, Kaizen, PDCA (Plan-Do-Check-Act), TPM, Autonomous Maintenance and Value Stream Mapping.

Some solutions are short-term applications, other are medium-term and others are long-term applications. The implementation of Lean-TRIZ solutions would have a very positive impact, with results in improving the maintenance service and employee motivation.

Keywords: Lean, Maintenance, TPM, TRIZ.

1. Introduction

Increasingly, the manufacturing facilities of industrial companies consists of automated systems for industrial processes with more complex mechanisms and the most varied type of machines. The need to ensure fewer stops due to equipment malfunctions and under specific conditions, caused an increasingly important role of the industrial maintenance.

The present work aimed to study of the maintenance service of the food business company Dan Cake (industrial unit situated in Póvoa de Santa Iria, Portugal).

The study focused on the analysis of the maintenance department and in the elaboration of proposals aimed at increase its efficiency and to improve the organization.

Lean and TRIZ methodologies were the main elements of the study. The implementation of the methodology involves the application of several techniques in order to identify waste and to provide solutions that reduce or eliminate waste those found.

With the implementation of solutions based on the Lean methodology, it is intended that the preventive maintenance activities will increase and the corrective and curative maintenance activities will decrease.

2. Lean Methodology

In today, any company wishing to be competitive will have to invest in management programs, methods and technologies in order to differentiate itself from their competitors. Currently, one of the most popular investment choices, is the Lean production (Demeter and Matyusz, 2011).

The birth of the Lean production had its origin in Japan, within Toyota automobile construction company, by Taiichi Ohno in 1940. The Toyota Production System (TPS) was based on desire to produce a continuous-flow process, in which did not depend on long production runs to be efficient (Melton, 2005).

This was exactly the opposite of what was done in the Western world where the mass production, initially developed by Henry Ford, was based around the planning of material requirements and complex computer systems. This production method was based on producing with a high volume of stock (Melton, 2005).

When Taiichi Ohno began to build the foundations of Lean production, he began by examining the production systems used in the West, which in his opinion had two failures (Holweg, 2007):

(1) The first failure was that the production of high batches would result in excessive inventories, This would make that they increase capital costs and the warehouse space.

(2) The second failure consisted in the inability to adapt to customer preferences for greater product diversity.

His main concerns were mainly the reduction of the cost of production through the elimination of waste (Holweg, 2007).

In order to describe the concept of the work philosophy and practices of the Lean production by the Japanese companies, particularly Toyota with TPS, it was established that the Lean production should address the continuous process improvement through a variety of tools and methods. It would then necessary reduce the waste and activities that do not add value but also connect all the steps that contribute with value. The Figure 1 represents the activities with added value and no added value.

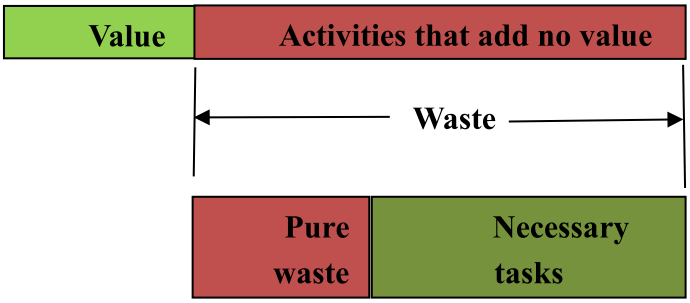

Figure 1. Value-added activities and non-value added activities (adopted from Nogueira, 2010).

The Lean philosophy is based on the implementation of several methods that aid in the identification of existing waste and improvement solutions in a production system or in the maintenance.

3. Systematic Innovation in Engineering with TRIZ Methodology

The Theory of Invention Problem Solving is a methodology especially suitable for solving problems in science and engineering. The TRIZ methodology seeks to solve the problem of solutions generation. This approach was developed by Genrich Altshuller from 1946 (Altshuller, 1995). TRIZ is a systematic methodology oriented for humans, based on knowledge, for inventive problem solving (Savransky, 2000).

Altshuller examined more than one and a half million patents and found that certain problems are often solved in different technical fields using only a small number of principles of invention. Altshuller systematized the solutions described in patent applications, dividing them into five levels (Altshuller, 2001):

- Level 1: Routine solutions using well known methods in the respective area of specialty. This category represents around 30% of the total.

- Level 2: Minor corrections in existing systems, using methods well known in the industry. Around 45% of the total.

- Level 3: Major improvements that resolve contradictions in typical systems of a given branch of industry. Around 20% of the total. This is where creative design solutions appear.

- Level 4: Solutions based on the application of new scientific principles. About 4% of the total.

- Level 5: Innovative solutions based on scientific discoveries not previously exploited. Less than 1% of the total.

TRIZ aims to assist the development of projects and the solutions generate, especially in environments characterized by profound changes or based on the application of radical scientific discoveries, where the use of traditional engineering and management practices cannot produce remarkable results.

The practice of traditional engineering attempts to solve such problems finding acceptable compromises, while TRIZ aims to eliminate such a commitment. TRIZ seeks to overcome these conflicts through the application of creative solutions (Savransky, 2000).

The TRIZ methodology is based on the following grounds:

- Ideality.

- Contradiction.

- Resources.

- Systematic Approach.

- Functionality.

According to Altshuller, problems contain system conflicts, or contradictions, that is, the improvement of an attribute of the system leads to degradation of other attributes.

The typical conflicts are: reliability / complexity; productivity / accuracy; strength / ductility, etc.

For example, in the case of the design of an automobile, there is a conflict between the need to ensure a good shock resistance, and at the same time, the requirement for reduced weight.

According to TRIZ methodology, the problems are divided into local and global problems (Altshuller, 1995):

- The problem is considered local when it can be mitigated or eliminated by modifying a subsystem, keeping the rest unchanged.

- The problem is classified as a global when it can only be solved by developing a new system based on a different principle of operation.

At the beginning of the analysis process of a system, a project team faces a situation involving inconsistencies (contradictions) that need to be clarified (Navas, 2013-a). Thus, the first step in the resolution of contradiction is elaboration of a statement of the problem in order to reveal the contradiction contained in the system. Then, identify the parameters that enhance and hinder system performance. Next, the contradictions are eliminated by modifying the system or one of its subsystems.

Altshuller found that, despite the great technological diversity, there are only 1250 typical system conflicts. Moreover, he identified 39 engineering parameters and product attributes that engineers usually try to improve (Altshuller, 2001). All these 1250 conflicts can be resolved through the application of only 40 Principles of Invention (Altshuller, 1999), (Altshuller, 2001), often called Techniques for Overcoming System Conflict (TOSC).

The full development of TRIZ consists of several concepts (Fey and Rivin, 1997), (Terninko et al., 1998):

- System for formulation of problems.

- Resolution of physical or technical contradictions.

- Concept of an Ideal State of a Project.

- "Substance - Field" Analysis.

- Algorithm for Inventive Problem Solving (ARIZ).

The TRIZ methodology can be seen and used at various levels (Navas, 2013-b). At the highest level, TRIZ can be seen as a science, as a philosophy or a way of being in life (a creative way and a permanent quest for continuous improvement). On the practical level, TRIZ can be seen as a set of analytical tools that aid in the detection of contradictions in systems, in formulating and problem solving through the elimination or mitigation of found contradictions.

The use of standard solutions allows to analyze larger number of potential solutions, create more creative solutions, saving time and resources.

4. Dan Cake Company: Introduction and Production Process

Dan Cake is a Portuguese company, founded in 1978, and its field of activity the food sector. Currently, the company has two production units (Coimbra and Póvoa Santa Iria), in which manufactures cakes and confectionery.

The company has invested in sustainable development, currently has a production capacity of 45 tons and with margin for growth. Dan Cake has a strong national and international presence with export of its products to various continents. At national level Dan Cake also produces for other brands of retail companies.

Currently is internationally certified as "Higher Education" by the British Retail Consortium and International Food Standard.

The study of the maintenance department carried out in the Dan Cake company was done in the production unit of Póvoa de Santa Iria. In this unit, there are several processes, passing through production of ingredients, up to the end of the product packaging.

The production unit of Dan Cake, in Póvoa de Santa Iria, has a high production capacity of various products. It consists of a set of 12 the production lines, some of them operating in continuous production, and require maintenance. However, due to the complexity of evaluation of production lines and maintenance service, was proposed by the head of the maintenance department the restriction to only one of the production lines, this case was the production line nº 7.

The production line nº 7 contains a set of equipment and laborers working in three shifts. And so, in this section the production processes were studied.

Table 1 describes which products manufactured in the production line 7, and the number of workers allocated to the production of each product family.

Table 1. Products and number of workers on the production line nº 7.

Products	Nº Workers	Autonomous Maintenance	Production Shifts
"Luxury"	10	There is no	Production according to demand
"Luxury" with sweet	11		
"Half Moon"	11		
"Half Moon" with Icing	12		
"Rondo"	9		

The manufacture of the 7th production line products contains various stages of production and passage through various production equipment to reach the final product.

To point out that the 7th production line is also formed by different equipment needed for production, their functions can be the most varied, from mixing the ingredients until the injection of the mass.

5. Factory Maintenance: Organization and Resources

The area reserved for the maintenance service provides facilities, where technicians can perform repairs and tests of components in equipment, also serving as materials stock warehouse.

The maintenance service is divided into five sections:

- Electrical / Automation;

- Mechanics;

- Locksmiths;

- Purchasing and spare warehouse;

- Outsourcing service.

Figure 2 represents the org chart of the maintenance department.

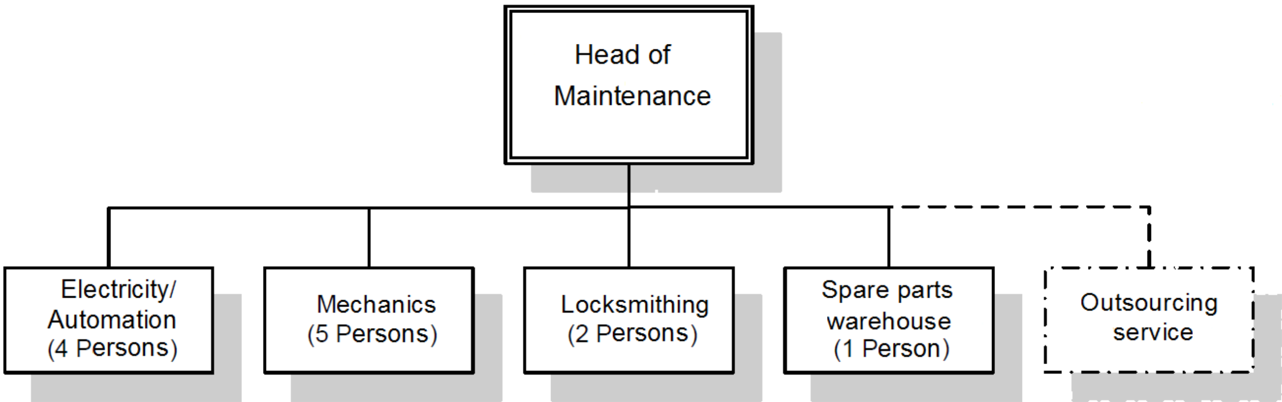

Figure 2. Organization chart of the maintenance department.

In case of the service is outsourced, specialized maintenance technicians are required when there is work with some complexity, that the local elements are unable to satisfy. Where a external services are requested, the tutelage becomes the person in charge of maintenance.

As previously mentioned, the complex production process performed in the Dan Cake factory involves a total of twelve production lines. Given the large number of constituent equipment of each production line, it is necessary to take into account the high production rate in each of these twelve production lines, some of which work in 3 shifts, and, therefore, the stops in the production are almost inexistent. In view of a production is very close to continuous, the time for equipment adjustments is reduced.

6. Identification and Analysis of Wastes in the Maintenance Activities

The determination and categorization of wastes is the starting point for a clear statement of measures and best-practices to develop in relation to required work by the maintenance activities.

The scope of the waste identification presupposes location and categorization of all existing wastes. In order these problems will resolved, it is necessary to study its causes in the routine of the Dan Cake Factory.

However, as the first step of implementation of Lean, it is important to define the value added activities and non-value added activities in the maintenance department. After definition of value, the approach to situations that do not add value can be carried with the aid of the Lean techniques of analysis of wastes. Table 2 shows the value added and non-value added activities.

Table 2. Definition of the value for maintenance service.

Value added activities	Non-value added activities
❒ Preventive work orders	❒ Displacements to the maintenance service ❒ Submission of breakdowns and work orders ❒ Stocks registration ❒ Search for tools ❒ Search for components

The following wastes and problems were identified:

- ❖ Time spent looking for work tools or equipment components
- ❖ Loss of time lacking any component or difficult access to the component
- ❖ Disorganization in equipment manuals
- ❖ Failures in the stock control of the components
- ❖ Failures in the organization inside the maintenance services
- ❖ Inexistence or poor visibility of the standards of quality and occupational safety
- ❖ Deficit track record of breakdowns
- ❖ Filling of failures file
- ❖ Exceeded in the limits of implementation of preventive work orders

In the spare parts warehouse is where the storage of several small size parts, such as various types of screws, washers, nuts, and other components. There are also reels, bearings, gears, and other components in the warehouse.

Figure 3 shows the arrangement of the elements on the spare parts warehouse Nº 1.

Figure 3. Section of the maintenance department - spare parts warehouse Nº 1.

Figure 4 shows the arrangement of the elements on the spare parts warehouse Nº 2.

Figure 4. Section of the maintenance department - spare parts warehouse Nº 2.

Further to the conversations with maintenance personnel and the visual analysis, it was observed, as illustrated in Figures 3 and 4, a disorganization and a lack of rules of storage, with the presence of objects on the floor without identification labels.

7. Problem Solving and Elimination of Wastes in the Maintenance Service

As an approach to waste elimination, it was implement TRIZ-Lean mixed methodology in the maintenance service. This methodology seeks to solve the problems and to make the workplace more pleasant. It should follow the steps below:

1) Eliminate all types of existing equipment if:

- make it hard or obstruct the access to materials and equipment;
- unnecessary or outdated information;
- materials or equipment that is no longer used.

2) Arrange materials and equipment from the inventory of the maintenance department:

   - to develop or improve the existing markings, so that space is freed;
   - creation of labels for all the components;
   - improving the identification of the whole workshop and rooms of components.

3) Clean up all space of the maintenance department:

   - removing rubbish from the floor;
   - equipments of daily use.

4) Normalize all the maintenance service:

   - create procedures and internal standards for the quality;
   - create procedures and internal instructions for cleaning;
   - create procedures and internal safety regulations;
   - create procedures and internal work standards.

5) Comply with the changes made in the maintenance service:

   - keep all changes;
   - leave entire workshop clean and orderly.

The proposal for the spare parts warehouse follows the idea of the necessity of reduce the time of localization of the components.

8. Conclusions

The study aimed to develop a broader discussion on the integration of TRIZ and Lean methodologies to maintenance issues in an industrial company. The methodologies trend was significantly driven, either directly or indirectly, in the search for solutions to the process improvement.

Since the beginning of the study, it has always been presented an approach focused in creative wastes elimination.

It is of great importance that companies adopt an approach focused in the lowest cost of production, in the identification and elimination of wastes, without it reflects on the quality of products. On the other hand, an approach for the identification and elimination of wastes leads to high quality services and competitive prices. It should be noted that a reduction in waste becomes less time-consuming tasks in the short-medium term.

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Integrated Systematic Problem Analysis and Solving Technique

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Abstract

In order to overcome the problems in the ARIZ, this research establishes an integrated problem solving process which integrates many TRIZ tools and some non-TRIZ tools for systematic problem solving. The process includes five stages: (1) problem definition, (2) problem analysis, (3) solution generations; (4) solution selection and integration; and (5) solution verification. This structured problem solving process could help people to solve problems effectively by aiming at solving of the critical key disadvantage(s). In addition to the traditional TRIZ tools, the process uses the Pugh matrix to select and integrate solutions from a plurality of solutions to obtain a set of integrated best solution. Afterwards, applying the super-effect analysis can maximize the effectiveness of the solution. According to the final conceptual solution obtained, the algorithm of virtual verification through rigorous cause-effect inference can logically verify that the expected goal can be achieved, and the secondary problem can also be eliminated. Finally, a practical example is provided for the illustration of the proposed integrated problem solving technique.

Keywords: TRIZ, ARIZ, Systematic Innovation, Super-Effect Analysis, Pugh Matrix.

1. Introduction

TRIZ (Theory of Inventive Problem Solving) is a systematic and creative problem solving methodology that provides many disciplined tools and processes to generate solution ideas or solutions. In 1950s, it was invented by Altshuller (1996). Its main purpose is to help the users to escape the general inertia of logical thinking, where it can convert the problem by solving specific problem patterns for solutions seeking (Mann, 2007).

In 1956, Altshuller developed the ARIZ (Algorithm for Inventive Problem Solving) in order to develop a "creative problem solving deductive method". It is considered as one of the important methods to analyze and solve problems in TRIZ, which integrates various ideas and tools in TRIZ. According to Marconi and Works (1998), ARIZ is a method that can analyze and solve problems, and its aim is to eliminate physical contradiction by developing a further analysis of the problem as well as the solution conversion. ARIZ has many versions, such as ARIZ-56, ARIZ-59, ARIZ-61, ARIZ-77, ARIZ-85, etc. ARIZ-85, which proposed in 1985, is currently the most commonly used version, but the latest version of ARIZ is ARIZ-91. ARIZ-85 integrates TRIZ tools and helps to solve the problem through a total of nine steps in three stages, and they are as follows:

(1) Restructuring of the original problem:

1.0 Analyze the system

2.0 Analyze the resources

3.0 Define the ideal final result and formulate the physical contradiction

(2) Removing the physical contradiction:

4.0 Separate the physical contradiction

5.0 Apply the knowledge base

6.0 Change the "mini-problem"

(3) Analyzing the solution

7.0 Review the solution and analyze the removal of the physical contradiction

8.0 Develop maximum usage of the solution

9.0 Review all the stages in ARIZ in "real time" application

After the ARIZ-85C was released for several years, educators found some difficulties for people to learn, such as need more explanations, comments and illustrations. In order to overcome these problems, the ARIZ-91 was developed (Zlotin and Zusman 1991). In addition, the ARIZ-91 integrates two steps of problem analysis and solution generation together to avoid an interrupt between these two steps.

Although the above development, the full problem solving process of ARIZ is still considered that its problem solving steps are very complex, it is not easy to learn for a beginner, and it takes a lot of time to solve a problem (Cooke 2009), therefore, not many people actually use the ARIZ. In addition, it only contains a few of early developed tools and does not cover the new tools developed in recent years. At the same time, when we look into ARIZ-85 and ARIZ-91 deeply, we can have the following findings. Before the stage of "analyzing solution" in the ARIZ-85, there are many processes of problem solving with tools used; however, at the stage of "analyzing solution", it has only ideas but no practical steps and tools for development. On the other hand, ARIZ-91 lacks the stage of "analyzing solution" to expand the application and validation of solutions. Moreover, Sheu (2007) studied the relationships among the TRIZ tools, but they cannot help to maximize the utility of the solutions and to ensure that the expected goals could be achieved. However, the above facts motivate this study.

This study will develop an integrated and systematic problem-solving process, which clearly defines the problem, analyzes the problem and solves the problem systematically.

During the problem solving stage, this study will go through the steps of solution selection & integration and solution verification in order to integrate and synergize all the tools for maximizing the utility of the solution.

2. Selection and integration tools

There are many tools used in TRIZ, and they can be classified into two areas: problem analysis and problem solving. In the problem analysis area, the tools have Function Attribute Analysis (FAA), Function Relationship Analysis (FRA), Cause Effect Chain Analysis (CECA), Cause Effect Contradiction Chain Analysis (CECCA), etc. The CECCA tool was developed by combining the advantages of the tools of CECA, Root contradiction analysis (RCA), and Root Conflict Analysis (RCA+) (Sheu and Tsai, 2011). In the problem solving area, the tools have Function-Oriented Search (FOS), Evolution Trends, Trimming, Solution Directions, Resources Analysis, Subversion Analysis, etc. Besides these two areas, this study will also use tools in another two areas: solution selection & integration and solution verification.

The most widely used solution selection method is the Pugh method (decision-matrix method, or Pugh concept selection), which is invented by Stuart Pugh (Pugh, 1996). The method can quickly reduce the number of concepts or possible solutions and combine several better ideas into the optimum solution. The Pugh matrix can be divided into two stages that are concept filtering and alternatives rating. Using evaluation criteria to compare alternatives with a baseline solution or the existing solution, the worse alternatives can be quickly filtered. Then we can enhance the value of the possible solution by improving and integrating alternatives, finally, we select the optimal outcome.

The Super-Effect Analysis can help identify new resources to expand a problem solution for maximizing its benefit. The analysis mainly takes the advantage of the characteristics obtained from the improved system and uses the deductive analysis method to improve the system additionally. The super-effect is also called inventive resource, and it consists of not only natural resources, but also financial and human resources. Furthermore, super-effect is defined as one of the resource categories that is systemic resources by Zlotin and Zusman (2005), which represents a new and useful attribute. The system can use its resource to combine and connect other related systems to improve some other parts in order to enhance its effectiveness. According GEN3 (2009) the proposed deductive method of super- effect analyzed is:

(1) Describe the improved system as a system that exists conditionally.
(2) List the changes to the initial Engineering System.
(3) Identify the new features of the improved system introduced by these changes.

(4) Using the identified features as a resource, identify additional ways to improve the system.
(5) Describe the next generation of the improved system.
(6) Repeat steps 1-5 for the next generation system.

The logical thinking process developed by Goldratt is composed of five distinct trees (current reality tree, evaporating cloud, future reality tree, prerequisite tree, and transition tree) (Dettmer, 1997) and one of them is the future reality tree (FRT), which simulates the future and looks for possible risks to correct countermeasures. Based on this concept, the final conceptual solution obtained before can be verified through a set of rigorous cause-effect inference in order to make sure that the future un-desired effects can be avoided and the expected goal can be achieved.

3. The proposed approach

3.1 ISPAST process overview

This research provides an integrated systematic problem analysis and solving technique (ISPAST) and its process developed here is divided into five stages, as shown in Figure 1, namely, (1) problem definition, (2) problem analysis, (3) solution generations; (4) solution selection and integration; and (5) solution verification. The tools covered by green (or dark) area are problem-solving tools of ARIZ and the dashed links indicate the suggested solving processes of ARIZ. TRIZ tools for each stage will be described in the subsequent sections.

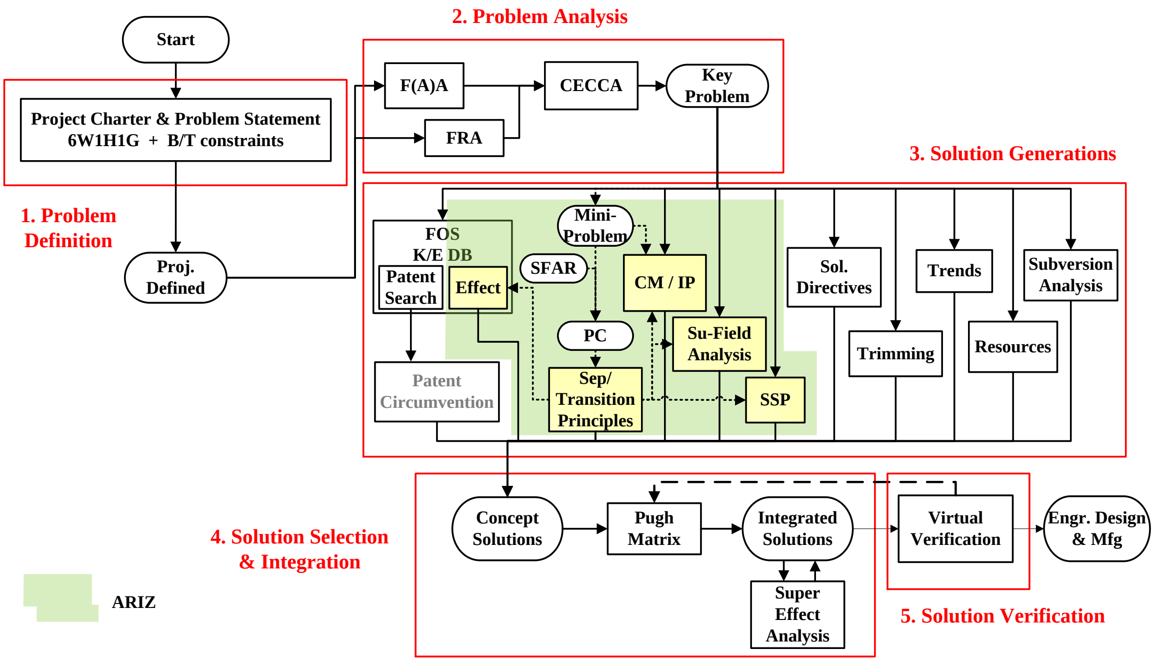


Figure 1. ISPAST problem-solving flowchart

3.2 Problem definition and analysis

(1) “Problem definition” stage: Using the problem description form of 6W1H1G to clarify the issues and determine the scope, limitations of the problem, as well as the project goal.

(2) “Problem analysis” stage: Recognizing the relationships among the components through functional (attribute) analysis (F(A)A) and identifying potential conflicts between negative functions and other functions. Use the component analysis and the interaction analysis to understand the functional relationships among components, then a function model can be represented. Or using the functional relationship analysis (FRA) to help users understand the link relationship among system functions in order to identify the phenomenon of generating function (produce) or suppressing (counteract) another function, then draw a function relationship diagram (Sheu and Chen, 2012). The next step is using the cause effect contradiction chain analysis (CECCA), as shown in Figure 2, to explore the root causes of function disadvantages in order to identify the critical key disadvantage (CKD) and then define it key problem. The logic operators used here are A (and), O (or), and C (combine).

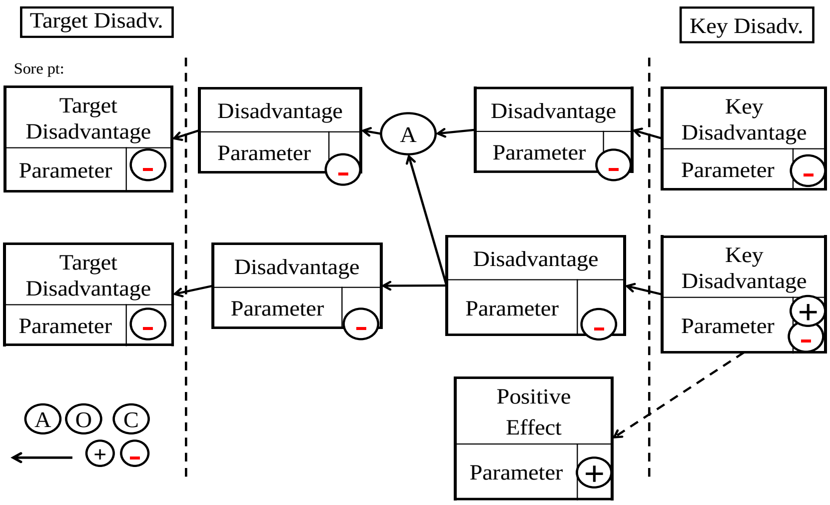


Figure 2. Cause effect contradiction chain analysis

3.3 Solution generation

“Solution generating” stage: After the key problem of the system is realized, the next step is to use a TRIZ solution tool to trigger the user for seeking a concept solution to eliminate the key problem. The following tools can be treated as parallel tools used for achieving multiple solution triggers. The tools include:

(1) Contradiction Matrix/Inventive Principles - eliminating engineering contradictions.

(2) Separation /Transition Principles - using separation principles when facing physical contradictions that are formulated by two justified opposite requirements for one of the parameters of the engineering system or its components. The methods of "separating" are: (1) in space; (2) in time; (3) on condition; (4) separating component and system; (5) parameter separation. Another way to solve the physical contradiction is to use the method of system transition to seek for system resource, eliminating the contradiction by transfer it to its sub-system, super-system, alternative system or counter system.

(3) Function Oriented Search and Knowledge Database - searching for the successfully implanted existing technique in other areas and transfer it to an applicable method for the user. The tool used is the Patent/Knowledge search, shown in Figure 3.

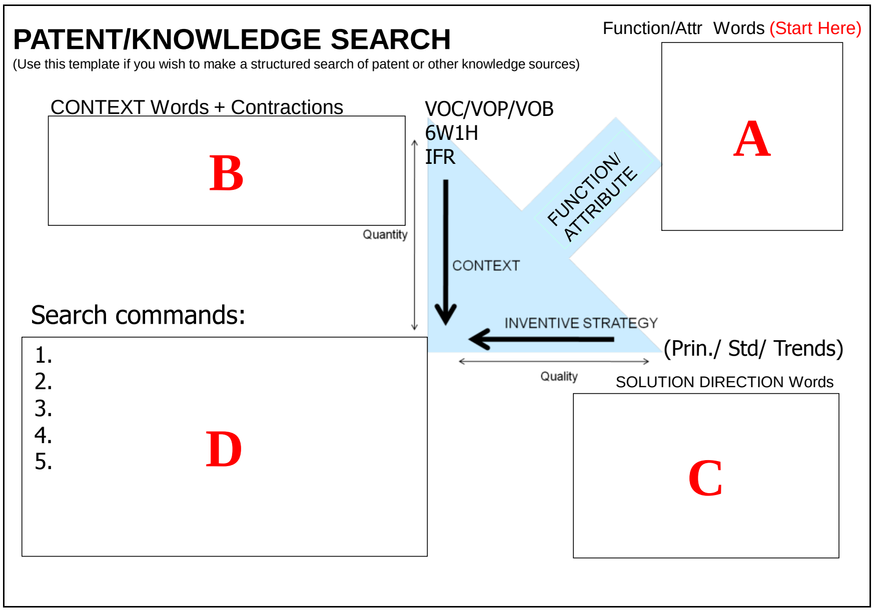


Figure 3. Patent/Knowledge search

(4) Evolution trend - Using thirty-seven evolutionary trends proposed by Mann (2002) to consider whether there is any evolution opportunity in each trend stage, and write down the specific solutions.

(5) Substance-Field Analysis - Analyzing the relationship between substance and field to solve the problem.

(6) Trimming - Reducing the element of system to innovate, and redistributing useful features in the system or its super system. This study uses the trimming process and the trimming rules (Rules A, X, B, C, D and E) proposed by Sheu (2012) to process the trimming plan.

(7) Systematic resources search - The objective is to search the entire resources in the system, and effectively use them to solve the problem. Using the demand function/ property of the problem solving as the demand-side, and the corresponding knowledge effect database as the supply-side, to find the resource that can achieve the expected effect. Resources been asked with questions like: How to use the resource to reach the demand function or effect? Pairing and finding ways to solve problems, resources pairing model as shown in Figure 4.

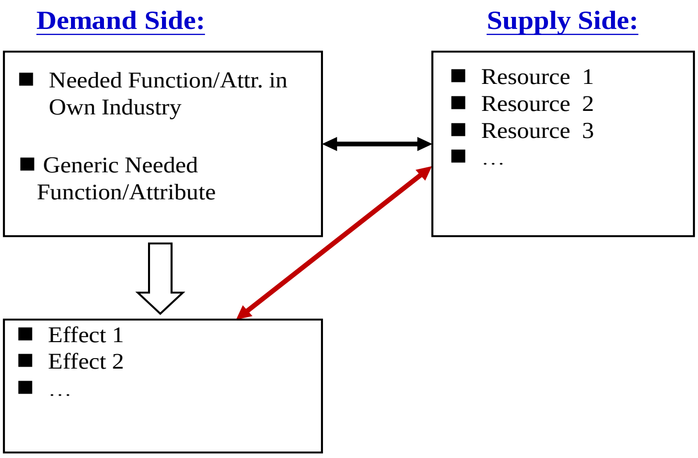


Figure 4. Resource pairing model

3.4 Solution selection and integration

This phase is to select and integrate the concept solutions after filtering the solutions obtained by the previous stage (usually in parallel) and to find the optimal solution, then do the super-effect analysis in order to utilize the resources introduced by the original solutions, and further improve or enhance other parts of the system. The steps of the process at this stage are shown in Figure 5.

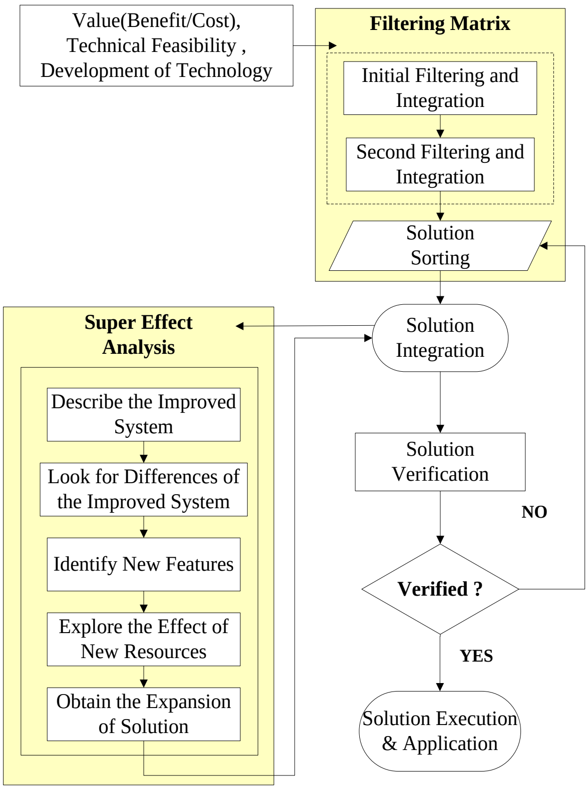


Figure 5. Solution selection and integration process

Figure 5 also shows that this stage is divided into two parts. The first part is evaluating solutions, using a two-stage filtering matrix to evaluate concept solutions. This study sets some necessary evaluation criteria that include the area of technical feasibility and the development of technology. According to the user's demand, the criteria can be added in when necessary. The filtering matrix is shown in Table 1.

Table 1. Initial filtering matrix

Evaluation Criteria	Concept Solutions			
	A	B	C	D
Technical Feasibility				
Development of Technology				
Summary of「+」				
Summary of「0」				
Summary of「-」				
Summary				
Rank				
Continue?				

When an initial filtering is performed, a baseline is selected for comparison with the concept solutions by a set of pre-determined criteria. Use the marks of “+” (better than baseline), "-" (worse), "0" (the same) to express the comparison results. At the first filtering, only for those concept solutions worthy of continuing will pass to the second filtering. After the initial filtering, the second filtering will be performed by using point-based scores (1-5 point). Before the second filtering is performed, the value of the survival concept solutions will be calculated. As shown in Table 2, each concept solution will be assessed the benefit brought by the weighted functions. With the cost, the value of each concept solution can be calculated.

Table 2. Value calculation for various concept solutions

	Function a	Function b	Function c			
Function Weight						
Concept Solution	Assessment of Satisfaction (s)			Sum	Estimated Costs	Value
A						
B						
C						

After the value of each concept solution is obtained, it is added into the evaluation criteria in the secondary filtering matrix, and the "weight" of each evaluation criterion is assigned. After the completion of the evaluation, the need for solution integration is required by combining good features from other concept solutions or improving some features of the best concept solution. Finally, select the highest total score as the best concept solution, and then we can proceed to the next step, solution expansion.

The solution expansion can be done by using the super-effect analysis and its objective is to seek whether there is an opportunity for the resources that are introduced by the initial concept solution can be applied to the other portions, inside or outside, of the system, which can obtain the additional improvement for the system. Its analysis steps are described as follows:

(1) Describe the improved system that we want to expand. As shown in Table 3, this step needs to describe the improvement and key problem from the initial concept solution, and expected result from the expansion.

Table 3. Description form of problem expansion

Initial Solution	Expected Result
{ Use this solution to achieve the initial improvement}	{Expected result after the expansion from the initial solution}
Key Problem	
{ Describe the further problem after initial solution}	

(2) Look for the differences between the improved system and the original system.

(3) Identify new features. Identify the change of resources in the improved system and the new features introduced by the change. The resources generated from the change of the improved system include the change of function, attribute, field, time and space that can be used in improved system, or the new substance generated. Using the six resources mentioned above, the new features can be generated to create the possible effects for the application of expansion, as shown in Table .

Table 4. New features identification table

Resources	New features
{ Resources changed in the improved system }	{ New features generated from the resources changed in the improved system }
New features include the resources can be used in the following items: (1) Function, (2) Attribute, (3) Field, (4) Time and (5) Space, and whether there is any (6) New Substance generated.	

(4) Explore the effect of new resources. New features identified in the former step can be treated as new resources. As shown in Table 55, the step explores the possible effects caused by the new resources or new features (supply side), which result in improvements on the other parts (demand side) of the system, including components and processes of the system that can obtain the expansion improvement.

Table 5. New features pairing form

Supply Side ***Demand Side***

New Resources	Possible Effects	Components
{New features identified in the former step can be treated as new resources}	{Possible effects caused by the new resources}	{**Component** of the improved system can be improved by the new resources}
■ ■ ■	■ ■ ■	■ ■
		Processes
		{ **Process** of the improved system can be improved by the new resources}
		■ ■

At this step, the following questions are asked often: "How can new resource help component get improved?" or "How can new resource help process get improved?" in order to expand the improvement of the other parts of the system.

(5) Obtain the expansion solution. Finally, we can describe the new improved system generated by the process of solution expansion. Through the integration of the initial improved process and the expansion process, we can obtain the integrated result.

3.5 Solution verification

Through a rigorous cause-effect reasoning to check whether the virtual validation of the resulting solution is indeed the goal of eliminating target disadvantage and achieving the desired goals. At the same time, for the foreseeable future the complications or side effects are eliminated. The verification process is shown in Figure 6.

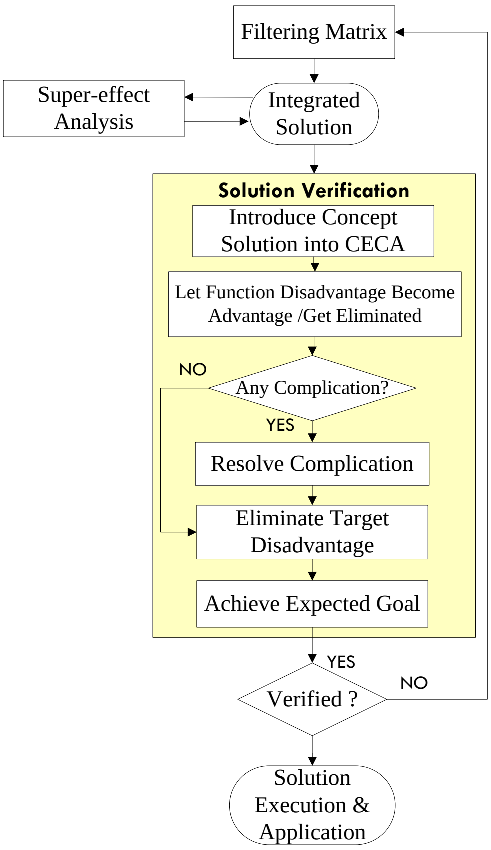


Figure 6. Process of solution validation and effectiveness review

4 Case study

A case study shown in Sheu and Hou (2012) will be used here to demonstrate the application of the proposed ISPAST process. Figure 7 shows a pictorial view of the CVD (Chemical Vapor Depositor) equipment used in the semiconductor manufacturing plant. The partial pictorial view is about one of the chambers in connection with the transfer module and the slit valve, also known as gate valve.

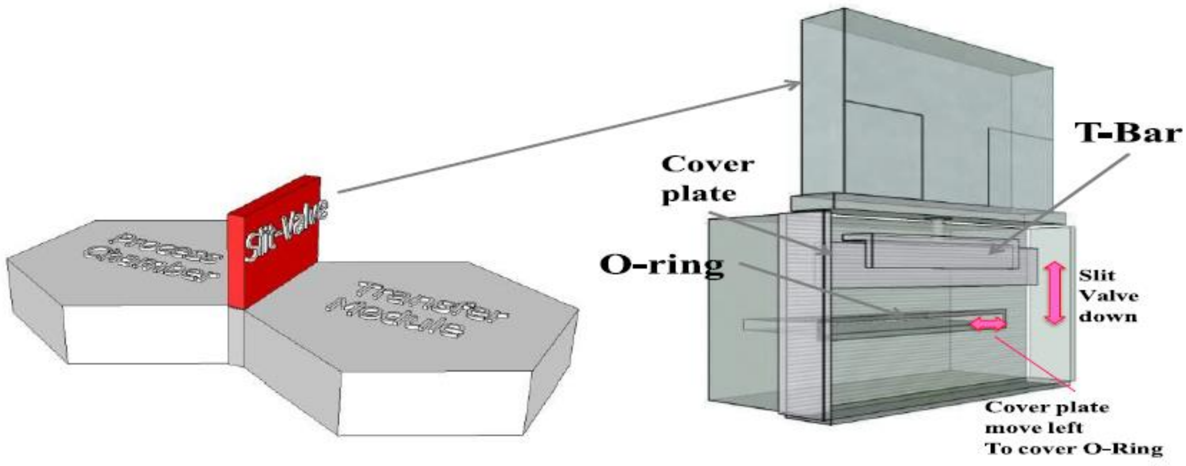
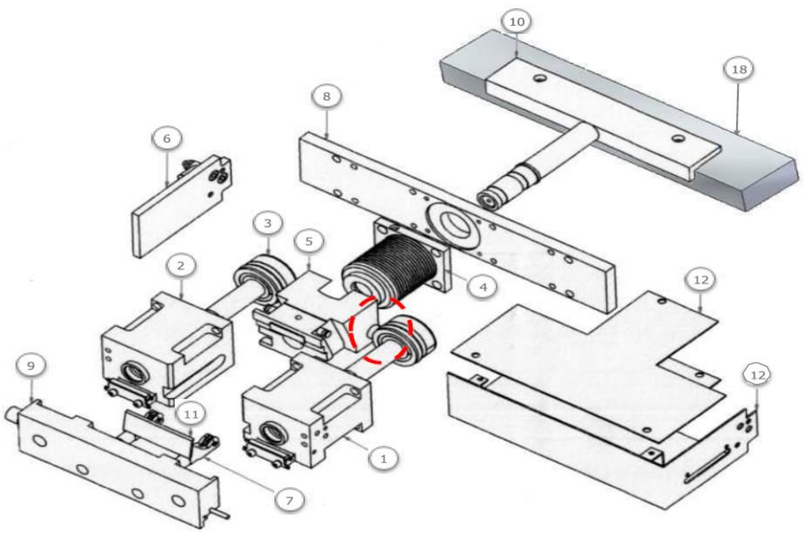


Figure 7. Pictorial view of slit valve and chamber (Sheu and Hou, 2012)



item	Parts Name
1	Air pressure cylinder assembly (left)
2	Air pressure cylinder assembly (right)
3	Piston assembly
4	Slit-valve (S.V.) Bellow/ G.V. Bellow
5	Sliding guide assembly
6	Cover assembly
7	Connecting bar assembly
8	Cover the bottom of S.V,
9	Piston fixed block
10	T Bar
11	Slider (Angle plate)
12	Upper and lower cover assembly
13~17	Hexagon screws
18	Cover

Figure 8. Problem point of the valve mechanism (Sheu and Hou, 2012)

The closing operation of the slit-valve consists of two steps: (1) Slit-valve pushes down T-Bar and (2) Cover plate moves left to press on the O-ring on the chamber wall. The opening of the slit valve follows the exact opposite order of the closing operation. The full mechanism of the slit valve is shown in Figure 8 where 18 components, some parts and some assemblies, are indicated. The problem comes when consistent defect patterns are found on the processed wafers. Engineers trace back to locate the causes and determined that the unexpected breakage on one of the two protruding pins, as shown with a red circle in Figure 8, of the Sliding Guide Assembly (item #5) causes the cover plate to close the door unevenly. The uneven movements of the cover create friction with the O-ring and generate particles that are tucked in by the vacuum operation in the process chamber and deposited on the wafer at the area close to the gate opening.

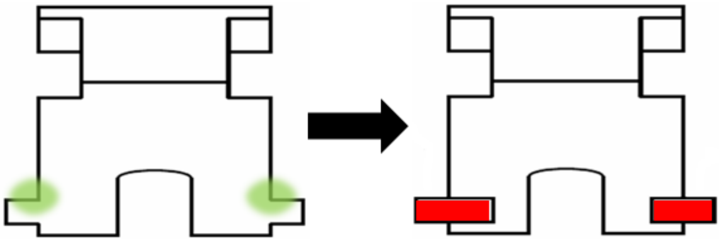


Figure 9. Breakage problem and current solution (Sheu and Hou, 2012)

The left side of Figure 9 shows the sliding guide assembly with protruding pins indicating where the mechanical fatigue and stress concentration occurred. The engineers in the factory solved the problem by replacing the pin on the sliding guide assembly as shown in the right side of Figure 9 hoping that with bigger contact area the stress concentration can be released. The replaced pin of the sliding guide assembly is able to restore equipment back to work, but the fundamental failure mode remains. The same problem can happen after a prolonged usage of the slit valve. Therefore, this study will apply the ISPAST process to the problem of the above case for finding a better solution.

4.1 Problem definition and analysis

A phenomenon of higher amount of dust was found in the wafer at production machine A in the CVD (Chemical Vapor Depositor) process area that directly affected the defective rate of the product. Based on the characteristics (odd/even pieces and repeat angled) occurred at wafers, the phenomena is caused by the mechanism of the slit-valve. Table 6. Problem description table of slit-valve failure by using the format of 6W1H1G.

Table 6. Problem description table of slit-valve failure

Problem Statement	
What problem? (sore point) What's the problem/ need/ opportunity/ sore point?	A phenomenon of higher amount of dust was found in the wafer at production machine A in the CVD (Chemical Vapor Depositor) process area that directly affected the defective rate of the product. Based on the characteristics (odd/even pieces and repeat angled) occurred at wafers, the phenomena is caused by the mechanism of the slit-valve.
When was it happen?	
Where is it found?	
Why? Why this happened? Why doing the problem?	
Who? Who caused? Whom been affected?	
How was it happen?	
What to do?	
Specific Project **G**oal.	Improving the design of Slit-valve and eliminating the problem of wafer pollution

Through 6W1H1G problem statement, it could be realized that the slit-valve, after long period of usage, is possible to have inner component damage which causes O-ring friction and generates dust to contaminate the wafer. Therefore, the objective of the project is set to improve the design of slit-valve in order to eliminate the wafer contamination problem.

After the problem is defined, we can perform the problem analysis using the Function Analysis to analyze the functional relationships between system components. The problem in this case is the slit-valve, disassembling the system down to the level of component, and its main function is to obstruct the air. The function analysis diagram of the system is given in Figure 7. From the function analysis diagram, we can develop a Cause Effect Contradiction Chain Analysis (CECCA), as shown in Figure 8, to find key disadvantages from the target disadvantages.

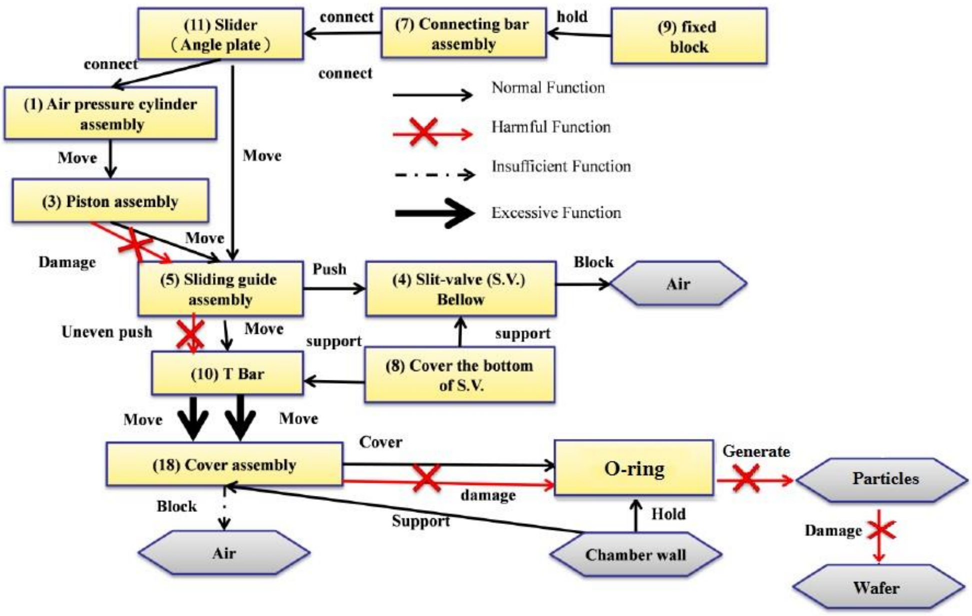


Figure 7. Functional Model of the System under Failure Situation

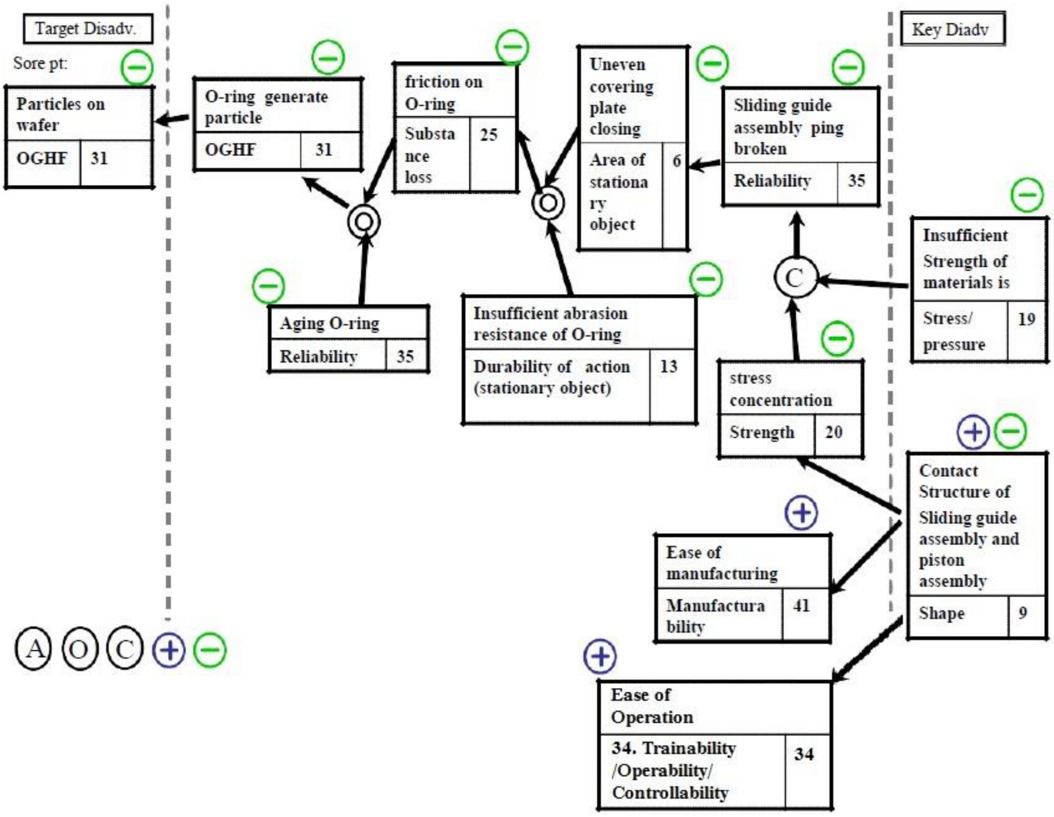


Figure 8. Cause effect contradiction chain analysis

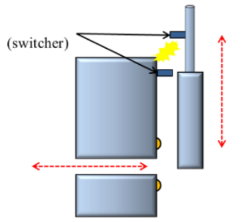
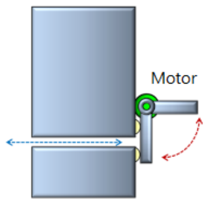
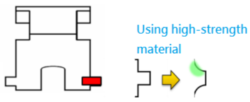
Based on the CECCA, the insufficient strength of materials and the contact structure (protruding pins) of sliding guide assembly and piston assembly are the key disadvantages. At the same time, he contact structure of sliding guide assembly is found to be a critical key disadvantage, while it can generate advantages such as ease of manaufacturing and ease of operation.

4.2 Solution generation

This section will describe how to use the various TRIZ tools in parallel to find the concept solutions. Here, we only give the results for shortening the length of the paper and their ideas can be found in the literature.

(1) Contradiction matrix/ inventive principle – three concept solutions (CS) are generated, as shown in Table 6.

Table 2. Concept solutions from CM/IP

Generic Solution	Specific Solution	Remark/Insert Diagram
28 (Mechanics substitution)	**Concept Solution 1**：When T-bar pushing downward, if it touches the switcher, it will trigger the solenoid valve assembly within the chamber, and the cover can automatically be adsorbed to the chamber wall using the electromagnetic force, which can avoid the possibility of wear.	
17 (Another dimension)	**Concept Solution 2**：Add an additional motor to drive the cover and the cover is attached to the axel of the motor for ease of rotation, changing the original line movement to arc movement.	
3 (Local quality)	**Concept Solution 3**：Change the shape of protruding pins of the sliding guide assembly from sharp 90 degree angle to round chamfer in order to reduce mechanical fatigue and stress concentration. In addition, add stronger material on the corner so that the harmful function is not sensitive.	

(2) Separation/Transition Principles – a concept solution is generated as follows.

Concept Solution 4: A connecting rod replaces sliding guide to avoid a breakage occurred in protruding pins, as shown in Figure 12.

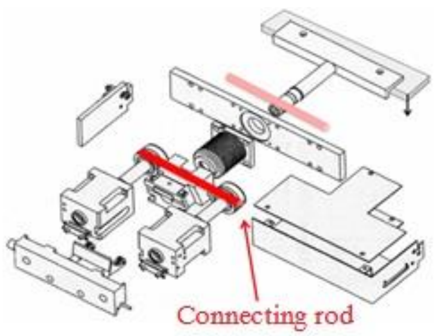


Figure 12. A concept of replacing sliding guide by connecting rod

(3) Function oriented search and knowledge database – a concept solution is generated as follows.

Concept Solution 5: According to U.S. patent US6764265 B2 valve design, the wear of O-ring can be avoided, as shown in Figure 9. The motion of slit valve cover is in 90 degree with the O-ring to avoid friction.

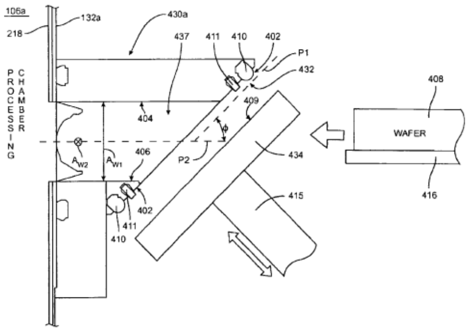


Figure 9. Wear-resistance design of slit-valve (US6764265 B2)

(4) Evolution trend - a concept solution is generated as follows.

Concept Solution 6: The material of O-ring or a coating covering the O-ring is designed to resist friction.

(5) Trimming design with systematic resources search - a concept solution is generated as follows.

Concept Solution 7: The concept is to use Rule B (pushing cover assembly by itself)+ Rule E (find alternative components for closing cover assembly) with the concepts of gravity, Ferro-magnetism force and pressure to make the cover assembly to cover the O-ring by itself to obstruct the air, furthermore, applying Ferro-magnetism force to control the cover assembly to be closed. The schematic diagram is shown in Figure 14.

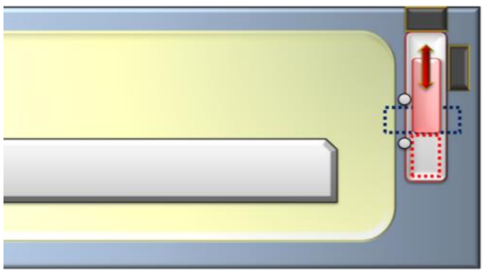


Figure 14. Concept solution of trimming design

4.3 Selecting and integrating solution

As discussed in Figure 5 in section 3.4, there are two phases of filtering. In the initial filtering, the main object is to make the multiple concept solutions quickly converge, then select three solutions with highest scores for the secondary filtering. In addition to the technical feasibility and technical development, the engineering system in this case adds evaluation criteria: ease of manufacture and ease of operability for solution evaluation. Using concept solution 2 as a basis, the initial filtering result for 7 concept solutions generated from the TRIZ tools is shown in Table 8.

Table 8. Initial filtering matrix of slit-valve concept solution

(Initial Filtering)	Concept Solution						
Evaluation Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**
technical feasibility	-	0	+	+	-	0	0
technical development	+ +	0	-	- -	0	-	++
ease of manufacture	0	0	+	+	-	+	-
ease of operability	0	0	-	-	-	-	+
Sum of「+」	2	0	1	2	0	1	3
Sum of「0」	2	4	0	0	1	2	1
Sum of「-」	1	0	3	3	3	1	1
Total	1	0	-2	-1	-3	-1	2
Rank	2	3					1
Continue?	V	V		+			V

There are three concept solutions been selected in the initial filtering, which are solutions 1, 2 and 7. Before the second filtering, we can consider whether there are any good concepts that can be combined. Because there is no enhancement for the O-ring in any of three selected concept solutions in second filtering, we find the concept of using a coating (such as nero material) to avoid wear in solution 6 (the other generated solution) that is capable of integration. Then we can use the integrated concept solution to proceed the second phase filtering.

Before performing the second filtering, the value is required to calculate. After this, the value is added into the evaluation criteria. First, list all the functions of the problem system, and write them as the form of “(Function)+(Object)”. From the function analysis, we know that the main function is obstructing the air, therefore it is the function of the highest importance, and then we can observe for the next major features. The result shows that "blocking the air", "cover the O-ring", "move the cover assembly" and "move the T-bar" are all four important functions of the system, and set the relative weight for the function importance which will be the major evaluation criteria in the next step of the concept evaluation, as shown in Table 9. After the weight of each function is determined, we can evaluate the satisfaction for each concept solution using scales 1-5, 5 is the best. Based on it, we can obtain the "Benefit" of each concept solution, and with each cost evaluated by the experts, we can calculate the value (Benefit/Cost) for each concept solution.

Table 9. Value calculation for selected concept solutions

	Block Air	Move Cover	Cover O-ring	Move T-Bar			
Function Evaluation (weightØ)	0.5	0.2	0.2	0.1			
Concept Solution	**Score of Satisfaction (s)**				**Total**	**Cost**	**Value**
1. Switcher Controls Slit-Valve	4	3	5	5	4.1	40000	4.1/4=1.025 **1**
2. Motor Rotates Cover	4	4	3	5	3.9	30000	3.9/3=1.3 **1**
7. Embedded Slit-Valve	5	4	5	5	4.8	10000	4.8/1=4.8 **5**

※Normalized Value and Rounding

After the value is calculated in Table 9, we normalize it (to the scales 1-5) and then add it into the evaluation criteria of the second filtering matrix, as shown in Table 10. Besides value and the evaluation criteria of the first filtering matrix, we also add "use durability" and "maintainability" into evaluation criteria for better solution being selected.

Table 10. Second filtering matrix for evaluating concept solutions

(Second Filtering)		Concept Solution					
		1. Switcher Controls Slit-Valve		2. Motor Rotates Cover		7. Embedded Slit-Valve	
Evaluation Criteria	**Weight**	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Value	25%	1	0.25	1	0.25	5	1.25
technical feasibility	15%	3	0.45	4	0.6	4	0.6
technical development	15%	4	0.6	3	0.45	5	0.75
ease of manufacture	15%	3	0.45	4	0.6	2	0.3
ease of operability	10%	4	0.4	4	0.4	5	0.5
use durability	10%	3	0.3	4	0.4	4	0.4
maintainability	10%	3	0.3	4	0.4	5	0.5
Total	100%		2.75		3.1		4.3
Rank			**3**		**2**		**1**

After the evaluation from the second filtering matrix, concept solution 7 is selected for having the highest score. Based on it, we proceed to the solution expansion phase. This phase will use the super-effect analysis to find whether there is any opportunity for improving other components or processes in the system in order to maximize the efficiency of the solution. The following five steps will be carried according to the super-effect analysis.

(1) Describe the improved system: In this case, the improvements achieved are using electromagnetic force to control the cover switch embedded in the chamber and coating the O-ring with a thin nano film. It will avoid the O-ring wear and strengthen its wear resistance, without polluting the wafer. After solving the initial problem, we need to find out whether there is any other initial problem left to be solved around the system components or processes. It could be found that due to its long-term effects of chemical gases in the inner wall of the chamber, the thin film process chamber will be contaminated with large quantities of chemical substances and difficult to remove. Therefore we expect to use new resources introduced by initial concept solution to solve this problem as seen in Table 11.

Table 11. Problem expansion describing table

Initial Solution	Expected Result
Use the electromagnetic valve to control the cover switch embedded in the chamber and coat a thin film with nano material on O-ring surface in order to increase wear resistance.	Using new resource added in initial improved system to eliminate the problem.
Key Problem	
Chamber has been affected by chemical gases used in wafer processing for a long time, and it needs to clear chemical substances in the chamber periodically.	

(2) Look for the differences of the improved system: Comparing the difference between initial solution and original valve mechanism in general operating situations, and the result is shown below:

a. Cover assembly falls by its own gravity
b. Using electromagnetic force to control the switch of slit-valve cover
c. The only components left in original mechanism are cover assembly and O-ring
d. Coating O-ring with nano film
e. Valve mechanism change from external to internal

(3) Identify the new features: From the differences listed in the former steps, we can identify the change of resources in the system which includes: Ferro-magnetism, Gravity, nano film, and hollow wall. When these resources are used in the initial improved system, we could obtain new features, such as function, attribute, field, time, space, and new substance. The identification results are shown in Table 12.

Table 12. Identify new features

Resources	New Features
■ Ferro-magnetism	■ Absorb object ■ Fix object
■ Gravity	■ Move object
■ Nano film	■ High Density ■ Low contamination ■ High Wear Resistance ■ Corrosion resistance
■ low contamination	■ Light Weight
New Features includes：whether there is any (1) Function, (2) Attribute, (3) Field, (4) Time and (5) Space that can be used, and whether is any (6) New Substance generated?	

(4) Obtaining new resources: In this step the new features obtained from the former step will be used as the new resources. This step also tries to find the possible effects that may occur when initial improved system operates with the new resources. By using questions such as: "How to let New Resource help Component or Process to improve?" in this case study, we could find "low contamination" and "corrosion resistance" as new resources that can be used to improve "chamber" component. The results are shown in Table 13.

Table 13. New resources paring table

Supply Side New Resources	Possible Effects	*Demand Side* Components
■ Absorb Object ■ Fix Object ■ Move Object ■ High Density ■ Low Contamination ■ High Wear Resistance ■ Corrosion resistance ■ Light Weight		■ Cover Assembly ■ O-ring ■ Robot Arm ■ Wafer ■ Chamber ■ Transfer Module **Processes** ■ Slit-valve Closing ■ Wafer Manufacturing ■ Slit-valve Opening ■ Robot Arm Taking out the Processed Wafer ■ Robot Arm Putting in the Un-processed Wafer

By using new resources such as “low contamination”, “corrosion resistance”, we can apply further improvement towards the chamber, which can be seen in Table 14.

Table 14. Expansion improvement

New Resources	Means	Further Improvement
■ Low contamination	■ Coating nano-film in chamber	■ Prevent chamber from chemical contamination and prevent the clearing difficulty.
■ Corrosion resistance	■ Coating nano-film in chamber	■ Prevent chamber from chemical corrosion.

(5) Obtain the expansion solution: After finishing the expansion improvement, finally we use integration table (Table 15) to integrate the solution (right side of the table). Through the table we can see the improvement and benefits of using the new resources.

Table 3. Expansion Solution Integration Table

Initial Improvement		Further Improvement		Integrated Solution	Integrated Result
Resources	Means	New Resources	Means		
✓ Nano-film	Coating on O-ring surface to increase the wear resistance.	✓ low contamination ✓ Corrosion resistance	Coating inside the chamber	Using electromagnetic to control the switcher inside the chamber, and coating nano-film on O-rings surface to increase the wear resistance.	Prevent O-ring from wear, and prevent from being contaminated by chemical gases.

4.4 Solution validation and effectiveness review

This case will use the integrated expansion solutions obtained from the supper-effect analysis to process the final stage of virtual validation. The validation steps are as shown in below:

(1) Introduce concept solutions into cause effect chain

This case uses the concept of the “solenoid valves built inside the cover wall”, where it mainly focuses on improving “sore point”. Therefore, place the concept at target disadvantage and start validating.

(2) Turn negative factors into positive / eliminate

Table 16. Expected results

Negative Factor	Positive Factor
Structure and shape protrusions of the guiding slider.	No structure and shape protrusions of the guiding slider.
Insufficient strength of the material	Great material strength
Stress concentration, inconsistent thrust	Stress dispersion, uniform thrust
Bearing fracture of guiding slider.	No bearing fracture of guiding slider.
T-bar position offset.	No T-bar position offset.
Low wear resistance of O-ring	High wear resistance of O-ring
O-ring wear	O-ring have not been wear
O-ring aging / hardening	O-ring aging / hardening resistance
O-ring generates dusts.	O-ring doesn‘t generate dusts.
Wafer pollution	No Wafer pollution

First, turn negative factors into positive before validation. Those positive factors will be the expected results of solving the problem, as shown in Table 16. Validation process starts from solving problems, as shown in Figure 10.

(3) Solving derived problem

“Cover assembly controlled by electromagnetic attached to O-ring” might cause “the failure of valve”, therefore, we need to use “choosing high reliability magnetic switch” to eliminate the negative factor in order to avoid complication.

(4) Eliminating target disadvantage

By solving the identical complication, there is no other negative factor that could lead to the situation of polluting wafer. This concept also eliminates the target disadvantage. It could be considered that this concept solution successfully verifies and achieves the desired goals. Additionally, adding nano coating so that the wall component will not be contaminated and polluted.

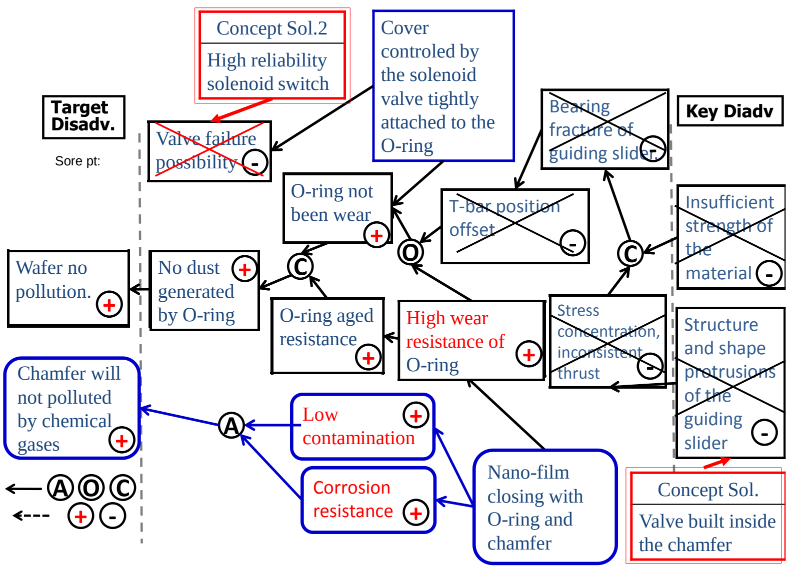


Figure 10. Virtual validation of solenoid valve

5 Conclusions

In this study, we developed an integrated analysis and problem-solving process, which could help users to use a step-down decomposition analysis toward target disadvantages to obtain solutions. The ISPAST process introduced in this study consisted of 5 phases which are the (1) problem definition, (2) problem analysis, (3) solution generations; (4) solution selection and integration; and (5) solution verification. In the process, we added the concept of value to do the evaluation and perform the super-effect analysis. Furthermore, we expanded the usability of system resources to optimize the efficiency of concept solutions. In addition to problem analysis and obtaining solutions, we further integrated the concept selection and integration. At last, for solution validation part, we used virtual validation to identify the complication in order to eliminate it, and to make sure that the objective was achieved. Therefore the feasibility of applying the concept solutions to practical engineering design would increase significantly.

This study applied a five-stage analysis and problem solving process to the valve mechanism problem. It used the TRIZ tools in parallel to obtain many concept solutions and used many criteria to evaluate and integrate solutions. Finally we obtained the most feasible solution, which using solenoid valve embedded in the chamber to control the cover switch. With the resources of Ferro-magnetism, gravity and different pressure, we could effectively block the air without wearing O-ring in case of wafer pollution. The generated solution had a good performance of cost-down by trimming the system components. Additionally, we used the super-effect analysis to improve chamber of the machine to prevent contamination, pollution, and eliminating the difficulty of cleaning.

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Team Organizational Mode for Systematic Innovation and Improvement of Existing Products

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Abstract

As for general and small technical innovational projects, project undertaker, served as the innovation subject, uses innovation theories, techniques and available resources to propose solutions to technical problems. Common trainings on innovational techniques aim to make the learners master innovational techniques and further apply those techniques to actual innovation activities, in order to improve the efficiency and level of technical innovation. The role of each team member is important, particularly when the team is faced with complex technical problems that need technical innovation. This paper analyzes the functions of different team members in innovation activities, with an example of the winner project of The 3rd Global Exhibition on Systematic Innovation, so as to explore approaches to achieve innovation goals through team wisdom.

Keywords: Technical improvement, Team innovation, Organizational Processes, Process management, Role management

1. Background

From TRIZ in the last century, founded by G. S. Altshuler, to the current systematic innovation, innovation method has achieved great progress in theoretical realm. More professionals start to learn and master innovation theory and technique, including TRIZ and systematic innovation training schemes. By the practice of Samsung and other companies, the method of systematic innovation techniques has been proven potent on technical forecasting, research and development of new product, and improvement on current product. However, these techniques have not been extensively applied in enterprises in general. Common trainings on innovational techniques and TRIZ aim to teach professionals to master these techniques. Can those learned professionals improve the innovative capability of their enterprises? Why do most learners believe that TRIZ and innovational approaches alike are useful, but find them very difficult to implement in their work? Therefore, It is worth studying how to apply systematic innovational techniques to the enterprises' technical innovation.

Often times, enterprises encounter technical problems, failures or unsatisfactory conditions. The technical innovation concerning those existing problems is called "improvement and innovation of existing products", which accounts for a majority of all innovational work of enterprises. One main focus of this paper is how to quickly and efficiently carry out systematic innovation activities, especially team innovation activities, within the existing organizational structure of the enterprise, given that most staff has zero or limited training on systematic innovation.

1.1 Characteristics of "Existing Product Improvement"

(1). Specific issues;

(2). Clear innovation demands;

(3). Fixed mindset of professional technicians and different levels of privileges of staff at different levels

(4). Professional technicians' lack of knowledge to systematic innovation methods;

(5). No structured working mode for systematic innovation to be integrated into existing management mechanism.

1.2 Research Objectives

Through research, we hope to figure out basic workflow, task subdivision and organizational mode of the innovation procedure, in order to facilitate enterprises in applying the systematic innovation approaches to daily technical innovation.

2. Basic Workflow and Details of Systematic Innovation of "Existing Product Improvement"

2.1 Basic Workflow

Regarding the characteristics of "existing product improvement", the workflow is divided into four steps (problem analysis, determination of solving direction, solution development, and implementation) based on the ideas and methods of systematic innovation, combined with innovation goals of the enterprise, as shown in figure 1. The first three steps are basically similar with the common systematic innovation process. However, the "implementation step" should be integrated since the goal of enterprise innovation is to obtain the desired product. When one phase fails, return to the initial phase, make adjustments accordingly, repeat the steps until a desired solution is reached to achieve the desired goals.

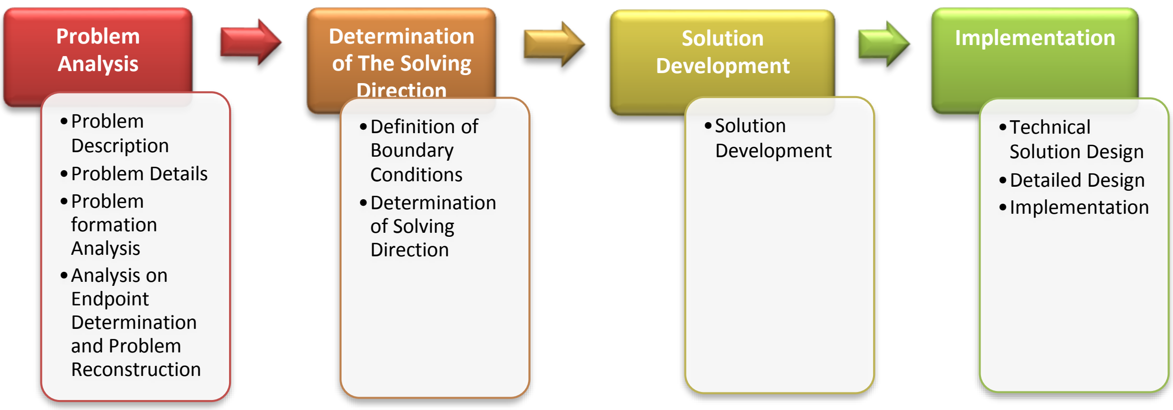

Figure 1: Workflow

2.2 Problem Analysis

Problem analysis is commonly referred to as problem definition; the main contents are as follows:

(1). Problem Description

Conduct necessary description on technical problems and necessity of solution;

(2). Problem Details:

Sort superficial phenomenon and disadvantages of technical problems, weigh the technical problem in the whole system, and determine the necessity and importance of the solution;

(3). Problem Cause Analysis:

From the appearance of the problem, analyze the causes of problem, the nature of the causes and the relationship between them, and trace the root cause of the problem;

(4). Analysis on Endpoint Determination and Problem Reconstruction:

Sort the relationship between different parts of the problem based on innovational theories and techniques, determine the causes of the problem, reconstruct it, and form problem model.

2.3 Determination of The Problem Solving Direction

The main task of this step is to define the problem-solving direction and boundary conditions; the main contents are as follows:

(1). Theoretically Sound Problem Solving Direction

Under the guidance of innovation theories and methods, form as many theoretically feasible problem solving directions as possible;

(2). Definition of Functional Boundary

According to the scope of job functions, define problem solving directions that can be included in the work scope;

(3). Definition of Technical Boundary

According to existing technical conditions, define problem solving directions that can be included in the work scope;

(4). Definition of Environmental Boundary

According to the degree of urgency to solve the problem, economic conditions, time and other factors, define problem solving directions that can be included in the work scope.

This part is similar to the analysis of "Technical Resource and Environmental Resource Map" in some scholarly essays, except that here we focus more on the conditions of organization and implementation of innovation activities of the enterprise, as well as the ability of various roles.

2.4 Solution Development

This step develops the solution based on innovational methods.

(1). Development of The Initial Solution

Develop initial solution with innovation theories and methods when determining problem solving direction. This link requires divergent thinking. Although some initially developed solutions may seem infeasible, they could evolve into more ideal forms as research progresses. Hence, all solution at this stage cannot be ignored.

(2). Development of The Final Solution

As for imperfect solution or new problems, examine various boundary conditions, repeat the process of "problem analysis - problem solving direction - solution development" an adequate solution is reached. Through research in this link, the solution gradually becomes feasible.

2.5 Implementation

The idea of systematic innovation can only become productive after the step of "implementation", which benefits the enterprise. Through such a complete process, systematic innovation approaches are able to gain recognition within the enterprise, and therefore place the company in a beneficial cycle of systematic innovation.

The main contents of this step are: conduct special technical research for feasible innovation solutions, acknowledge actual technical and environmental conditions, develop and implement practical technical design and detailed design, and complete the process of "innovation - design - implementation".

3. Organizational Mode

3.1. Organizational Mode Analysis

Common organizational modes include independent innovation, introduction-based innovation and co-innovation.

(1). Independent Innovation

Generally, small technical innovational projects are characterized by problems caused by specific reasons, a single system, and definite innovation objectives. For such projects, the project undertaker can serve as the innovation subject, utilize innovational approaches and available resources to work for solutions to technical problems, with the assistance of experts or innovation engineers who master innovational theories and techniques.

Some experts give independent systematic innovation consulting, but this requires certain preconditions: commissioning documents must comprehensively and accurately reflect actual situation and various boundary conditions. Even so, it is difficult in the document to accurately define the fuzzy boundaries for change and adjustment. If innovation experts fail to accurately apprehend the problem and/or boundary conditions, the proposed innovative solution is easily denied or shelved by the technical decision maker.

(2). Introduction-based Innovation

The introduction of external technologies will bring out a high success rate and fast returns. Nonetheless, this is detrimental to the long-term development of the enterprise because the company pays for the technology instead of owning it. Outsourced technology-involved research also belongs to this category. The client needs to describe problem expectations in great detail before the consignee carry out its work. In real-case innovation research projects, small and simple problems are most likely to be commissioned successfully. In contrast, when the problem involves multiple systems and complex environment, new situation may evolve as the work proceeds. As a result, the solution to a complicated situation can extend beyond the scope of the client's responsibility or authority, causing the work to run aground or fail to achieve expectations.

(3). Co-innovation

As to complex technical innovational projects, there are more causes to the problem, more complicated systems, and more technical and non-technical factors affecting the solution. Consequently, those projects demand more specialized staff or departments to work as a team. The article centers around this complex mode and discusses the advantages and disadvantages of team members, and studies effective means of communication and cooperation.

3.2 Orientation of Innovation Organization

(1). Innovation team is placed in the functional organizational structure of the enterprise.

A functional organization framework is generally established in the enterprise to ensure the normal operation of daily business. The functional organization has strong executive power, dominating the daily business of the enterprise. Systematic innovation process is not entirely consistent with the daily business process, so it is necessary to establish a cross-functional and interdisciplinary innovation team to implement systematic innovational projects. This innovation team must be arranged in the organizational structure in operation, not only working following systematic innovation process, but also supporting the original functional structure under the functional leadership. If the team was independent of the existing organizational structure, problems will arise in staffing, key decision making and process execution, leading to abnormal implementation of innovation activities.

(2). Innovation team is engaged in multiple functions and disciplines.

According to the characteristics of systematic innovation activities, the innovation team calls for cross-functional interdisciplinary members or external personnel to organize and participate in the activities. Full play will be given to each role in the team by reasonably arranging workflow, positioning roles at each stage and defining their responsibilities.

(3). Innovation team follows the leadership of functional organization while executing relatively independent workflow and tasks. Only when the relationship between the innovation team and the exiting organizational structure is well handled, can innovation activities be smoothly implemented. Team leader takes primary responsibility for this matter.

3.3 Problems of Co-innovation

The following problems are found in the co-innovational projects that are already implemented:

(1). Basic technicians, professional technical directors, and professional technical decision-makers view problems from near to far and from low to high level, but basically from the perspective of their own area of expertise. As shown in figure 2.

Figure 2: Perspectives of Technical Personnel

(2). Outcomes of innovation theory and technique trainings

Enterprises can conduct innovation theory and technique trainings for basic technicians, professional technical directors and professional technical decision-makers, in order to improve their ability of innovation. Previous training shows the following obstacles:

a. For all-staff training, if later on there were no suitable projects or timely practice, the knowledge learned would not play a role in real cases, and the training would only serve as a textbook that familiarizes the staff with theories of innovative methodological knowledge.

b. For trainings for staff with innovation demand and questions, the learners mainly concern the information about their own ongoing projects and area of expertise. Training effect is limited by learners' time, understanding of innovation methodology, and sensitivity control. As a result the learners take longer time and a lot of practices to gradually master the knowledge.

(3). The mindsets of innovation experts and professional technicians are quite different.

When sorting problem details and analyzing and proposing solutions, innovation experts approach the issue from perspectives different from those of profession technicians. With quite dissimilar ideas, they have to reach a consensus through communication at different stages.

(4). Innovation team needs frequent communication and coordination with existing functional organizations.

Co-innovation team needs to mobilize staff at different stages for the work, and communicate with and obtain support from functional organizations in terms of technical conditions, environmental conditions, and innovation objectives, and assign personnel to take charge of such communication and coordination.

3.4 Features of Roles within The Co-innovation Team

Learning from the analysis of the characteristics of innovation and the improvement of existing product, we believe that co-innovation team should include the following staff:

(1).Business decision-maker

Analyze problems from the standpoint of enterprise development strategies, find out the key issues behind the problem and development direction, and deploy innovation activities. The input of the decision-maker determines the level of innovative issues and the quality of innovation outcomes. The participation of the decision-maker can guarantee funds, manpower and time required for innovation activities.

(2).Professional technical decision-maker

Have a wealth of technical expertise and professional experience in design, review technical problems from the perspective of the entire industry, control the feasibility of solutions, and play a decisive role in innovation targeting. Technical decision-maker initiates problem analysis and determines the expectations of problem solution, in order to pinpoint the innovation goal within a reasonable range.

(3).Innovation theory and technique experts (hereinafter referred to as innovation expert)

Master innovation theories, have practical experience in the application of innovation techniques to solve technical problems, comprehensively and systematically sort and analyze problems, and propose solutions.

(4).Professional technical director:

Have a wealth of technical expertise and professional design experience, approach the issues from the perspective of the project boundary, roughly judge the necessity and importance of the solution.

(5).Basic technician

Witness the rising of the problem, have technical expertise, can make descriptions of technical problems, undertake the task of transforming innovation solutions into feasible technical solutions and detailed designs, and supervise their implementation.

(6).Innovation engineer

Have sufficient technical expertise and professional design experience, understand innovation theories and master some basic innovation techniques, correctly understand and can pass down the ideas of technical decision-makers and innovation experts, assist the communication between innovation team members, especially between innovation expert and professional technician, and transform the innovation ideas of innovation export into innovation technical solutions acceptable to professional technicians.

(7).Innovation team leader:

Whether collective wisdom can be mobilized in innovation activities to achieve high efficiency, the key lies in the management of innovation team. Co-innovation team is composed of staff from different departments and disciplines. To achieve the goal of innovation, team leader needs to carefully design workflow and flexibly arrange personnel and organize the work. Moreover, the leader should actively communicate and coordinate with functional departments to guarantee funds, manpower and time. Served as a bridge and lubricant among various roles of the team, the leader needs to flexibly handle management issues and coordinate the cooperation among works and staff. Team leader also takes duties of innovation engineer, so he/she is also an innovation engineer.

4. Organization of Innovation Activities

As mentioned above, the systematic innovation of the enterprise includes four links: problem analysis, determination of solving direction, solution development, and implementation, as shown in figure 3.

Figure 3: Basic Workflow

4.1 Roles and Responsibilities Involved in All Stages

In combination with tasks at different innovational stages, roles and responsibilities are analyzed as follows.

(1). Problem Analysis

a. Problem description:

Key personnel: basic technician and professional technical director

Task: they are the first ones discovering technical problems and adverse effects, so their description is relatively close to actual condition.

b. Problem details sorting

Key personnel: professional technical directors and innovation engineers

Task: they have a better understanding of the weight of the technical problems in the entire project, and can roughly judge the necessity and importance of the solution.

c. Problem cause analysis

Key personnel: innovation expert, innovation engineer, professional technical decision-maker, and professional technical director

Task: this stage requires adequate communication between all participants, and correct understanding of the problems and related information. The causes of the problem are analyzed under the guidance of innovation experts with approaches such as 5W2H, 9-9 squares, functional analysis and so forth, to search for the root cause of technical problem.

d. Endpoint determination

Key personnel: professional technical decision-maker, professional technical director, and innovation engineer,

Task: they have long been engaged in their disciplines, have a good understanding of the functional area of the team, technical conditions of problems and environmental boundary conditions; determine the reasonable endpoint of problem analysis so that the follow-up innovation solution can be feasible.

e. Problem reconstruction

Key personnel: innovation expert and innovation engineer

Task: use systematic innovation methods to redefine the problem and establish problem model

(2). Determination of Solving Direction

This stage includes two steps: divergence and convergence:

a. Divergence

Key personnel: innovation expert and innovation engineer

Task: according to systematic innovative ideas, seek logically possible solving direction and form intentional solution.

b. Convergence

(a).Key personnel: innovation engineer, professional technical director, and professional technical decision-maker

(b).Task:

Determination of functional scope: professional technical director

Determination of technical conditions: professional technical decision makers

Determination of environmental boundary: professional technical director

Determination of the direction of solving: professional technical decision maker

(3). Solution Development:

Solution development: innovation theory and technique expert, innovation engineer and professional technical director

Research on transformation of feasible solution into implementation plan: professional technical director and basic technician

(4). Implementation: Technical Design, Detailed Design and Implementation

Conduct technical design for feasible innovation solutions, develop and implement practical technical design and detailed design, and complete the process of "innovation - design - implementation": professional technical decision maker, professional technical director and basic professional technician

(5). Weight of All Participants Involved in All Stages

See the following table for the importance of the participants at each stage and each step: 1-5 for critical-minor，as shown in Table 1.

Table 1: The Weight of Different Roles at Each Stage

	Basic Technician	Professional Technical Director	Professional Technical Decision-Maker	Innovation Expert	Innovation Engineer
Problem Analysis					
Problem description	1	2			3
Problem Details Sorting		2	4	3	1
Problem Cause Analysis		4	3	1	2
Endpoint Determination and Problem		4	1	2	3

Reconstruction					
Solving Direction					
Determination of functional boundary		1			
Determination of technical boundary		2	1		
Determination of environmental boundary		1			
Determination of solution		3	1		2
Theoretically possible directions of problem solution				1	2
Solution Development					
Problem solution development	3	2		1	4
Implementation					
Technical (patent) plane design	4	3	1	2	
Detailed design	1	2	3		
Implementation	1	2			

4.2 Relationship between Innovation Team and Enterprise Organizational Structure

The decision makers of the enterprise can fully understand the importance of systematic innovation, and the establishment of innovation team is part of the innovation strategic layout. The innovation team, founded for improvement and innovation of some exiting product, is arranged in the organizational structure in operation and consists of the leaders of original functional departments within the enterprise. Team members participate in innovation activities through the deployment of functional department. This way, personnel can be effectively deployed, and the timeliness can be guaranteed in innovation activities. The team will be disbanded immediately after the task is completed.

4.3 Key Issues in Organizational Work of the Co-Innovation Team

The author has chaired and participated in the organization and management of a number of systematic innovation projects. Based on the author’s analysis on success and failure, there are some key issues in the organization of the co-innovation team:

(1). It is necessary to select urgent innovative project on the basis of the systematic innovation activities of existing products, giving sufficient root power to new innovation activities. The enterprise is willing to make appropriate adjustments for innovation activities worth doing. Once the enterprise recognizes the work of the innovation team, functional departments will show effective support, and it is easier to deploy funds and personnel across functions and disciplines.

(2). Within the co-innovation team, except for the project leader and innovation engineers who are full-time staff, the other members work flexibly and need to be mobilized by functional departments. Such project mode is different from both traditional centralized management and project management. On one hand, his mode costs fewer human resources and places low requirements of the knowledge to innovation theories and techniques on team members. On the other hand, associated workflow needs to be developed in strict accordance with specific tasks and participants, and it demands strong communication and coordination abilities from the project leader

(3). "Give full play to advantages of every participant and achieve innovation goals with the wisdom of all team members" is the purpose of the organization of co-innovation team which should be adhered throughout the activities. In the workflow design, participants need a clear grasp of the tasks and emphasis of each link. For staffing, it is necessary to carefully analyze the competence boundary and ability level of each member, the weight of the role, and the expectations at each stage. The work should be arranged as far as the members' strength is concerned in order to take full advantages of each role.

(4). When making staffing plan and schedule, it is necessary to ensure not only innovation activities are orderly implemented, but also that it takes up as little time as possible of the staff. Team leader should communicate to the functional departments the relativity and importance of the innovation activities, as well as the brevity of the time that human resources would be occupied. In this way, personnel deployment can be realized easily.

Experience has shown that when the above issue is handled, organization work can be easy and smooth.

5. An Example of Team Innovation Activities

The author hosted and participated in the "large-span tunnel innovative design", a team innovation activity described as follows:

5.1 Project Overview

(1).Background:

In the implementation of tunnel project, the enterprise encountered such problem that the ultra-thick fillings exerted excessive pressure on the tunnel structure. There were two alternatives: one is to build multiple small-span tunnels, which is not the most ideal; the other is to change the railway position in a roundabout way, which will increase project cost. These alternatives were unsatisfactory to the client, and it was urgent for the enterprise to resolve technical problem for making large-span tunnel feasible. To this end, the enterprise established a multi-disciplinary, cross-department and cross-enterprise "large-span tunnel innovative design" co-innovation team.

(2).Task: to develop feasible large-span tunnel innovative design and patent the design during innovation.

(3).Duration: 2 months

5.2 Team Composition:

(1).Departments involved: 8 internal departments and 1 external department of the enterprise;

(2).Team members: 25 persons;

(3)The team composition is described as follows:

a.Four planning, financial and manpower security: one executive decision maker, one technical decision maker, and two functional department leaders;

b,Three functional management and coordination: two functional department leaders and one administrative manager;

c.Three tunneling technical experts: one each industry-, enterprise- and department-level professional technical decision maker;

e.Three innovation experts: all external, holding Level 3 certificates issued by M-TRIZ;

f.Two innovation engineers: one served as team leader and one holding Level 2 certificate;

g.One innovation team leader: received TRIZ and other systematic innovation trainings. He didn't receive TRIZ and other systematic innovation trainings;

h.Nine engineers: didn't receive TRIZ and other systematic innovation trainings.

The chart of team organization system is shown in figure 4.

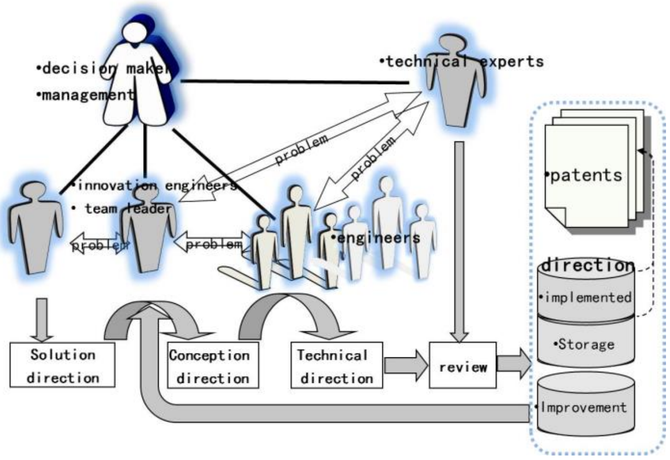

Figure 4: Team Organization System Chart

5.3 Teamwork System

During the innovation project, team leader and innovation engineers worked full-time.

One innovation expert worked full-time, and other two experts part-time;

The rest of the staff stayed in their original positions, and participated in the innovation project for a short time if needed.

5.4 Workflow

In application of the innovation methods, we designed a workflow chart in consideration of the differences in the ability boundary of innovation technique expert, tunneling technical expert, and common tunneling engineer. The chart of workflow-in-process is shown in figure 5.

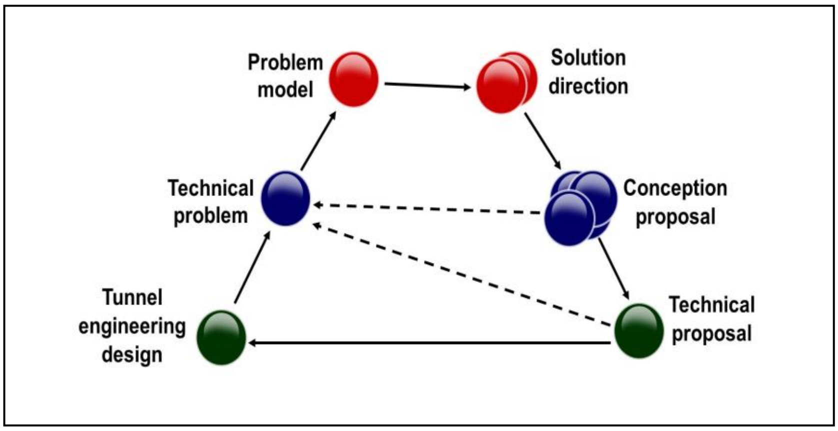

Figure 5: Workflow-In-Process

5.5 Key Points of Each Link in Innovation Workflow

Solving direction: innovation technique expert led the way, which facilitated technical breakthrough. Innovation engineer followed up in a timely fashion, assisting the innovation expert in understanding the problems in the tunneling project.

Conceptual solution: innovation engineer played a major role in the work with the assistance of the tunneling engineer, and developed as many as conceptual plans based on the solving direction.

Technical solution: the tunneling expert guided the work, engineers transformed conceptual solution into implementable technical solution, and the innovation engineer extracted the patent solution from technical solutions.

Solution implementation: tunneling engineer develops feasible engineering design solution on the basis of innovation technical solution, under the guidance of tunneling design requirements.

5.6 Achievements

With meticulous organization and intensive study, the team made the following achievements in the project by applying systematic innovation methods and learning from other enterprises in the industry, as well as from cross-industry technologies.

(1). Worked out open tunneling technology roadmap

A systematic open tunneling technology roadmap was developed, standardizing the associated direction of technical innovation, and specific contents.

Obtained various open tunneling technical solutions in different directions, providing sufficient technical support for further open tunneling design and research.

(2). Found out the best solutions for problems encountered in engineering design

Two solutions were immediately applied to the tunneling works of some transport hub, and another one was used for a project that turned railway tunnel back into farmland. Those solutions optimized the original designs and achieved the desired goals.

(3). Obtained patented open tunneling technical innovational solution

Worked out dozens of open tunneling technical solutions, among which 9 have invention patents and a few have utility model patents. With the continuous cycle and in-depth research by all subsystems, the scope and number of achievements will increase.

(4). Made an example of systematic innovation approach in the enterprise

With successful demonstration of the case, the enterprise continued to perform systematic innovation activities for more than twenty projects in the same mode.

6. Conclusions

Different innovation environment and objectives require different innovation modes. The following conclusions are made through the practice of "existing product improvement and innovation":

- **A. It is recommended to select urgent innovational projects for systematic innovation.**

When the enterprise encounters an urgent problem, systematic innovation could be most effective on that problem as a result of necessity and great driving force

- **B. It is recommended to select appropriate products to launch systematic innovation.**

Systematic innovation approaches have their own characteristics. Selected products should be prone to be patented, e.g., structural products and equipment, which can facilitate the application of innovational approaches.

- **C. Innovation team that is within the functional organization of the enterprise is conducive to innovation activities.**

It is easier to secure funds, manpower and time when the objective of innovation activities matches that of the functional organization of the enterprise.

- **D. The organization and coordination ability of innovation team leader is the key to organizational management.**

In the cross-functional and interdisciplinary innovation team, one member should be appointed specially for workflow design and organization, whose communication and coordination ability directly affects the efficiency and results of innovation activities.

- **E. Each team member should work in their area of expertise in order to bring their advantages into full play.**

Comparative advantages should be considered in team building, workflow design, and task scheduling, etc., Work should be arranged based on individual strength, in order to improve the quality and efficiency of innovation activities.

- **F. Innovation engineer serves as a bridge between the innovation expert and professional technicians.**

Innovation engineer assists the innovation expert in understanding technical problems and environmental conditions, while developing technical solutions for professional technicians, based on innovational ideas of the innovation expert.

- **G. Different roles in the team may master systematic innovational approaches at different levels.**

When the innovation expert is present, it is unnecessary to perform special training of innovational approaches on all participants. The team leader and the innovation engineer are allowed to only understand innovation theories and techniques to some extent, and the majority of the professional technicians take active roles in designing for the implementation of innovation solution.

- **H. Innovation expert controls the direction of innovation solution.**

Due to the broad range of systematic innovation theories, specific problems should be solved with the most appropriate tools. The experience of innovation expert in real cases will facilitate the selection of the tools. The innovation expert also controls the direction of the innovation solution.

7. Summary

Once the enterprise has adopted the plans made with innovational theories and techniques, the enterprise needs to make decisions and therefore undertake the associated risks. It must invest capital, personnel, equipment, materials, time, organization and coordination work, and so forth. The more the enterprise invests in planning, the smaller the risk would be. At the current stage, through research and practice, we believe that the "cooperative innovation" mode is a most reasonable way for the enterprise to apply innovational approaches.

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A Semantic-interactive Model and Application in the field of Computer-Aided Inventive Problem Solving

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Abstract

Most Computer-Aided Innovation (CAI) software has integrated various innovative tools in the process of solving inventive problems. However, most designers, particularly new hands, are frustrated about which tool they should choose to finish the design work. To solve problems, this paper has analyzed the application of various innovative tools, and has proposed a semantic-interactive model for solving inventive problems in the computer-aided innovative design process .This model consists of four phases: problem description, problem analysis, problem solution, and solution formation. System recommends different tools in each phase. The type of problem is basically determined during the interactive dialogue between the system and designer. Based on the types of problems, each phase recommends innovative tools for a corresponding problem, that the user can choose from to complete the construction of problem models and obtain the final solution by assessing the solution.Our project team has completed the software system based on the this model. The proposed software system although still at a prototype. At last the operation process of the system was demonstrated by an example to verify its integrity and feasibility.

Keywords: CAI, Interactive, Inventive problem , Semantic , Innovative tools.

语义交互式计算机辅助发明问题解决过程模型的研究与应用

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摘要

多数 CAI 软件在发明问题解决过程中都集成了多种辅助创新工具。然而大部分设计人员，尤其是设计新手在使用辅助创新工具进行设计的过程中对要选择哪种工具才能更好完成设计而感到困惑。针对这一问题，本文在分析了各种创新工具的应用方式的基础上，提出了语义交互式计算机辅助发明问题解决过程模型。该模型分为问题描述、问题分析、问题解决、方案形成四个阶段，每个阶段都为用户推荐不同创新工具。系统在与设计者对话交互过程中，首先初步确定问题的类型，根据问题的类型推荐用户选择相应的问题分析工具完成问题模型的构建，进而根据不同问题模型采用相应的问题解决工具得到概念方案，最后经过方案评审得到最终方案。本项目组在此模型基础上已经完成了软件原型。最后通过一个实例证明了该模型的有效性及可行性，并展示了原型软件的相关界面。

關鍵詞： CAI，交互，语义，发明问题，创新工具。

1. 前言

基于计算机辅助创新技术的软件系统（CAIS）的出现帮助设计者正确地分析并辅助设计者解决技术系统中存在的问题，进行新产品的开发。CAI 的发展已有十多年的历史，目前国内外研究 CAI 系统的机构较多，类似软件也不少，如美国 Invention Machine 公司开发的 Goldfire， CREAXNV- Mlk 公司开发的 CREAX Innovator Suite， 亿维讯公司开发的 Pro/Innovator， 河北工业大学开发的计算机辅助创新系统 InventionTool3.0、InventionTool-net 以及创新知识云平台 InventionKnowledgeCloud (IKC)，其中不少软件已有了广泛的应用。

大部分软件在发明问题解决过程中都集成了多种辅助创新工具。问题分析部分的辅助工具包括：根原因分析法，资源分析法等。在问题解决部分的工具包括：冲突原理、效应、标准解等。这使得大部分设计人员，尤其是设计新手在使用辅助工具进行创新设计过程中对选择哪个创新工具才能更好的辅助设计感到困惑(S. Ahmed, 2004)(S. Ahmed,2007)。而设计者之所以不知道选择哪种工具才能更好地解决问题，主要是因为对问题的特性抓不住，而且对各种工具适于解决哪种问题不够清楚。因此，本文在系统的分析了各种问题解决工具的特点，并总结了各自擅长解决的问题类型的基础上，提出了一种语义交互式的发明问题解决过程模型来帮助设计者更好的解决发明问题。

2. 语义交互式发明问题解决过程模型

2.1 创新工具介绍

运用 TRIZ 理论解决发明问题之前， 熟悉和掌握各种 TRIZ 理论发明问题解决工具是综合实现 TRIZ 创新算法的前提。下面详细的分析并总结了主要的几种 TRIZ 创新工具的特点及适用情形，为有效利用 TRIZ 理论进行产品创新设计提供了选择方法。

2.1.1 问题分析工具

1）因果分析工具

当设计者面对一个技术问题的时候，往往牵涉的因素很多，有种无从下手的感觉。这是问题分析的关键就在于理顺问题产生的原因，充分挖掘技术系统内外资源，以找到最有效解决问题的方案。因果分析工具为找到问题产生的原因提供了有力的方法。

2）组件分析工具

设计者通过组件分析工具对技术系统进行分析，建立功能模型来理解一个系统；并通过分析找出当前系统的不足，定义系统存在的问题。组件分析工具有效地揭示并解决技术系统中存在的问题功能以及对应的问题组件，从而为进一步提升和改进技术系统功能做铺垫。

3）理想化分析工具

理想解使设计人员在解决问题之初，抛开各种客观限制条件，通过理想化来定义问题的最终理想解，以明确理想解所在的方向和位置，避免了传统创新设计方法中缺乏目标的弊端，提升了创新设计的效率。理想化分析工具经常被用于初始解决方案目标的确定以及物理冲突的确定。

4）物质-场分析工具

物场分析是 TRIZ 理论中一种重要的问题描述和分析工具，用以建立与已存在的系统或新技术系统问题相联系的功能模型，根据物场模型所描述的问题，来查找 TRIZ 理论相对应的一般解法和标准解法。适用于功能改进型问题的解决。

5）九窗口分析工具

九窗口法对情境进行整体考虑，不仅考虑目前的情境和探讨的问题，而且还有它们在层次和时间上的位置和角色。可将所探讨的问题视为一组相互关联的问题，这样便可对其进行更为全面的理解。此工具一般用于从层次和时间上找到问题出口和可用资源。

6）功能分析工具

从系统抽象的功能角度来分析系统，分析系统执行或完成其功能的状况。从功能映射到结构探求多种方案，再进行技术经济评价，经优化筛选，得到最佳方案。功能分析工具主要用于功能求解型问题的解决。(Gao C,2006)

2.1.2 问题解决工具

1）冲突矩阵

运用冲突矩阵解决问题时，首先要对具体问题确定技术冲突，然后将技术冲突采用标准的两个技术参数描述，最后通过查找冲突矩阵确定可采用的发明原理。此方法的好处是形式简单，易于使用，可提供大量的冲突解决方法。但是在使用此方法之前必须确定系统的冲突所在，必须采用 39 个工程参数进行描述冲突。因此利用冲突矩阵解问题的方法较适用于便于用 39 个工程参数描述的技术冲突问题。

2）分离原理

解决物理矛盾的核心思想是实现矛盾双方的分离。通常分离原理有如下四种形式：空间分离、时间分离、基于条件的分离、整体与局部的分离。然而，分离原理应用的前提是该技术系统已经确定了物理冲突，因此该方法适用于物理冲突的已经明确的问题。

3）76 个标准解

物场模型描述出了系统的问题模型。标准解法系统是解决存在问题的物场模型的有力工具之一。将物场模型作为问题模型，中间工具是标准解法系统，对应的解决方案的模型是标准解法系统中的标准解。使用此方法可以结构化的分析问题，易于产生不同的新概念。但是需要设计者具备较强的相关问题的工程背景。通常适用于为已有的设计方案产生新概念的问题的解决。

4）效应

效应是发明问题解决理论中一种基于知识的工具。效应与产品之间的关联性，可用于产品设计中原理解的确定。效应作为解决问题的工具，适用面较广，但是要求使用者有较好的知识背景而且知道该问题的该如何解决的大体情况。

2.2 模型概述

运用 TRIZ 理论解决发明问题之前，对创新问题进行定性的分析和认识，是有效地选择相应 TRIZ 理论问题解决工具，提高发明问题解决效率的关键。问题的表现形式是多种多样的，因此解决问题的手段也是多种多样的。最重要的是区分技术系统的问题属性和产生问题的根源。根据问题所表现出来的参数属性、结构属性、资源属性，TRIZ 问题的问题模型可以划分为四种形式：技术矛盾、物理矛盾、物场问题、知识使能问题。针对不同的问题模型采取不同的问题解决工具，如冲突原理、分离原理、76 个标准解，效应知识来解决。

本模型是在 ARIZ 算法(ALTSHULLER G，1999)的基础上，把问题解决过程进而归结为四个阶段：问题描述、问题分析，问题解决、方案形成。每个阶段都为用户推荐不同的创新工具。系统在与设计者对话交互过程中，首先初步确定问题的类型，根据问题的类型推荐用户选择相应的问题分析工具完成问题模型的构建，进而根据不同问题模型采用相应的问题解决工具得到概念方案，最后经过方案评审得到最终方案。图 1 给出了该模型的结构图。

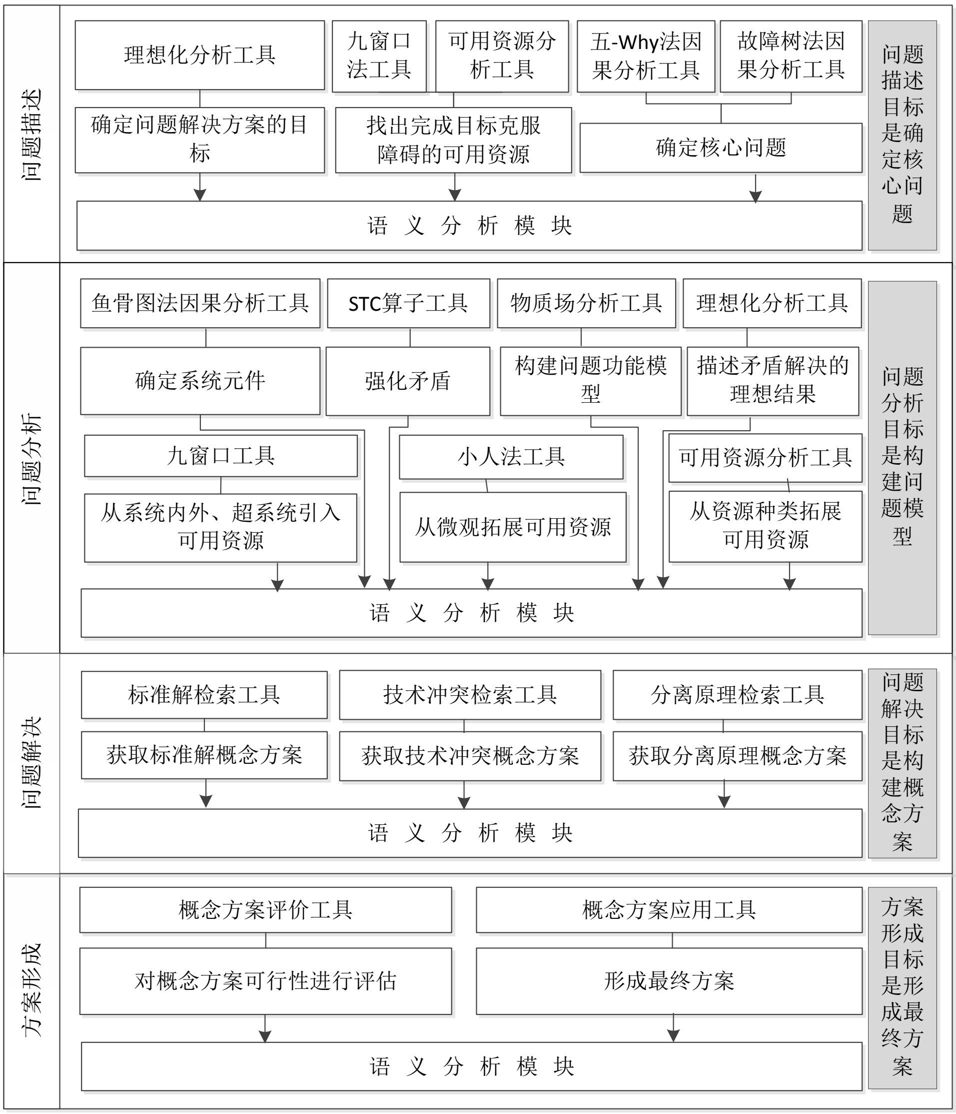

图 1 语义交互式发明问题解决过程模型

2.2.1 问题描述

发明问题的解决过程就是向着确定“问题的原因”和“问题的方向”发展的过程。因此，我们首先要明确核心问题以及解决方案的理想目标。

1）对问题情境分析，描述主要问题。

2）描述问题解决的理想目标。

3）确定核心问题。

系统推荐设计者使用因果分析工具，利用该工具查找问题的根源，帮助设计者发现隐藏在表层问题背后的真正问题。通过对核心问题的分析，可以将问题分为功能改进型、系统发展不均衡或参数改进型、功能求解型问题。通过与设计者交互对话，了解问题若为功能改进型，则引导设计者进入组件分析工具或功能分析工具；若为系统发展不均衡或参数改进型问题，则引导设计者进入冲突描述；若为功能求解型问题，则引导设计者进入功能分析工具；若还是对问题依然不清楚，则进入问题分析阶段。

2.2.2 问题分析

问题分析阶段主要目标是将一个状态模糊的初始问题通过问题分析工具的辅助转换为表述清晰的标准问题模型。

1）系统分析

利用因果分析工具的鱼骨图法分析系统组成组件，然后利用组件分析工具对技术系统进行分析，建立功能模型来理解一个系统；并通过系统分析找出当前系统的不足，定义系统存在的问题功能。通过对问题功能的分析，可以将问题分类，若为功能改进型问题，则设计者进入物质场-分析；若为系统发展不均衡或参数改进型问题，则引导设计者进入冲突分析；若为功能求解型问题，则进入功能分析工具。

2）物质-场分析

若为功能改进型问题，也可利用物质-场分析工具来解决。根据之前组件分析工具确定的有害功能或缺陷功能，构建其物质-场模型。产品的有害功能或缺陷功能的物场模型建立后，分析其属于哪种物质-场模型类型，进而进入问题解决阶段，使用 76 条标准解完善其功能。若对得到的概念方案并不满意，系统引导进入冲突分析。

3）功能分析

若为功能求解型问题，那么可以利用功能分析工具对问题的功能分析是在得到技术要求目标的基础上，从完成功能的角度分析系统、子系统和部件。该过程要仔细研究每一个功能是否必需，看是否和其他功能产生冲突，然后确定冲突的类型。如果没有冲突，可以得到设计的具体要求；如果有冲突进入冲突分析部分。

4）冲突分析

若为系统发展不均衡或参数改进型问题，系统推荐进入冲突分析模块。

①技术冲突描述。分别从正反两方面描述技术冲突 TC1、TC2，采用物质-场分析工具分别建立矛盾 TC1、TC2 的图解模型。选择对系统主要功能最为重要的矛盾作为系统的改进方向。

按照技术冲突描述格式对冲突进行描述，确定改善特性和恶化特性，并对其向 39 个工程参数映射。将获得的参数传入问题解决阶段的冲突检索工具，来获得对应冲突原理和实例，获取概念方案。若对概念方案不满意可以直接进入下一步。

②利用 STC 算子工具激化矛盾。通过将系统参数设为极限状态的方式，强化矛盾。

③假设引入 X 资源可以解决矛盾，陈述这一资源应执行的功能。

④转入物质-场分析工具进行标准解检索。

⑤定义矛盾发生区域和时间

⑥利用九窗口工具定义可用的资源。

⑦利用理想化分析工具定义理想解 1、2，描述物理冲突。

⑧尝试用物质场分析工具解决物理冲突。

⑨利用小人法工具或可用资源分析工具扩展物质-场资源。

2.2.3 问题解决

问题解决阶段的目标是形成初步的概念方案。针对上一步形成的问题模型，采取相应的问题解决工具解决。物理冲突用分离原理解决，技术冲突用发明原理解决，物质-场模型用 76 个标准解解决，知识使能问题对效应库进行功能检索。从而得到该问题的概念方案。若对得到概念方案并不满意，可以重新对问题进行描述、分析。若对概念方案满意，则进入方案形成阶段。

2.2.4 方案形成

方案形成阶段的目标是形成最终方案。设计者利用方案评价工具对上述得到的概念方案进行管理筛选和方案细化修改，删除不合理的方案，并选择一种评价方式进行方案评价，选择出最适合的概念方案进而形成最终方案。方案评价有最小资源、最小时间、最小成本三种默认的标准，用户也可根据实际需要定义评价标准。这一步需要用户输入方案中的时间、资源、成本的比重，系统根据方案占用的比率给出最终方案的排序，如果最终产生的方案经过评价具有可行性，则选择生成文本报告，对整个解决方案产生的过程及解决方案的详细内容进行整理归档，并可选择将问题解决方案加入私有知识库或共享知识库中，提高了知识的可迁移性及共享性。如果方案不可行，则对问题进行重新描述或者退出流程。

2.3 语义分析模块

自热语义理解是人机对话系统和口语翻译系统中的重要组成部分,其任务是对用户口语化的输入进行解析,理解用户的目的及提取其中的关键信息。目前相关技术还达不到对自然语言的完全语义理解，本文应用了一种语义框架的概念来解决自然语义理解的问题。

由于直接对用户的问题描述进行直接分析比较困难，本文中将每个工具都由一系列的问句组成。其中每个工具就是一个语义框架，而工具中集成了许多待填参数，从而对通过对语义框架中参数进行提取，然后对问句中的参数进行语义分析，进而理解用户的问题描述信息。下图 2 给出了实例加以解释。

问句：

1 系统的主要功能是[PF]

2 系统组成有哪些[COM]

3 有害作用有哪些[HF]

4 有害作用功能体、功能受体是什么[S1][S2]

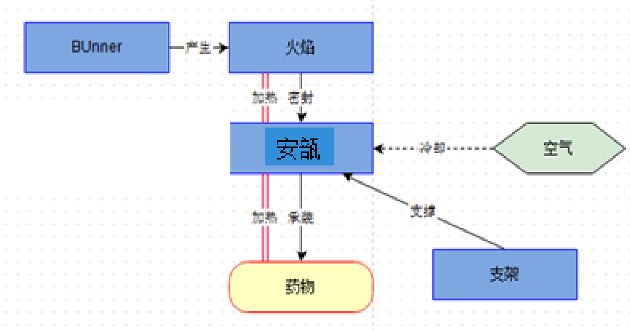

图 2 组件分析图

这是一个组件分析工具的实例，工具中包含问句的回答以及组件功能的图的绘制。首先设计者对系统提出的问题的回答，并且进行问题功能的组件功能图的绘制；然后系统对设计者的结构化描述进行参数抽取，可以直接获取设计填写的主要参数，如[COM]，[HF]等，也可以直接进行图像分析获取参数；最后时候，该工具通过对参数的分析得出初步语义理解结果：有害作用是“加热“，存在于安瓿对药物加热过程中。

3.工程应用实例

大部分林木生物质原料在开发利用前期都需要进行粉碎加工处理，以便进一步加工利用。 现需设计一台粉碎机，粉碎颗粒尺寸为 1mm 以下，生产率为 1t/h 以上，通过查询、调研，没有可以满足上述要求的粉碎机产品，拟借鉴锤式粉碎机的结构，如图所示。现有的锤式粉碎机一般由机体、电动机、转子、锤刀和筛网组成，利用高速旋转的锤刀在粉碎室内对物料进行打击、切割，粒度合格的物料通过筛网的筛孔排出。这种结构的主要问题是粉碎颗粒尺寸过大（多为 10mm 以上）；生产率低；刀具磨损快、 寿命低。需要对其进行改进设计。(Fu M,2010)

3.1 问题描述

1）主要问题：工具粉碎物料有效性差。

2）核心问题：利用因果分析工具分析问题根源：物料形成一层环流层，降低了物料和刀具的相对速度；同时由于离心力的作用，使大粒度物料紧靠在筛网上，阻碍了合格的小粒度物料及时过筛。下图 3 为画出的因果分析图。

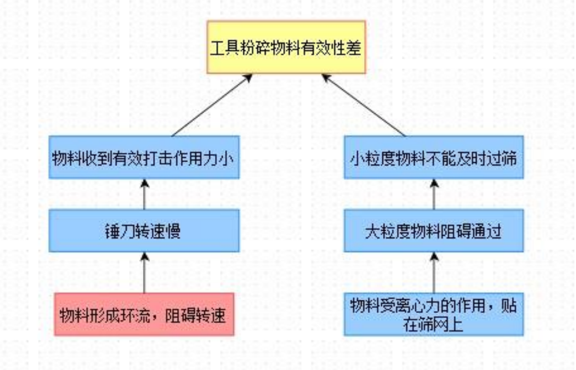

图 3 因果分析图

3）理想目标是：不增加系统复杂性的前提下，能将物料粉碎至所需粒度（1mm）。

3.2 问题分析

1）系统分析

系统的名称：粉碎机。 系统的功能：粉碎物料。 系统的组成部分有物料、刀具、筛网、粉碎室。利用组件分析工具建立组件功能图。可以看出有害作用在物料和刀具以、物料和筛网之间。然后通过与设计者交互，确定此问题是功能改进型问题，然后系统推荐其使用物质-场分析工具。下图 4 为画出的组件分析图。

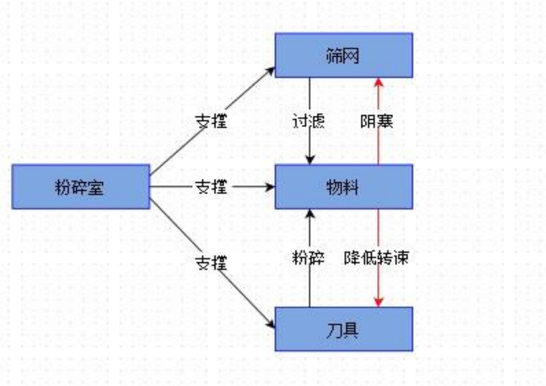

图 4 组件分析图

2）物质-场分析

建立物质-场模型图 5，刀具 S2 对物料 S1 的作用力不足，可应用标准解系统中的第二类标准解“增强物-场模型”得到三个概念方案。设计者对这三个方案不是特别满意，进而系统推荐设计者使用冲突分析工具。

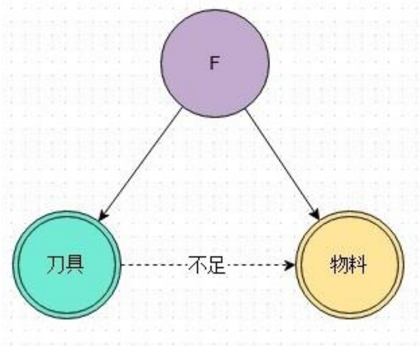

图 5 物质-场模型

3）冲突分析

（1）技术冲突描述：

TC1：若刀具排列密度大，可以将物料粉碎很细，但增加系统复杂性。

TC2：若刀具排列密度小，不能很好地粉碎物料，但制造容易、 成本低。

选取主要技术矛盾。选取与技术系统的主要功能有密切联系的技术矛盾进行解决。本系统的主要目的是将物料粉碎至所需细度，因此选取技术矛盾 TC1

（2）激化矛盾：指出组件作用的极限状态。刀具排列密度很小（只有一把刀具），而能将物料粉碎很细

（3）必须找到一个 X 元素，即能维持刀具排列密度很小，又能保证物料粉碎很细（理想化分析）

（4）描述冲突发生的时间和区域

①确定操作区域：

刀具和物料接触处。一般操作区域就定义为问题模型中矛盾出现的地方。一般操作区域就定义为问题中矛盾出现的地方。

②确定操作时间：

操作时间包括矛盾发生的时间（机器开动，粉碎作业时）以及矛盾发生前的时间（预处理物料、进料时）

③确定技术系统、外界环境以及作用对象的物质-场资源，资源列表如下图 6

可用资源	物质资源	场资源
工具	锤片	机械场
系统组成部件	物料 、转子总成	机械场
特定的环境	风 、空气 、热	热场 、风场
超系统	筛网粉碎室	

图 6 可用资源

（5）调动和使用物场资源 SFR。建立“小人”模型。下图 7 左为当前系统小人模型，由于高速环流层的作用，物料贴在筛网内壁，刀具追打物料，有效粉碎性差。图 7 右为改进系统小人模型，每个物料小人都被刀具小人包围，提高有效打击力度。

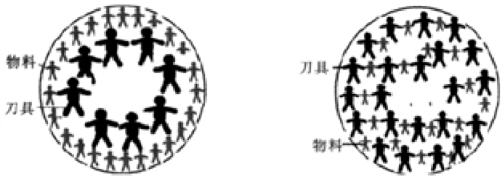

图 7 小人模型

3.3 问题解决

由上步形成物质-场模型检索到三种概念方案：

1）由图 8 标准解 15“并联物质-场” 现有系统的有用作用力 F1 不足，可以加入第二个场 F2 来增强 F1 的作用，得到概念方案 1:采用风力输送，通过高压风机产生的风力，加速合格物料通过筛网。

2）由图 9 标准解 17“工具细化”提高完成工具功能的物质分散度，得到概念方案 2：让粉碎室内布满刀具，可在筛网上加底刀。

3）由图 10 标准解 21“物质结构化”将均匀的物质空间结构变成不均匀的物质空间结构，得到概念方案 3：采用不规则粉碎室如椭圆形，水滴型粉碎室替代圆形粉碎室，破坏物料环层， 增加有效打击力度。

图 8 并联物质-场

图 9 工具细化

图 10 物质场结构化

3.4 方案形成

由改进后的小人模型，结合资源分析，综合分析概念方案 1-3，得到问题的解决方案：双层筛孔尺寸小，解决了单层筛结构中大粒度及时过筛的问题。采用风力输送合格物料。在里层筛网上安装底刀，对物料起辅助切削作用；底刀的存在也破坏了物料的高速环流层，增大了物料和刀具的相对运动速度，从而提高了刀具对物料的有效打击力度。两层筛之间的物料可定期导出后返回粉碎室继续被粉碎，也可利用双层筛分的结构生产两种不同粒度要求的产品。

4.总结

本文在分析了各种创新工具的应用方式的基础上，提出了语义交互式计算机辅助发明问题解决过程模型。该模型分为问题描述、问题分析、问题解决、方案形成四个阶段，每个阶段都为用户推荐不同创新工具。由于实际问题有复杂的表象，不一定在第一次分析时就能对问题作出正确的描述，设计者可以对本模型进行循环利用，实现对初始问题逐步深入分析和转化，最终解决问题。

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Applying TRIZ method on improvement of iron bar windows

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Abstract

Within the building infrastructure of Taiwan, the culture of buildings implementing iron bars on windows to prevent theft and for safety reason such as children accidentally falling is still extremely popular. But in comparison to emergency safety concepts, most citizens still apply more emphasis on theft, and ignore the fact iron bars are one of the many obstacle during emergency evacuation. According to the national fire agency from 2009 to 2013 statistical analysis of fire hazards, the highest type of fire hazard is single building fires. In another report analyzed by the New Taipei City fire department stated that the mortality rate caused by iron bars blocking the windows accounts for 30 % of fire related-death, thes ㎞ location of the key is known, moving around in the smoke will shorten the time needed for escape . The main purpose for this study is to improve the ordinary locks seen on most building windows, by implementing patent information index and patent analysis to investigate, perform with universal design and adding the innovative theory of TRIZ to build a foundation for a new design. Using the engineering parameters and substituting the parameters into the TRIZ matrix of contradiction to achieve the basic principle of the design, also consulting with the patent index database to make sure that none intellectual conflict has occurred. Finally is to produce a skeleton model/prototype model using a rapid modeling mechanical apparatus.

應用 TRIZ 方法於住宅鐵窗之改善

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摘要

在台灣的住宅型態中，於建築物外加裝鐵窗來防盜與防止幼童攀爬墜樓的情況相當盛行，但相較於緊急避難逃生觀念，大多民眾仍將重心優先放於防盜上，而忽略掉鐵窗常也是阻礙逃生的兇手之一。根據消防署從 98 年至 102 年逐年對於國內火災發生數據統計顯示，火災型態皆以獨立住宅火災所佔比例最高，新北市消防局分析歷年來火場死亡因素，發現因鐵窗阻礙逃生件數佔火災死亡人數 3 成，尚不含因鐵窗阻礙引發嗆傷等情形。本研究的目的主要在於改良一般常見以鎖頭形態設計的住宅鐵窗，利用專利資訊檢索系統進行相關專利分析，將使用者簡單操作概念與人因工程融於設計中，再應用 TRIZ 創新發明原則，經由專利迴避做改善創新設計，最後，透過 CAD 動畫模擬產生的雛型。

關鍵詞：關鍵詞：鐵窗、逃生、矛盾矩陣、專利迴避、萃智創新。

1. 前言

1.1 研究背景動機

在台灣住宅區中不論是公寓或是一般透天住宅皆不難發覺加裝鐵窗情況相當普遍，加裝鐵窗主要目的包含(1).防止宵小利用集合住宅外窗入室偷竊 (2).防止家中幼童攀爬陽台窗戶發生墜樓意外 (3).增加陽台使用空間。加裝鐵窗雖然滿足住戶的住宅需求，但近年來在鐵窗規格大小不同、裝設與否不一的情況下，已漸漸被列為住宅美學的有礙之物，再加上多次災害事件發生的真實案例，鐵窗已衍生成為逃生上的一大有害之物。

根據消防署從 98 年至 102 年逐年對於國內火災發生數據統計顯示，火災型態皆以獨立住宅火災所佔比例最高【16】，新北市消防局分析歷年來火場死亡因素，發現因鐵窗阻礙逃生件數佔火災死亡人數 3 成【17】。現今住宅的鐵窗設計，不論外觀款式的如何改進，或是是否在鐵窗上留有一扇活動逃生門，最後大多仍以鎖頭上鎖當作鐵窗的最後一道防線，但鎖頭因暴露於室外，在多年風吹日曬下鎖孔多已生鏽不堪始用。若在鐵窗鎖頭狀態良好情況下，倘若發生火災，因火場煙霧瀰漫導致視線不良，不但不易順利取得鑰匙，再加上逃生時的緊張慌亂氛圍下，就算熟知鑰匙位置也需花費時間摸索，這些都足以威脅寶貴逃生時間。

1.2 研究目的

本研究的目的主要在於改良一般常見以鎖頭形態設計的住宅鐵窗，透過專利資訊檢索與專利分析先進行鐵窗相關專利探討，並且結合通用設計，將使用者簡單操作概念融於設計中，再以 TRIZ 系統性創新理論建立產品創新設計要點，利用欲改善工程參數與避免惡化工程參數代入 TRIZ 矛盾矩陣中求得適當發明原則，並將未與專利檢索資料有衝突之創新設計透過 CAD 動畫模擬產生的雛型。

1.3 研究範圍與限制

防盜窗之種類、設計安裝特徵皆有所不同，在考量研究目的與時間成本下，本研究以傳統防盜窗為主要研究對象，傳統防盜窗是以金屬材料製成欄狀或格狀構造，並安裝於陽台或窗戶外，且防盜窗的鎖門裝置是一栓桿及一鎖具的組合。本研究運用 TRIZ 工具產生之創新發明方案中，在考量通用設計情況下僅運用 PPP 量表評價設計結果。

1.4 研究架構

本研究首先介紹研究背景與動機，接著介紹本研究的目的及研究流程。經由文獻探討了解研究方法及理論。透過專利檢索分析與迴避，結合 TRIZ 創新理論，找出適當的改良設計，並以 CAD 3D 模型展示具體化設計雛型，本研究架構如圖 1-1 所示。

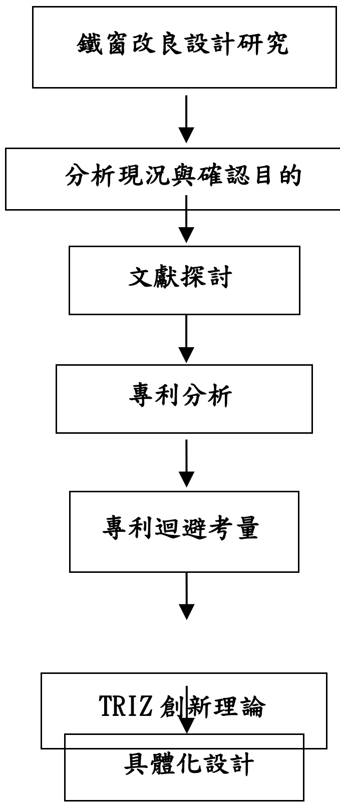


圖 1-1 研究架構

2. 文獻探討

2.1 住宅鐵窗

走到台灣都市中，幾乎都可以看到建築物外加裝鐵窗，甚至已被認為是台灣的「特色」。 推敲「鐵窗文化」形成的原因，建築師李清志認為，戰爭讓老一輩台灣人多有逃難心態，建造鐵窗是一種「臨時」、「將就」，但能維護身家安全的措施。經過多年的演變，鐵窗的功能已不僅是保護小孩以及防範小偷的功能，在寸土寸金的時代裡，許多大都會區民眾開始在鐵窗上動手腳，其中又「陽台外推」最常見，透過鐵窗裝設後，不但陽台增加了曬衣、堆放雜物或是擺放植栽的空間，甚至還有居民將整座瓦斯桶都架上外推的陽台鐵窗上，形成特殊的「進化式鐵窗」。(信義房屋 愛。幸福雙月刊 2011 No.21)

根據中華保全協會於2012年針對台灣地區600戶保全服務現用戶與潛在用戶的一項問卷調查研究顯示，安裝鐵窗的公寓戶數為71%，透天厝為70%，雖然兩項住宅類型以安裝鐵窗強化安全的比例皆已較2011年下降8%，但安裝比例仍相當普及。（2013，台灣地區消費者保全服務需求調查研究）

「鐵窗」只是消費者溝通上習慣的通稱，事實上鐵窗未必是「鐵」做的，只是在過去住宅陽台上所裝設的防盜窗一般都是鐵製的，但隨時代的變遷，現今已經發展出許多不同的材質與樣式的防盜窗，藉由本研究的資料蒐集，以材質簡單區分目前台灣常見的幾種鐵窗款式：

(1)不鏽鋼材質

不鏽鋼材質即生活上常說的「白鐵」，在設計上有空心與實心的之分，但因為實心不鏽鋼單價較高，因此，市面上大多數民眾都是選擇以空心設計的不鏽鋼窗為主，如圖2-1。不鏽鋼窗的優劣，較難從外觀上分辨， 特別是材質與厚度在焊接後幾乎看不出來差別，因此施工前應加以確認以確保不鏽鋼窗的品質。不銹鋼相較鐵質來說雖較不容易生鏽，但也非完全不會生鏽，由於台灣是海島型氣候再加上酸雨影響，縱使是使用316超耐酸鹼的不鏽鋼材質等級依然會生銹，由其是焊接處因為焊接時產生的高溫，使得不銹鋼產生敏化，因此長年下來，仍有生鏽的情況發生。

圖 2-1 不鏽鋼防盜窗

(2)鋁料材質

鋁料材質防盜窗常見的形式為新型鋁製穿梭管與鋁花格窗兩種。新型鋁製穿梭管最重要的特色是橫料與直料互交叉貫穿，如圖2-2，而非不鏽鋼的焊接方式，也因為是交叉貫穿，結構上相較不鏽鋼窗穩固、不易變形、耐撞擊性也較強。鋁花格窗材質上比較軟，安裝時常會於底部加上鋁板，以確保承載過重而斷裂，如圖2-3。鋁料材質相當不易生鏽，若在其表面加以電鍍或烤漆處理，更能大幅延長鋁料材質窗外觀的完整性。若以樣式來加以區分鐵窗款式，除了一般常見的格狀防盜窗的設計，另一種為近幾年才推出的「隱形鐵窗」，隱形鐵窗又名鋼索窗，透過高純度不鏽鋼線與鋁合金框架組合而成，之所以叫隱形鐵窗是因其鋼索在15公尺外即無法看到安裝處，不僅不會影響大樓建築外觀，更不會阻擋住宅落地窗外的美景，如圖2-4。隱形鐵窗每一根鋼絲可承受140kg以上的拉力，並增加高智慧隱形防護裝置，一旦遭到破壞即會自動發出警示聲，並自連接電話或警局，有效嚇阻違法侵入者。

圖 2-2 新型鋁製穿梭管

圖 2-3 鋁花格防盜窗

圖 2-4 隱形鐵窗

2.2 TRIZ 方法

TRIZ 是俄文 Teoriya Resheniya Izobretatelskikh Zadatch 字首的縮寫，TRIZ 英文全名為”Theory of Inventive Problem Solving”， 依據字面意義為：創新問題解決方法之理論，或簡稱"萃思"或"萃智"【4】。TRIZ 是是由俄國學者 Genrich Altshuller 在任職於前蘇聯海軍專利局擔任專利審核員期間，研究近二十萬件專利著作中，所歸納出專利發明的創新發明邏輯與其中的共同性，Genrich Altshuller 將其研究成果彙整公佈之後，吸引許多人士加入研究，保守估計約有超過百萬件專利運用此方法進行歸納研究【3】。TRIZ 的基本工具包含 39 工程參數與矛盾矩陣分析、40 項發明原則、資源分析、76 種標準解、質場分析及六大資源等工具【24】。

Altshuller 為 TRIZ 建構的理論架構是將發明問題建構一個或多個分類制度，對於每個類別的問題確認出解決方法的運算式【3】。如圖 2-5 所示，將特定發明問題抽象化的轉換成 TRIZ 標準問題的類型，再將此問題類型運用 TRIZ 理論的途徑尋求公式化的 TRIZ 解決方案，最後將 TRIZ 標準解答轉回特定問題的解答。

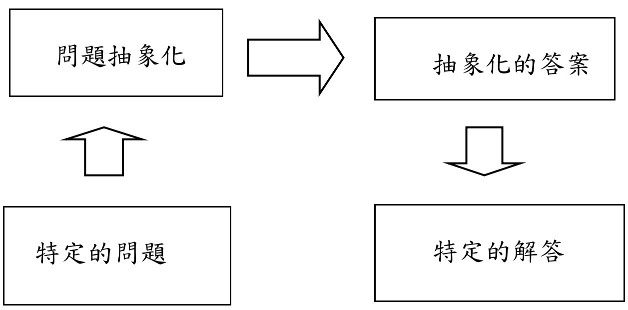


圖 2-5　TRIZ解決方法流程

2.3 專利探討

2.3.1 專利資訊

專利資訊(Patent information)與專利文獻(Patent document)皆是由專利制度衍生而成，兩者意義相當類似，但所包含層面與範圍卻略有差異。專利資訊是包括印刷與電子形式等各種類型專利資訊，專利文獻則是指印刷形式的專利資料，為各種專利文件的總稱，因此專利文獻為專利資訊的一部分【2】。

專利資訊可透過專利說明書中的申請人、申請日期、核準日期、發明人、申請人、核准專利號碼、國別、摘要、參考文獻或專利、詳細說明書、圖示…等欄位所取得。專利資訊分為廣義的專利資訊及狹義的專利資訊，狹義的專利資訊指的是發明、新型或新式樣專利的說明書，廣義的專利資訊除了發明、新型或新式樣專利的說明書外，還包括各國專利主管機關定期出版的專利公報、專利分類表、統計資料及不公開發行的所有伸查過程中的文件【6】。

專利資訊資料庫的建構不但可以避免著作者互相侵害著作，另一項重要功能為企業確認研發策略，企業在研發通常需要投入大量資源，透過專利範圍分析可確認侵權風險與專利研發的可行性。透過專利分析可以瞭解企業及競爭對手之專利權擁有情況；競爭對手的專利策略；專利在過去、現況及未來發展趨勢以及瞭解研發產出、產業趨勢、競爭者動態、策略規劃與購併決策等【22】。

2.3.2 專利檢索分析與迴避

專利檢索是指從眾多的專利資訊中，找出特定資料以便利用。紙本式專利檢索工具書雖能協助檢索，但卻相當耗時，相較之下，網路專利資料庫具有迅速舉得的優勢。現今許多先進國家均可透過專利查詢網站獲得大部分的專利文件資訊，如世界智慧財產組織（WIPO）、美國專利與商標局（USPTO）、歐洲專利局(UPO)、日本特許廳(JPO)與中華民國專利資訊網。根據世界智慧財產組織（WIPO）的資料，全世界每年的發明成果90～95%在專利文獻中可以查到，而其他技術文獻指反應5～10%，同時WIPO還指出在研究工作中查閱專利文獻可以縮短研究時間60%，節省研究經費40%【1】。

專利分析(Patent Analysis)是指將各種與專利相關的資料，以統計的方法，加以整理成各種可以做分析、解讀的圖表訊息。專利分析係指將各種與專利文件相關所包含的資訊進行統計、分析及比較之方法，藉此呈現各種圖表訊息、專利資訊及情報，以供企業探查技術展與資源分配之關係【4】。專利分析就是將專利資料轉換成更為有價值之資訊亦稱之為專利地圖，是科技研發規劃與智慧財產權管理的有效工具，可作為科技競爭分析、技術趨勢分析、以及權力範圍判斷【1】。

專利迴避係研究如何避開他人專利的一種學問。當研發人員在研發新的技術時，首先，研發人員應該先分析相關的專利技術，以了解是否會侵害別人的專利。研發人員了解新產品會侵害那些專利後，應研究如何避開這些專利，避免專利侵權。由於侵犯別人的專利可能要使公司付出權利金，使公司受制於他人，所以研發人員應研究如何進行專利迴避，這是研發新產品時必要的動作。企業在開發新產品時，常有研發資源缺乏與技術取得不易的問題，若能妥善集中整體資源將市場領導產品進行有效的迴避設計，則可容易以市場追隨策略進入市場獲取利益。

3. 研究方法

本研究採專利文獻資料分析法調查設計問題，結合文獻導入TRIZ方法理論，建置一個創新的矛盾矩陣，將所產生的發明原則配合質場分析，再將最後方案具體化實現，研究流程如圖3-1所示:

專利分析

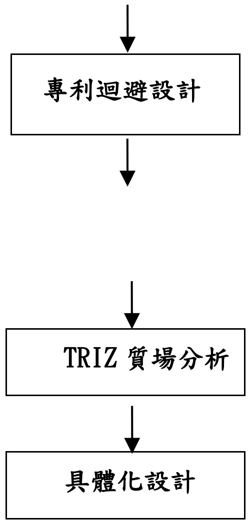


圖 3-1 研究流程

3.1 專利分析

以中華民國專利資料庫網址(http://www.tipo.gov.tw/ch/)搜尋研究目的同類產品相關公開專利文獻資料，本研究利用關鍵字防盜及鐵窗檢索尋找到下列四個符合相關條件需求的專利文獻分別列表分析。

表 3-1 安全式防盜鐵窗專利分析表

專利名稱	安全式防盜鐵窗			專利狀態	
專利號碼 (Patent No.)	M401691	申請日 (Date of Filed)	99.10.18	公告日 (Date of Issued)	100.04.11
專利申請人 (Assignee)	楊開翔		發明人 (Inventors)	楊開翔	
分析人員	陳正哲		技術關鍵字	多邊形限位孔	

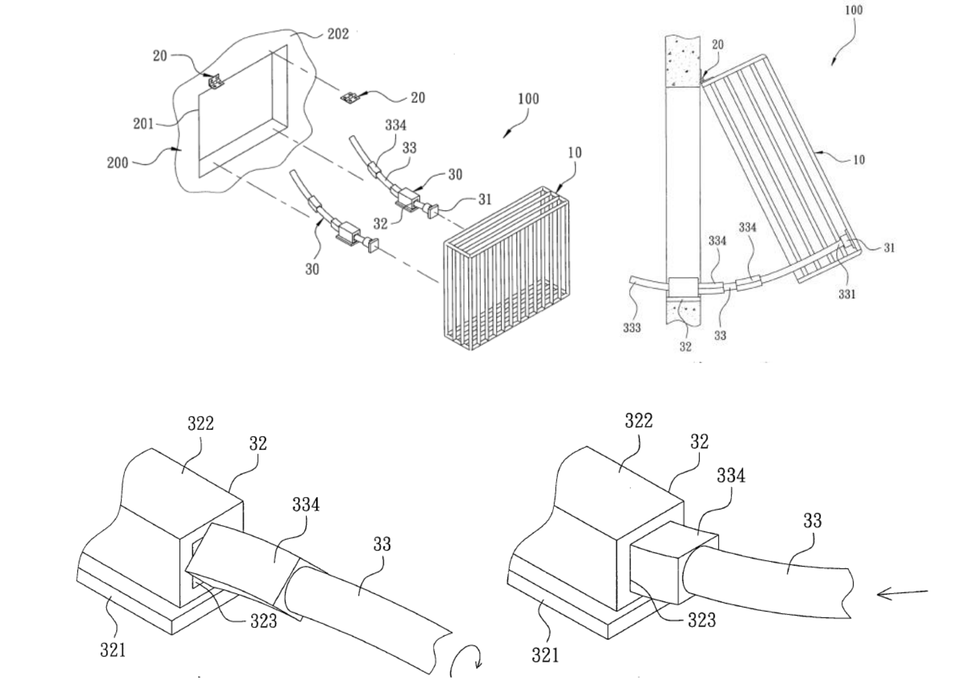
先前技術缺失	大多數鐵窗相關專利僅針對平面或向外突出之窗體擇一做改良，此專利設計可適用於這兩種鐵窗型態上。
專利功能(Functions)	樞接座設置於鐵窗本體上，且樞接座上設有一樞接孔，而限位座則設置於窗口上，該限位座上對應樞接孔並設有一多邊形之限位孔，而該推桿之一端則設有一樞接部，並穿過該限位孔樞設於該樞接孔內，另端則設有一握持部，可供使用者握持者，同時，該推桿於該樞接部與該握持部間更設有至少一卡止部，且該卡止部係形成對應該限位孔形狀之多邊形，而可在特定角度穿過該限位
達成結果(Results)	使用者操作時只需轉動推桿，讓卡止部與限位孔對合後，便可使鐵窗本體解鎖，順勢向外推開鐵窗本體，即可與窗口間形成缺口，供使用者進出。
技術方式與關鍵圖示(Ways)	

表 3-2 閂鎖構造專利分析表

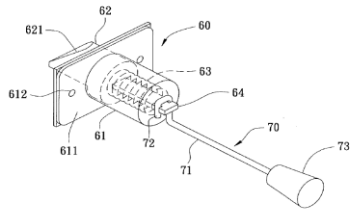
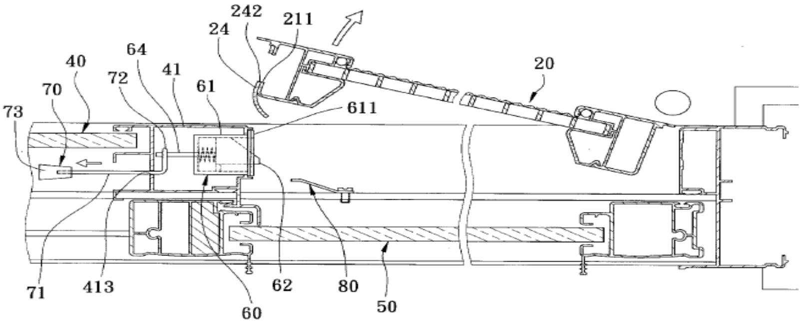
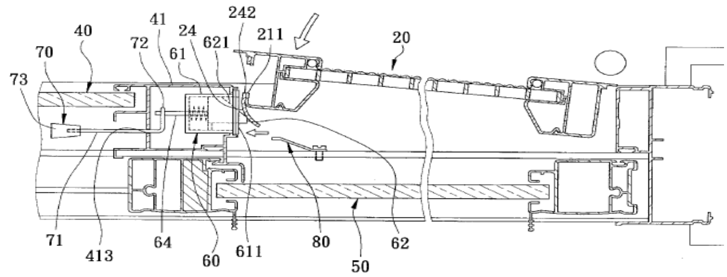
<table>
<tr><td>專利名稱</td><td colspan="3">快速鎖固與開啟防盜紗窗之閂鎖構造</td><td>專利狀態</td><td></td></tr>
<tr><td>專利號碼
(Patent No.)</td><td>M291462</td><td>申請日
(Date of Filed)</td><td>94.11.30</td><td>公告日
(Date of Issued)</td><td>95.06.01</td></tr>
<tr><td>專利申請人
(Assignee)</td><td colspan="2">趙秀雄、趙領暹</td><td>發明人
(Inventors)</td><td colspan="2">趙秀雄、趙領暹</td></tr>
<tr><td>分析人員</td><td colspan="2">陳正哲</td><td>技術關鍵字</td><td colspan="2">彈性突伸及壓掣內縮之閂舌</td></tr>
<tr><td>先前技術缺失</td><td colspan="5">透過簡單操作的彈性閂舌，可省去繁雜的開鎖動作，保留更多緊急逃生時間。</td></tr>
<tr><td>專利功能
(Functions)</td><td colspan="5">本創作提供一種快速鎖固與開啟防盜紗窗之閂鎖構造，主要是在防盜紗窗與外窗扇間相對設置一可相互閂扣之閂鎖裝置與一閂孔，用以閂鎖固定防盜紗窗，且該閂鎖裝置上裝設有一延伸至室內之操作柄，可供拉掣開啟閂鎖裝置。</td></tr>
<tr><td>達成結果
(Results)</td><td colspan="5">本創作所提供之閂鎖構造，可藉由閂鎖裝置快速鎖固防盜紗窗，以達到安全防盜效果，更可在不須使用鑰匙之情形下開啟防盜紗窗，作為安全逃生通道者。</td></tr>
<tr><td>技術方式與關鍵圖示(Ways)</td><td colspan="5">

</td></tr>
</table>

表 3-3 免鎖防盜逃生窗改良專利分析表

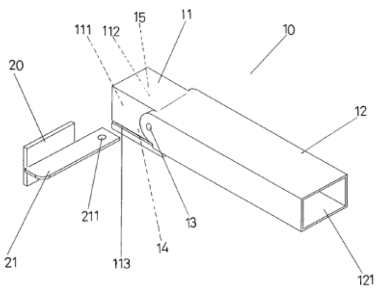
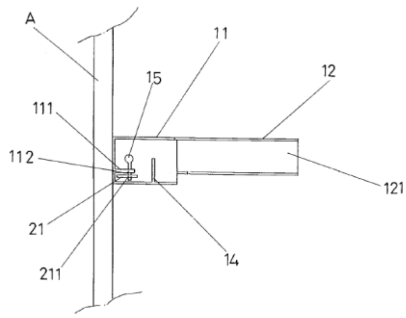
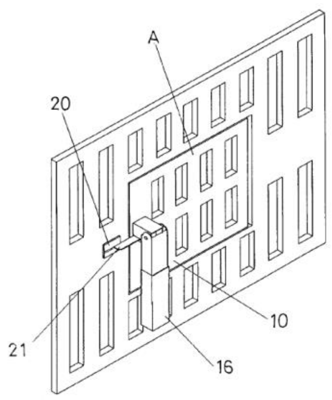
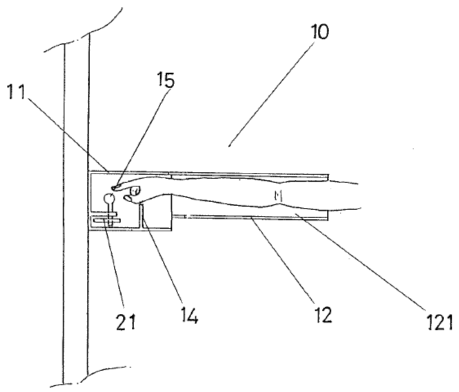
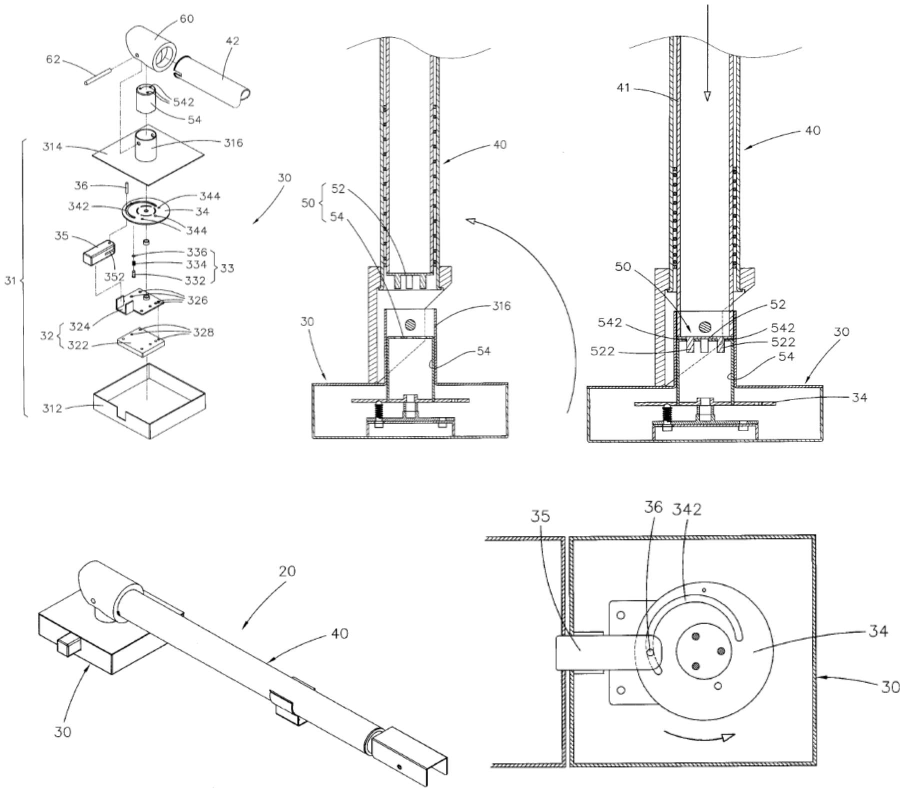
<table>
<tr><td>專利名稱</td><td colspan="3">免鎖防盜逃生窗改良</td><td>專利狀態</td><td></td></tr>
<tr><td>專利號碼
(Patent No.)</td><td>M261583</td><td>申請日
(Date of Filed)</td><td>93.06.09</td><td>公告日
(Date of Issued)</td><td>94.04.11</td></tr>
<tr><td>專利申請人
(Assignee)</td><td colspan="2">徐玉堂</td><td>發明人
(Inventors)</td><td colspan="2">徐玉堂</td></tr>
<tr><td>分析人員</td><td colspan="2">陳正哲</td><td>技術關鍵字</td><td colspan="2">滑塊門閂、圓球插銷</td></tr>
<tr><td>先前技術缺失</td><td colspan="5">固定滑塊之插銷設計為圓球狀，可減少防範宵小利用工具勾開破解</td></tr>
<tr><td>專利功能
(Functions)</td><td colspan="5">防盜逃生窗之外窗設有一固定滑塊,該固定滑塊滑設有一門閂,其門閂上設有一穿孔,活動塊體內設有一通道;該樞設元件介於本體與活動塊體之間;該擋片設於本體內側;該插銷,用與本體固定凸塊之穿孔及固定滑塊門閂之穿孔相對應插設鎖固。</td></tr>
<tr><td>達成結果
(Results)</td><td colspan="5">防盜免鎖裝置之設置可避免宵小經由外側伸手進入防盜免鎖裝置內奪取插銷，故可完全防範宵小開啟</td></tr>
<tr><td>技術方式與關鍵圖示(Ways)</td><td colspan="5">   </td></tr>
</table>

表 3-4 防盜窗鎖結構專利分析表

<table>
<tr><td>專利名稱</td><td colspan="3">防盜窗鎖結構</td><td>專利狀態</td><td></td></tr>
<tr><td>專利號碼
(Patent No.)</td><td>M289801</td><td>申請日
(Date of Filed)</td><td>94.11.22</td><td>公告日
(Date of Issued)</td><td>95.04.21</td></tr>
<tr><td>專利申請人
(Assignee)</td><td colspan="2">黃珀慧</td><td>發明人
(Inventors)</td><td colspan="2">黃珀慧</td></tr>
<tr><td>分析人員</td><td colspan="2">陳正哲</td><td>技術關鍵字</td><td colspan="2">長桿狀按動部位解鎖</td></tr>
<tr><td>先前技術缺失</td><td colspan="5">配合舉起、按壓及轉動三種不同的操作動作才能解開，可防止家中幼童輕易開啟。</td></tr>
<tr><td>專利功能
(Functions)</td><td colspan="5">本創作包括一鎖體裝置及一操作裝置，該操作裝置係安裝在該鎖體裝置上，配合舉起、按壓及轉動三種不同的操作動作，即可解除該鎖體裝置所產生的鎖門效果，而達到免鑰匙且方便操作的效果。</td></tr>
<tr><td>達成結果
(Results)</td><td colspan="5">該操作裝置設計成一長桿狀，特別是，長度以超過一般人手臂長度為最佳。據以上設計，即使外界有人將該操作裝置舉起形成預備開鎖狀態，也無法接觸到位在該操作裝置遠端的按動部位。由於外界的人無法按動該操作裝置，自然無法有效解鎖，所以本創作具有高防盜功能。</td></tr>
<tr><td>技術方式與關鍵圖示(Ways)</td><td colspan="5"></td></tr>
</table>

本研究將表 3-1 至表 3-4 防盜鐵窗相關專利文獻分析中出現較高之問題，確認產品設計改良欲改善的工程參數並分析該方法可能造成副作用的參數轉換到 TRIZ 中的 39 項工程參數；找出一組或多組設計問題，可利用欲改善的參數尋找對應建議之法則，構想可行的發明原則。

3.2 矛盾矩陣與 40 項發明原則

TRIZ 將矛盾分為物理矛盾(Physical Contradiction)與技術矛盾(Technical Contradiction)兩類。在解決問題中，必須先了解此矛盾是技術矛盾還是物理矛盾。技術矛盾利用 39 項工程參數與 40 項發明原則來解決；而物理矛盾則用分離原則來解決【4】。Altshuller 分析眾多的專利從中歸納出的第一個重大突破即為技術矛盾，技術矛盾的存在常因為嘗試改進一個參數 A 時，卻又使得參數 B 惡化，過去當遇到矛盾問題時，多半都是採取妥協的面對或是折衷處理，但這是在創新發明中所不考慮的，一個好的發明應該是使兩個參數都往正向發展【3】。

Altshuller 在分析這些技術矛盾中共歸納出 39 個工程參數，還有各項專利中常運用的 40 個發明的法則，透過矛盾矩陣表，能幫助在減少矛盾衝突時，不會又產生另一個新的問題。矛盾矩陣表為 39 × 39 之矩陣，橫軸代表 39 個欲改善的參數，縱軸代表 39 個會惡化的參數，如表 3-5 所示。針對矛盾矩陣所提出之建議解答為 40 個創新法則中的數個最常用者，相關的 39 個工程參數定義與 40 個創新法則之詳細說明可參閱參考文獻【4】。

表 3-5 矛盾矩陣表

惡化參數 / 改善參數		1. 移動件物體重量	2. 固定件物體重量	…	10 力量	…	39 生產力
1	移動件物體重量	——	——		8，10 18，37		3，24 35，37
2	固定件物體重量	——	——		8，10 19，35		1，15， 28，35
…	…						
39	生產力	24，26 35，37	3，15 27，28		2，10 35，37		——

資料來源：本研究整理

導入矛盾矩陣有以下幾個步驟:(1)將待解決的問題以文字敘述，試著找出問題矛盾的起因。(2)在表中橫軸找出欲改善的參數。(3)在表中縱軸找出防止產生惡化的參數。(4)利用矩陣找出兩相互矛盾屬性的交叉方格，並在方格中得到對應的發明原則。(5) 將對應的發明原則轉為原先問題中可能的有效解決之道。

3-3 質場分析

物質-場分析法是基於 Altshuller 通過對功能的研究發現的定律：所有的功能都可分解為 3 個基本要素：兩個物質和一個場。物-場分析法是使用圖形描述系統中的相互作用或行為的符號語言，比文字語言更清楚直觀的描述系統的構成要素和構成要素之間的相互聯繫。根據物-場模型來查找相對應問題的標準解和一般解，這些標準解不依賴領域知識，具有很高的適用性[4]。

在建立質ㄧ場分析模型後,Altshuller 提出了 76 個標準解來處理有欠缺效應的系統、有害效應的系統、過多效應的系統與不足效應的系統。模型轉化為有效且完整的系統模型的途徑，即可得到解題的方向。此 76 個標準方法分為五大類，如表 3-6，18 個子系統，共 76 個標準解。發明者首先識別問題的類型，然後選擇一個或多個相對應標準解，將選定之標準解具體化為特定的解，即可得到問題的解答。

表 3-6　76 個標準解

類　型	說　明	標準解
第一類	不改變或少量改變改良系統	13個標準解
第二類	改變系統來改良	23個標準解
第三類	系統轉換	6個標準解
第四類	檢查與量測	17個標準解
第五類	簡化及改善策略	17個標準解
共76個標準解		

4. TRIZ 應用於鐵窗改良之設計

本章節又分兩部分，分別針對屏除鎖具設計、避免宵小輕易破解兩問題，利用 TRIZ 理論的矛盾矩陣進行解決問題的設計案例探討。每一設計按照矛盾矩陣求解步驟:(1)問題的描述、(2)定義矛盾、(3)矛盾矩陣、(4)建議的創新法則、(5)綜合相關提示，找出應用改進方案。

4.1　屏除鎖具設計

(1)問題的描述:

屏除防盜窗上活動門鎖具，雖然在危急時可增快開啟速度，但平時卻也隱藏宵小輕易開啟的隱憂。

(2)定義矛盾:

屏除防盜窗上活動門鎖具，雖然可增快開啟速度，卻也使得防盜窗的強度減弱，宵小可更加輕易的開啟侵入。即“防盜窗有害因素”與“防盜窗強度”之間的矛盾。將矛盾的兩方轉換成適當的參數：　“物體外在有害因素”為欲改善的參數; “強度”為防止產生惡化的參數

(3)矛盾矩陣:

從 39X39 矛盾矩陣表中找出物體外在有害因素(30)、強度(14)對應的發明原則，如表 4-1

表 4-1 欲改善“物體外在有害因素”(30)、避免惡化“強度”(14)的矛盾矩陣

避免惡化 / 欲改善	14 強度
30 物體外在有害因素	18、35 37、1

(4)建議的創新法則:

表 4-2“物體外在有害因素”與“強度”矛盾矩陣建議的創新法則

建議的創新法則	相關具體提示	應用改進方案
18 機械震動	1. 使物體震動或震盪 2. 增加震動的頻率 3. 使用共振頻率	(不適用此問題的解決方案)
35 參數改變	1. 改變彈性(伸縮性、彎曲性、可撓度)的程度 2. 改變壓力 3. 改變長度、體積 4. 改變其他參數	◆透過改變鎖具參數,改變傳統常見的鎖頭樣式,以其他形式呈現
37 熱膨脹	1. 利用材料的熱脹冷縮去完成有用的效應 2. 利用不同膨脹係數的多種材料,去完成不同的有用效應	◆透過熱脹冷縮原理,使發生火災環境產生高溫時,防盜窗能自動解鎖開啟
1 分割	1. 將物體分成獨立的部分 2. 使物體成為區段區塊或模組化(使容易組裝與拆卸)	◆使鎖具或固定活動窗之結構分割獨立,使其不與防盜窗直接結合且方便拆卸

4.2 避免宵小輕易破解

(1)問題的描述:

屏除防盜窗活動門上傳統形式鎖具,大多數會另外設計部份特殊結構避免外來侵入破解,不過特殊結構卻也容易造成危急時,因解鎖動作複雜導致拖延開窗脫困的時間。但在改善特殊結構同時,卻也容易造成整個特殊鎖具的可靠度降低,失去預期的功能。

(2)定義矛盾:

改善特殊結構以防危急時,因解鎖動作複雜導致拖延開窗脫困的時間,卻也容易造成整個特殊鎖具的可靠度降低,失去預期的功能。即“鎖具特殊結構”與“鎖具的可靠度”之間的矛盾。
將矛盾的兩方轉換成適當的參數:“裝置複雜性”為欲改善的參數;“可靠度”為防止產生惡化的參數

(3)矛盾矩陣:

從 39X39 矛盾矩陣表中找出裝置複雜性(36) 、可靠度(27)對應的發明原則，如表 4-3

表 4-3 欲改善“裝置複雜性”(36)、避免惡化“可靠度”(27)的矛盾矩陣

避免惡化 / 欲改善	27 可靠度
36 裝置複雜性	13、35 1

(3) 建議的創新法則:

表 4-4“裝置複雜性”與“可靠度”矛盾矩陣建議的創新法則

建議的創新法則	相關具體提示	應用改進方案
13 逆轉	1. 改用相反的作用取代原作用 2. 使活動的部份(或外在的環境)固定；使固定的部份活動 3. 將物體、系統、或程序反轉	◆將防盜窗的開啟方向相反，使其活動窗改為對內開閉，方便搭配特殊鎖具。
35 參數改變	1. 改變彈性(伸縮性、彎曲性、可撓度)的程度 2. 改變壓力 3. 改變長度、體積 4. 改變其他參數	◆透過改變鎖具參數，改變傳統常見的鎖頭樣式，以其他形式呈現
1 分割	1. 將物體分成獨立的部分 2. 使物體成為區段區塊或模組化(使容易組裝與拆卸)	◆使鎖具或固定活動窗之結構分割獨立，使其不與防盜窗直接結合且方便拆卸

4.3 綜合改進方案

根據矛盾矩陣分析後產生之應用改進方案得到以下設計構想:

(1)改變傳統鎖頭形式，另外分割獨立出能夠阻擋活動窗被開啟的安全裝置，而該裝置非直接扣於活動窗之門閂上。

(2)將防盜窗上之活動窗開啟方向改為對內開啟，以搭配阻擋裝置安裝於室內側，方便危急時開啟與保護裝置安全性。

(3)透過熱脹冷縮原理，使發生火災環境產生高溫時，活動窗上之鎖具能自動鬆開，方便迅速開啟。但此設計不但無法適用於所有開啟防盜窗時機，如：地震緊急逃生，亦無法在火災第一時間，即火場溫度未升高前就立即逃生，故暫不考慮此方案

由以上前兩點產生之設計構想，產生設計方案如下:

於陽台圍牆內側，安裝兩固定柱體支架座，搭配防盜窗活動門由外而內，轉軸設於上方向上掀起的開啟方式，將兩空心金屬長柱分別置入支架座上，以防止防盜窗活動門由外而內被推開，金屬長柱與支架座透過插銷固定，防止長柱被輕易抽起，該支架座位置亦須大於手臂長度，以防止宵小由屋外伸手入內拔取插銷而解鎖。如下圖 4-1 所示。

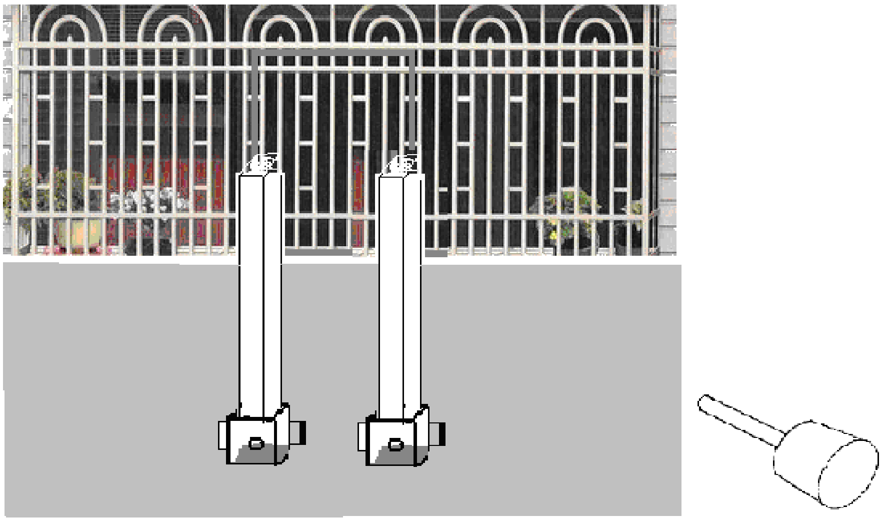


圖 4-1　金屬凹槽搭配長柱體門檔之設計

4.4 質場分析

本設計方案的質場分析模型，建立步驟如下:

步驟 1：指定 S1(目的物質)功能作用體為防盜鐵窗上的活動窗。

步驟 2：指定 S2(工具物質)功能主體為活動窗門檔。

步驟 3：確定場 F 為機械能。

步驟 4：建立質場模型如圖 4-2 所示，定義門檔為逃生窗開啟不具便利性之有害物質，因此建立一個「有害的物質-場模型」，並將此問題嘗試利用 76 個標準的解決方法依序考慮代入系統中，找尋出最適合的解決方式。

步驟 5：S2 功能作用體活動窗門檔在 S1 功能主體活動窗上的直接作用，可是卻存在著 S2 活動窗門檔固定插銷易被拔取與解鎖不便利性（需使力移除門檔），間接影響 S1 防盜窗上之活動窗開啟的便利性與開啟時間；在這個有害的物質-場模型中，嘗試加入一個新的物質，透過這新的物質來改善問題,透過物質-場分析法設計流程圖的操作,可以得到標準解 1.1.1 至 1.1.6 與標準解群 4.2,其流程操作如圖 4-3。

最後，經由圖 4-4 與圖 4-5 的引入物質-場模型，可得設計方案之進一步改善。即不用抽取空心金屬長柱，而改以增加支點轉軸經由按鈕得以快速旋開門檔的方式，如圖 4-6 所示

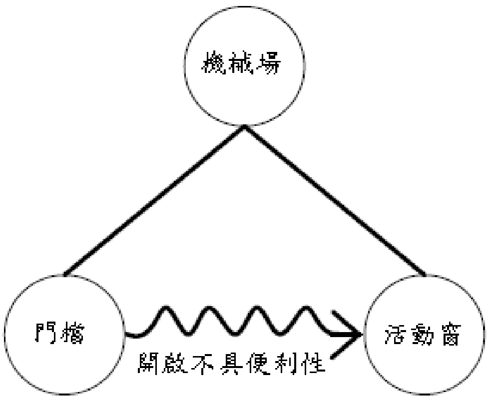


圖 4-2 門檔設計之防盜窗有害物質-場模型

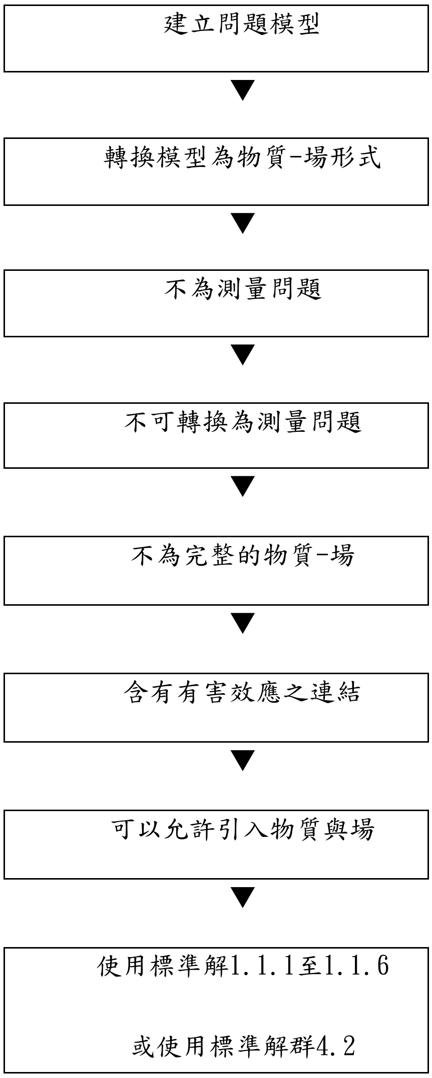
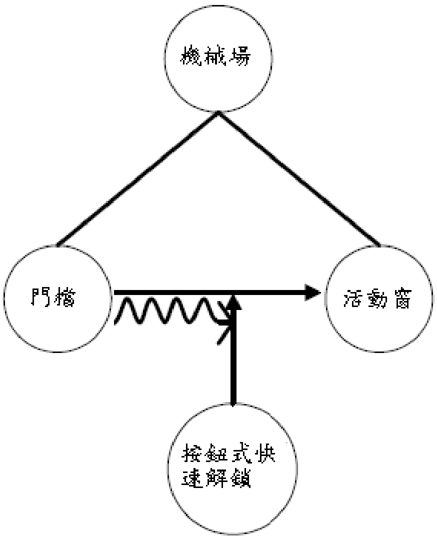


圖 4-3 質-場分析流程圖



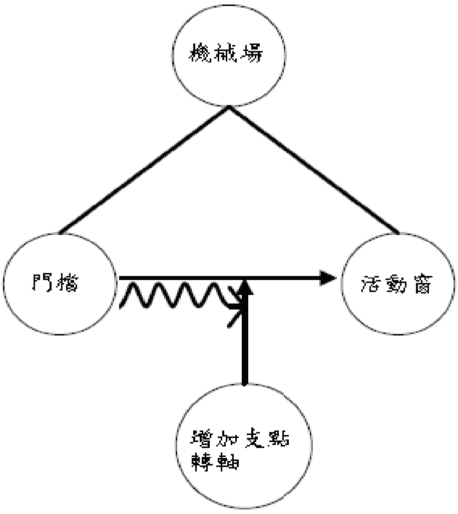


圖 4-4 門檔設計之防盜窗引入物質-場模型 I　　圖 4-5 門檔設計之防盜窗有害物質-場模型 II

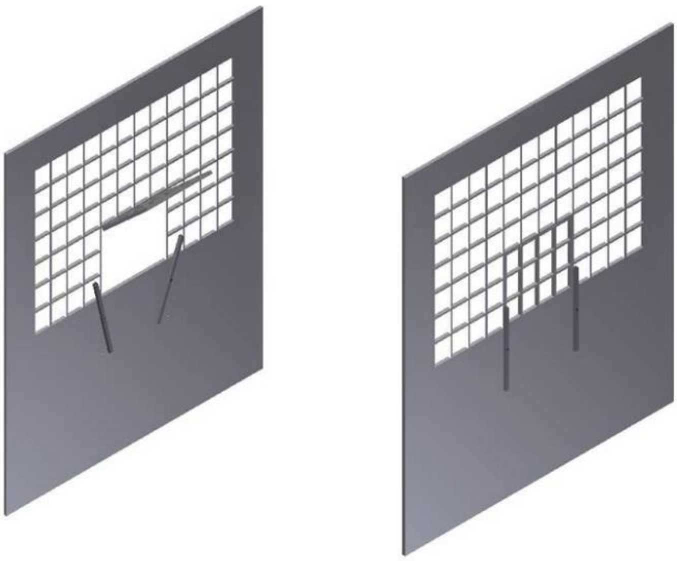


圖 4-6 防盜窗門檔設計示意圖

5. 結論與建議

在台灣住宅區中不論是公寓或是一般透天住宅皆不難發覺加裝鐵窗情況相當普遍，加裝鐵窗主要目的包含:(1).防止宵小利用集合住宅外窗入室偷竊 (2).防止家中幼童攀爬陽台窗戶發生墜樓意外 (3).增加陽台使用空間。加裝鐵窗雖然滿足住戶的住宅需求，但近年來在鐵窗規格大小不同、裝設與否不一的情況下，已漸漸被列為住宅美學的有礙之物，再加上多次災害事件發生的真實案例，鐵窗已衍生成為逃生上的一大有害之物。本研究的目的主要在於改良一般常見以鎖頭形態設計的住宅鐵窗。本研究利用專利資訊檢索系統進行相關專利分析，使用者簡單操作概念與人因工程融於設計中，再應用 TRIZ 創新發明原則與質場分析，經由專利迴避做改善創新設計，最後，透過 CAD 動畫模擬產生改善設計雛型。

未來，本研究的成果將進一步寫成發明專利並做出實體模型做進一步的驗證與改進。

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Innovation Design of Nondestructive Inspection Leaking Device Base on TRIZ

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Abstract

In this study, a systematic and innovative approach that use TRIZ concept will be applied to solve the pipe leaking problems of an reinforcement concrete building. Although the leaking from the pipe in the concrete material seems no damage of the building structure safety, it is truly concern and necessary in our living environment. This paper aims to develop an effective and nondestructive applicable electromagnetic wave method for pipe leaking inspection system. The proposed pipe leaking system for concrete building can inspect the range of leaking and the location of the pipe under the concrete ceiling / wall / column. It also can display the leaking information with 2-D or 3-D diagram. The advantages of this system can improve the building durability and safety.

Keywords: Electromagnetic wave, Nondestructive, Pipe leaking, TRIZ.

應用 TRIZ 創新方法開發非破壞性滲漏檢測系統

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摘要

本研究是使用系統化與創新的方法將 TRIZ 概念應用在解決的鋼筋混凝土建築的管線滲漏問題。雖然在混凝土材料的管線滲漏似乎對建築物的結構安全無損傷，但它確實對我們的生活環境造成影響。本文主要開發一個有效的、非破壞性的電磁波方法於管線滲漏檢測系統。此混管線滲漏系統可以檢測混凝土建築物內管線滲漏的範圍及混凝土天花版/牆/柱的位置。並以 2-D 或 3-D 圖顯示滲洩漏的信息，本系統的優點可提高建築物的耐久性和安全性。

*關鍵詞：*非破壞、電磁波、管線滲漏、TRIZ。

1. 前言

由於台灣四面環海，且位處多震板塊界面帶邊緣上，就整體環而言位處於高度腐蝕與地震頻繁的自然嚴苛條件。因此建築房屋結構與地下管線因老舊劣化所產生的裂縫、滲漏與腐蝕現象成為現代人們居住生活品質優寙非重要的指標。但是目前傳統滲漏檢測方法都無法在不損傷既有建築結構條件下準確快速及有效率檢測滲漏位置及範圍。因此如何在不破壞結構服務功能與安全原則下，有效率的檢測管線滲漏問題，維持人們優質生活之品質是一非常重要的課題。本研究將應用透地雷達電磁波技術，開發非破壞性可量化檢測滲漏系統，並以二維或三維判讀圖像顯示量測管線滲漏位置與範圍，以高頻透地雷達電磁波入射至標準砂內含 PVC 管線滲漏試體，由電磁波在材料內傳播時遇到材料(乾/濕界面)之電性參數差異，如反射電磁波的波形、振幅強度和時間的變化特徵，建立管線滲漏判定模式，進而判斷管線滲漏的位置、範圍和深度。

2. TRIZ 理論與解析

TRIZ 方法是多種問題解決系統方法學，由 G.S. Altshuller 研究機構自 1946 年開始分析 250 萬件發明專利，綜合多科學領域的原理與法則後所建立的理論體系。其發明解決理論的核心是技術系統進化原理，此技術系統持續進化之中，解決沖突是進化的動力，且進化速度隨技術系統的沖突解決而降低，使產生突變的唯一方法是解決問題，更進一步進化後解決更深層次的沖突。

運用 TRIZ 原理對問題進行分析，發現可節省問題處理的時間與問題決解過程所存在的矛盾。針對技術矩陣的 39 條技術參數，需被改善的技術參數是能不破壞混凝土檢測出管線滲漏範圍，而惡化條件技術特性為需不確定性的破壞混凝土找出管線滲漏位置，利用技術矛盾解決矩陣可由第 28 取代機械系統原理、第 36 相變化原理與第 22 改變有害成為有用原理內提及方法解決。

28th 取代機械系統原理

(1) 運用電磁場與物理進行交互作用

(2) 將非導電性質(混凝土、管線)及導電性質(水)視為一種電磁參數

36th 相變化原理

(1) 利用物質相轉換的現象

(2) 擷取所需資訊，如混凝土與水進行差異分離

22th 改變有害成為有用原理

(1) 利用有害因素-特別是環境方面-來達到有利結果

(2) 籍助非導電性質(混凝土、管線)及導電性質(水)利害關係，變為有利條件

由上述矛盾技術參數原理解決破壞混凝土量測管線滲漏的問題，將惡化的技術特性「水」變為有利的量測條件，改善混凝土管線滲漏問題且不破壞混凝土即可檢測滲漏的位置。

3. 實驗方法

本研究採用 1GHz 透地雷達天線進行標準砂內含不同含水層、單向測線掃瞄不同管線滲漏深度及雙向測線掃瞄管線滲漏深度試驗，擷取波形特性、波速與介電常數進行分析，建立標準砂內含管線滲漏前後之差異性。其實驗項目如下：

2.1 標準砂內含不同含水層深度試驗：

本試驗使用砂箱模型(60cm*30cm*25cm)、標準砂之含水量 10%，各含水層埋設深度分別為 0cm、5cm、10cm、15cm、20cm、25cm，鋪設完畢後依序回填乾砂，再以 1GHz 透地雷達天線進行掃描，擷取不同含水層深度之透地雷達剖面圖及反射訊號特徵，探討不同含水層之波傳行為、波速、相對介電常數之變化及乾濕界面分析，本試驗示意圖，如圖 1 所示。

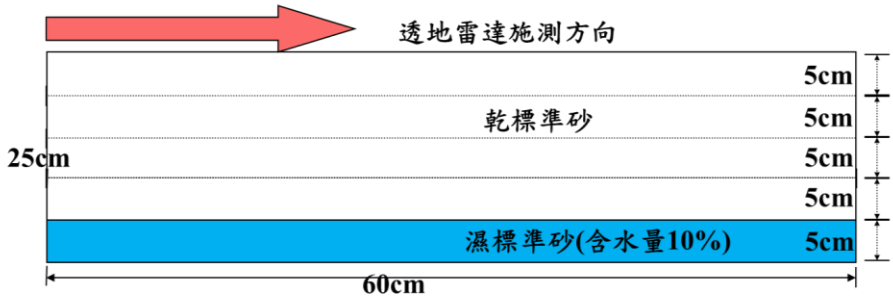


圖 1. 標準砂內含不同乾溼界面施測示意圖

2.2 單向標準砂內含不同深度管線滲漏試驗：

本試驗使用砂箱模型(60cm*30cm*25cm)內含、PVC 管埋設深度(8cm、14cm)，在 PVC 管中間挖一個直徑 2cm 的滲漏源，並倒入 750ml 的水靜置 10 分鐘後，再以 1GHz 透地雷達天線進行掃描，擷取不同深度管線滲漏之透地雷達剖面圖及反射訊號特徵，探討不同深度管線滲漏的電磁物理量及乾濕界面分析，本試驗示意圖，如圖 2 所示。

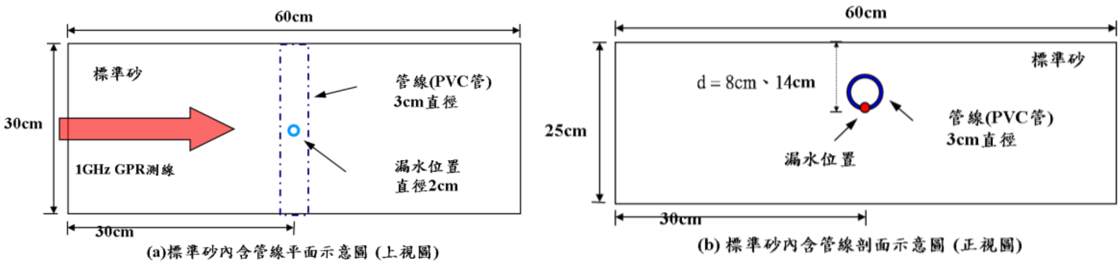


圖 2. 標準砂內含不同深度管線滲漏施測示意圖

2.3 雙向標準砂內含管線滲漏試驗：

本試驗使用砂箱模型(50cm*50cm*15cm)內含、PVC 管埋設深度 4cm，在 PVC 管中間挖一個直徑 2cm 的滲漏源，並倒入 750ml 的水靜置 10 分鐘後，再以 1GHz 透地雷達天線進行雙向測線，測線間距 3cm，擷取三維管線滲漏之透地雷達剖面圖及反射訊號特徵，探討管線滲漏之方向、乾濕界面分佈範圍及滲漏源位置分析，本試驗示意圖如圖 3 所示。

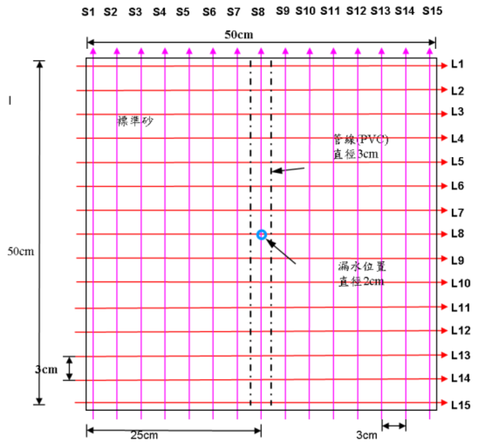


圖 3. 標準砂內含管線滲漏施測示意圖

4. 研究方法

透地雷達所發射之電磁波是以一輻射狀的形式傳播，根據電磁波波傳理論與電磁波能量涵蓋範圍觀念中可得知，當電磁波入射至不同材料界面時，各材料界面之反射訊號會依界面特性而有所改變，其透地雷達之波速、反射時間(即為雙程走時)、相對介電常數及深度，上述電磁波入射材料中之物理量可由下式公式求得:

$$V = \frac{2D}{t}$$

式中:V 為波速、d 為距離、t 為雙程走時

電磁波入射標準砂內之反射訊號、雙程走時及透地雷達剖面圖，如圖 4 所示。

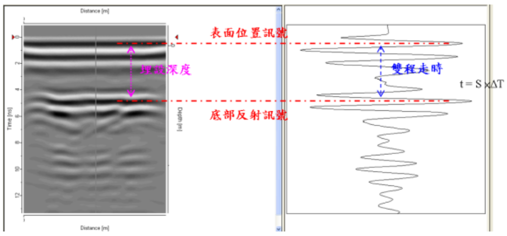


圖 4. 電磁波入射標準砂反射訊號

根據電磁波波傳理論可藉由材料波速求得材料之相對介電常數，如下公式所示：

$$\varepsilon_r = \left(\frac{c}{V}\right)^2$$

式中 εr 為相對介電常數、c 為光速

3.1 乾濕界面分析

透地雷達電磁波入射介質中之速度大小，主要受所材料介質之介電常數所影響，由電磁波入射不同介質所產生之波速時間差異進行乾濕介面之分析。其假設在同某一厚度材料中含有一部分乾燥及一部分濕潤材料，且透地雷達反射訊號擷取時是包含乾濕界面合成訊號，因此標準砂內乾溼界面差異示意圖，如圖 5 所示。

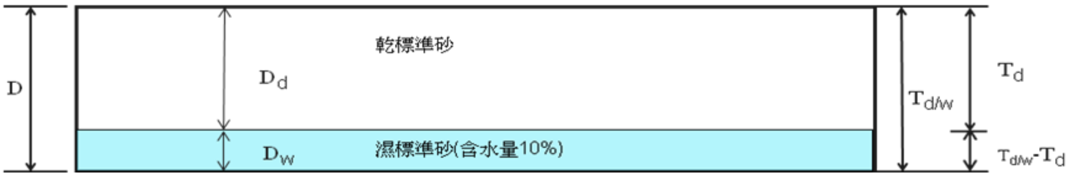


圖 5. 標準砂內乾溼界面差異示意圖

由上述假設，可將材料乾濕標準砂深度關係式如下：

$D = Dd + Dw$

式中：D：取樣深度(實際深度)、Dd：乾砂深度、Dw：濕砂深度

根據電磁波波傳理論可將上式修改：

$D = Vd \times Td + Vw \times (Td/w - Td)$

式中：Td：乾砂狀態之反射時間、Td/w：乾/濕狀態之反射時間、Vd：乾砂狀態之電磁波波速、Vw：濕砂狀態之電磁波波速

由透地雷達電磁波反射時間 T 為:

$T = S \times \Delta T$ (4)

式中：S：取樣點數、ΔT：等效時間間隔

將 T 代入上式，可得乾濕界面公式如下所示：

$D = Vd \times (Sd \times \Delta T) + Vw \times (Sd/w \times \Delta T - Sd \times \Delta T)$

式中：Sd：為乾砂狀態之取樣點數、Sd/w 為乾/濕狀態之取樣點數

將上式整理後可得下式：

$Sd = D - Vw \times Sd/w \times \Delta T / (Vd - Vw) \times \Delta T$

由乾濕狀態中之標準砂於乾砂層之取樣點數，即可求得標準砂於乾砂層厚度，
得知乾溼界面的位置，如下公式所示。

$Dd = Sd \times \Delta T \times Vd$

5. 研究結果

4.1 標準砂內含不同含水層深度試驗結果

由透地雷達掃瞄標準砂內含不同含水層為 Dw(0cm、5cm、10cm、15cm、20cm、25cm)結果顯示，隨含水層深度增加，透地雷達剖面圖底部反射訊號強度也隨之遞減，表示電磁波波速下降、雙程走時增加，如圖 6 所示。

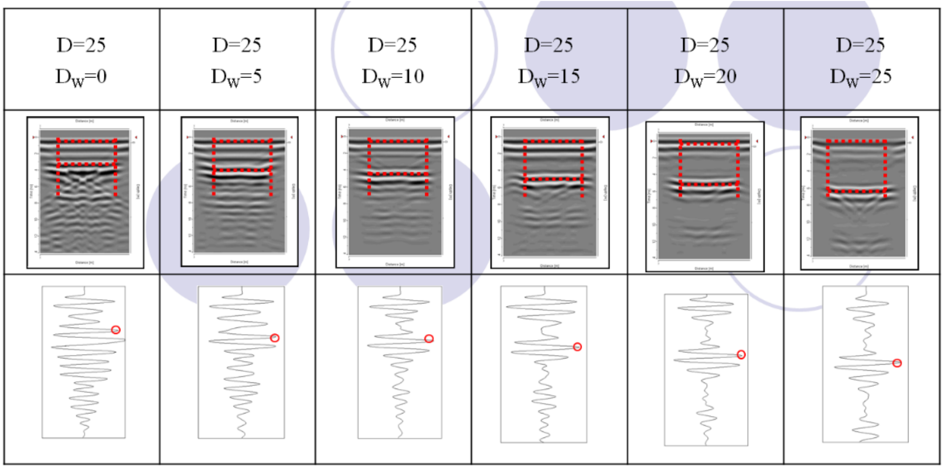
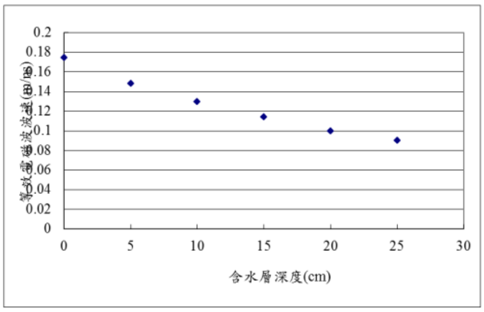
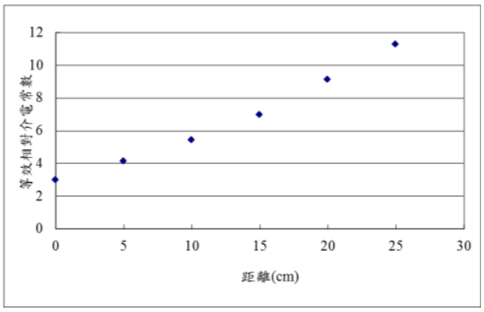


圖 6. 標準砂內含不同含水層之透地雷達剖面圖

依據標準砂內含不同含水層之分析結果，可瞭解不同含水層下之透地雷達電磁波波速、相對介電常數變化與差異，如圖 7 所示。



(a)電磁波波速



(b)相對介電常數

圖 7. 不同含水層深度之電磁波波速與相對介電常數變化圖

由上圖顯示，標準砂隨著含水層深度增加，其電磁波波速隨之下降，且材料之相對介電常數隨之上升。表示標準砂內含水多寡將會影響電磁波探測深度及材料相對介電常數之變化;藉此透地雷達掃瞄可擷取及分析標準砂、水及(砂+水)之三種材料性質混合時，可明確反應在電磁波反射訊號之中，根據乾濕界面分析原理，即可解出各含水層之界面及位置，如圖 8 所示。

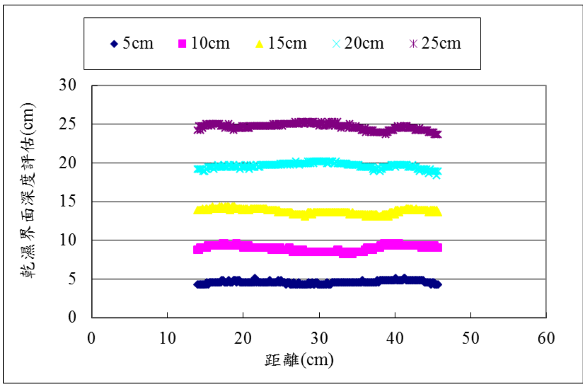
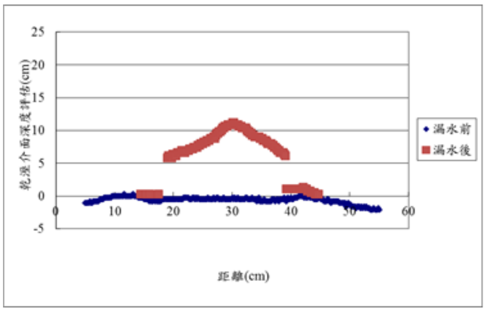


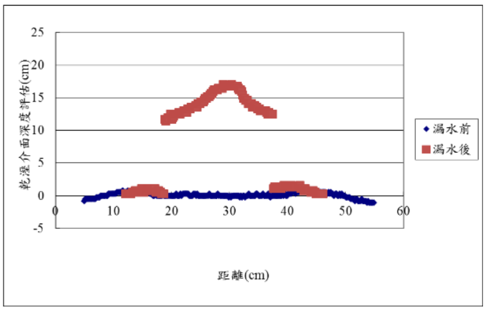
圖 8. 不同含水層深度之乾濕界面分析結果

4.2 單向標準砂內含不同深度管線滲漏試驗結果

本試驗結果是將標準砂內管線滲漏深度在 11cm 及 17cm 時，依本研究所開發之乾濕界面分析原理，可分離乾砂與濕砂位置及分佈範圍，其結果如圖 9 所示。



管線滲漏深度在 11cm



管線滲漏深度在 17cm

圖 9. 標準砂內管線滲漏分析結果

由圖可知管線滲漏位置之相對介電常數值急遽上升，而兩側管線滲漏前與後之相對介電常數值相近，表示管線下向為滲漏最嚴重之區域，隨著距離增加，滲漏範圍也隨之遞減，藉此可推估滲漏源在相對介電常數最高之位置及滲漏分佈範圍。並將試驗模型內之乾砂移除後，再與乾濕界面分析結果進行比對驗證結果相當符合，其結果如圖 10 所示。

(a)乾砂移除後濕砂分佈-俯視照片　　　　(b)乾砂移除後濕砂分佈-正視照片

圖 10. 乾濕界面分析與實際狀況比對驗證結果

4.3 雙向標準砂內含管線滲漏試驗結果

由本研究開發的乾濕界面分析方法，經不同含水層及單向管線滲漏分析探討，為更能應用於實際狀況;本節進行雙向標準砂內含管線滲漏掃瞄，擷取乾濕界面反射訊號之特徵，分析乾濕界面位置、相對介電常數之三維分佈圖;同時比對管線滲漏後，將乾砂移除後之濕砂分佈狀況，其結果相當吻合，如圖 11 所示。

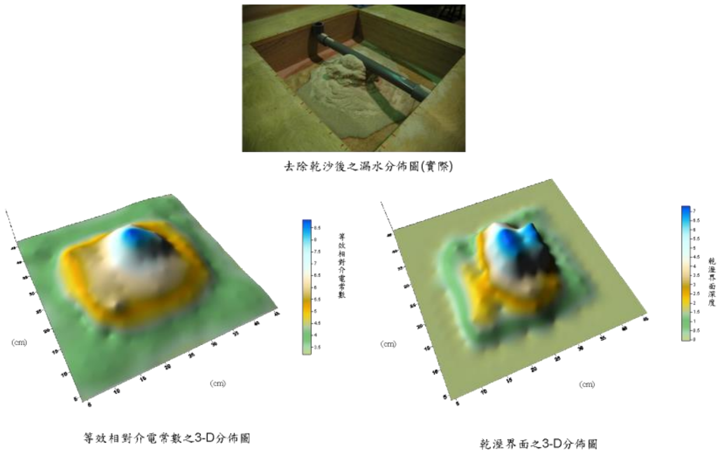


圖 11. 管線滲漏之乾濕界面/相對介電常數之三維分佈圖與實驗照片比對

由上圖可知，相對介電常數最大值之位置，即是管線滲漏最嚴重的地方，藉此推斷該位置為管線滲漏源所在區域，由三維分佈圖中可直接判定滲漏位置及範圍。

6. 結論

本研究應用 TRIZ 矛盾矩陣所提出之發明原理探討標準砂內含不同含水層深度、不同深度管線滲漏與雙向管線滲漏試驗，以透地雷達探頭 1GHz 天線進行掃描。由標準砂管線滲漏前後之變化，以透地雷達掃描後，擷取不同測線位置上之乾濕界面反射訊號特徵、相對介電常數等電磁參數，經乾濕界面分析方法進行相關反射訊號特徵的分析，可分離標準砂材料內之乾溼界面位置與推斷滲漏源與滲漏區域。本研究結果顯示距離管線滲漏源越近，其波速明顯下降而相對介電常數明顯上升，藉此建立標準砂內含管線滲漏分佈之檢測技術方法;並由雙向測線掃描與分佈結果，對應的管線滲漏三維分佈為視覺化之圖像，更能清楚瞭解標準砂內管線滲漏的情況，同時比對濕砂分佈狀況，可明確瞭解乾濕界面分析方法是可實際應用於材料內管線滲漏及乾濕界面分離之應用。

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Method and Application about Patent Design Around Based on Theory of TRIZ

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Abstract

Patent design around is an important part of enterprise patent strategies, is a means for enterprises to use the patent of others and avoid the patent of others, is a positive and practical patent strategy. This paper discusses a method to do patent design around according to the law of patent infringement judgment, using the function trimming of TRIZ .In combination with other effective tools of TRIZ, the patent useful function is preserved and strengthened, adverse effects and conflict to eliminate, reduce costs, generate new technical plan. At the same time, this method also can be used to avoid the infringement in the process of applying patent technology protection. The Portable cotton picker is analyzed as a case study by above theoretical method.

Keywords: Patent design around, Theory of TRIZ, Function trimming, Portable cotton picker.

基於 TRIZ 理論的專利規避設計及其應用研究

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摘要

專利規避設計是企業專利策略的重要部分，是企業合法提取和運用專利知識又規避他人專利的一種手段，是一種積極可行的專利策略。本文論述了根據專利侵權判定法則，運用 TRIZ 理論功能裁剪進行專利規避設計的方法。結合 TRIZ 理論的其他有效工具，使得專利有用功能得以保留和加強，不良作用和衝突得以消除，降低成本，產生新的技術方案。同時在申請專利技術保護過程中也能避免被侵權。應用該理論方法對可携式采棉機進行案例分析。

*關鍵詞：*專利規避設計，TRIZ 理論，功能裁剪，可携式采棉機。

前言

據有關資料統計，截至目前，中國的企業因智慧財產權引發的訴訟賠償金額已達十多億美元（Yang X.X, 2007）。自我國加入 WTO 以來，美國、日本等圍繞智慧財產權對中國企業提起訴訟的案件接連不斷（Zhan Y.Z, 2010）。

Design around，即“回避設計”，是一種常見的智慧財產權策略，即通過設計一種不同於受智慧財產權保護的新方案，來規避該項智慧財產權（Li W.W, 2011）。由此可以說：智慧財產權本身並不能回避，但是工程師可以採用不同於受智慧財產權保護的技術方案的新的設計，從而避開他人某項具體智慧財產權的保護範圍（Shi B.X, 2006）。

專利規避設計

專利侵權判定

要知道如何去回避某個專利，就要從瞭解專利侵權判定法則開始。只有從本質上掌握了專利的侵權判定法則，才能知道專利的保護範圍，才能分析歸納出專利回避設計的具體方法。

因此對專利回避設計方法的研究首先從專利的侵權判定法則開始，將專利侵權法則進行詳細的分析，掌握哪些行為會造成侵權，反之哪些行為可以利用該專利而不侵犯相應法則。對上述內容有一個深入理解後，在這個基礎之上就可以分析歸納出回避專利的具體方法。

侵權判斷原則的優先關係如圖 1 所示。

全覆蓋原則是指被控侵權物（產品或方法）將專利權利要求中記載技術方案的技術特徵全部再現（Chen X P, 2007）。

等同原則是指被控侵權物中有一個或者一個以上技術特徵與專利獨立權利要求保護的技術特徵相比，從字面上看不相同，但經過分析可以認定兩者是相等同的技術特徵，應當認定被控侵權物落入了專利權的保護範圍（Liu S.S, 2006）。

捐獻原則僅在說明書或者附圖中描述而在權利要求中未記載的技術方案，權利人在侵犯專利權糾紛案件中將其納入專利權保護範圍的，法院不予支持（Sun F T,1012）。

禁止反悔原則專利授權或者無效宣告程式中，通過對權利要求、說明書的修改或者意見陳述而放棄的技術方案，權利人在侵犯專利權糾紛案件中又將其納入專利權保護範圍的，人民法院不予支持。

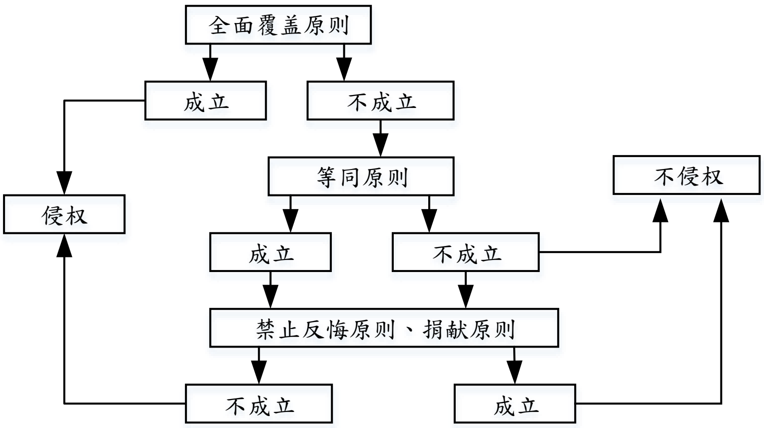


圖 1. 判定原則的優先關係

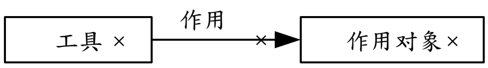
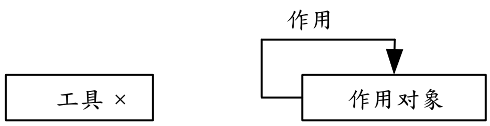
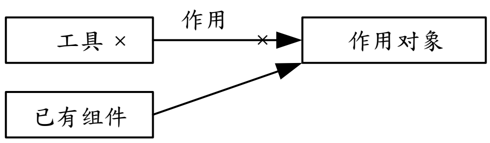
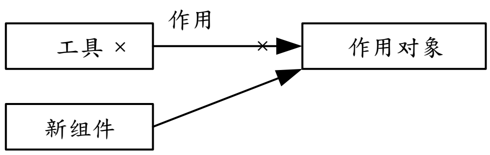
傳統規避設計流程

在新產品的開發規劃階段，企業根據當時市場需求和購買者的心理，分析目前開發的產品的過去、現在並預測將來的情況，還要對它的功能、結構、工藝、材料、成本、使用環境等作周密的市場調查、分析、比較和設想，提出新產品開發的依據和初步設計規劃;在新產品的方案正式審定合格，並決定試製和投產階段，要求設計人員與工程技術人員，及銷售人員等密切配合，共同協商，從產品的技術設計到工藝方法，從外形到色彩，從投產到包裝等均能按審定的造型方案去實現。最後在新產品投產銷售時，還需調查產品的銷售情況及消費者的資訊回饋，找出需改進之處，使構思有所發展，並為更新的產品規劃作準備。（Wu G J,2003）

功能裁剪

功能裁剪通常作為 TRIZ 理論中的問題分析工具，是定義問題和提高系統理想化程度與價值的有效方法。功能裁剪是當功能模型建立之後，通過對其非必要元件進行刪除、替換，或者利用其他資源添加到原模型中，以使設計系統最大限度的趨近於最終理想解的過程。(Jang P, 2012)

表 1. 技術系統的裁剪策略

裁剪策略	組件關係圖	說明
1		若沒有作用物件，則其也就不需要工具的作用，工具可以被裁剪。
2		作用物件能自我完成工具所的提供的作用，則工具可以被裁剪。
3		如果技術系統或超系統中其他已有元件可以完成工具的功能，則工具可以被裁剪。
4		技術系統的新元件可以完成工具的功能，則工具可以被裁剪。

針對技術系統實施裁剪，可以簡化系統結構，提高理想度#在企業實施專利戰略的過程中，裁剪方法也是進行專利規避的重要手段，有用功能得以保留和加強，降低成本，產生新的設計方案。(Gao C Q，2011)

基於 TRIZ 理論的專利規避設計

首先，在檢索相關現有技術後，發現了有潛在侵權風險的在先有效專利檔，對該目標專利檔中的權利要求書中的獨立權利要求進行分解和功能分析。

其次，在此分析基礎上，對其中的某些特徵進行修剪（刪減或重構），通常刪減那些為解決技術問題所不可或缺的必要技術特徵。

再次，需要找出其中的主要矛盾，並將該矛盾進一步分為技術矛盾與物理矛盾，進而採用不同的解決方案。

最後，利用下表的判定原則進行重新設計。(Li P, 2013)

表 2. 規避設計方法列表

規避設計類型	規避設計方法	規避設計方法運算式	規避設計要求
簡化	特徵減少	A+B+C+D→A+B+C	全面覆蓋原則
	特徵合併	A+B+C+D→A+B+E	特徵 C+D≠E，全面覆蓋原則和等同原則
替換	特徵替換	A+B+C1+D1 →A+B+C2+D2	特徵 C1≠C2 或 D1≠D2，全面覆蓋原則和等同原則
	特徵分解	A+B+C+D1 →A+B+C+D2+D3	特徵 D1≠D2+D3，全面覆蓋原則和等同原則

（1）找到規避對象：主要是進行相關專利的檢索與分析，從而找到所關注的競爭者關鍵技術的專利原形。

（2）找出規避的突破口：通過建立規避物件產品的功能模型，分析其技術元件之間的功能結構關係，確定規避設計所要進行的創新點與發展方向。

（3）解決問題：通過 TRIZ 理論中解決問題的各種有效工具，如衝突解決理論與物質—場分析得到問題解決的新思路，轉化為詳細設計的概念方案。

（4）專利的侵權分析：應用專利侵權判定原則對設計方案進行侵權判斷，選擇最優方案，進行產品的開發和技術的專利保護。

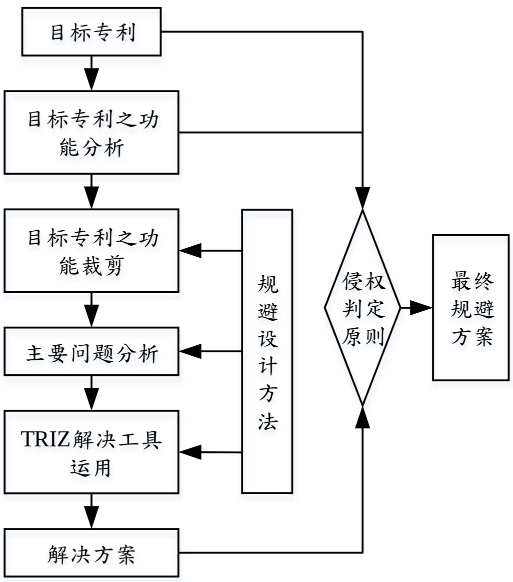


圖 2. 專利規避設計流程圖

實例應用

應用流程

應用流程從專利檢索和專利分析開始，明確目標專利需要回避的物件，運用功能裁剪和規避設計方法得到裁剪變體。找出變體所存在的問題，採取不同的方法和工具解決問題，最終產生新的技術方案，並對其分析是否侵權。

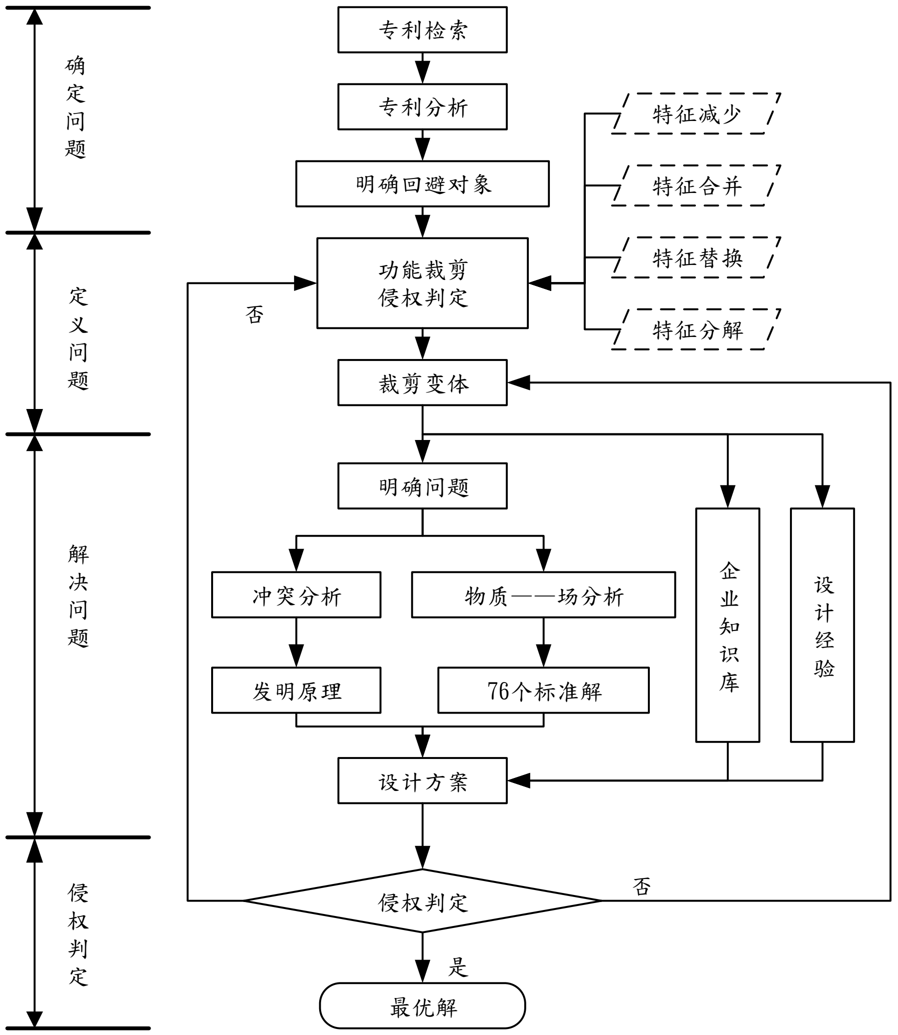


圖 3. 實例應用流程圖

具體步驟

（1）專利檢索和分析：

表 3. 可攜式采棉機專利檢索

序號	申請號	名稱	申請人	發明人
1	201320200622.X	手持轉盤式采棉機	曹立國	曹立國
2	201320200626.8	手持滾筒式采棉機	曹立國	曹立國
3	201220507289.2	一種可攜式采棉機	潘玲兵	潘玲兵

4	201120339336.2	可攜式手持采棉機	吳樂敏	吳樂敏
5	201120455515.2	可攜式手持采棉機	吳樂敏	吳樂敏
6	201120432776.2	可攜式手持采棉機	吳樂敏	吳樂敏
7	201320030062.8	一種可攜式手持采棉機	台州市虹靖盛塑膠模具有限公司	李加慶
8	201320404340.1	手提可攜式采棉機	陳偉利	陳偉利
……	……	……	……	……

對現有專利進行分析，其中 8 號專利採用的是空氣吸取的原理，不作為本次規避的目標。分析發現，此類可攜式采棉機的動力源都是蓄電池，鉛酸蓄電池生產中的有害物質有鉛、硫酸、炭黑、硫磺、瀝青等。其中接觸鉛和硫酸的人員最多，這 2 種物質對操作者的危害也很嚴重。而鋰電池均存在安全性差，有發生爆炸的危險。鈷酸鋰材料的鋰電池不能大電流放電，安全性較差。鋰電池均需保護線路，防止電池被過充過放電，生產要求條件高，成本高。

本次設計的專利是一種使用環保持續有效的動力源的可攜式采棉機。

（2）功能分析

經過分析之後，選定專利 7（申請號為 201320030062.8）作為目標專利。

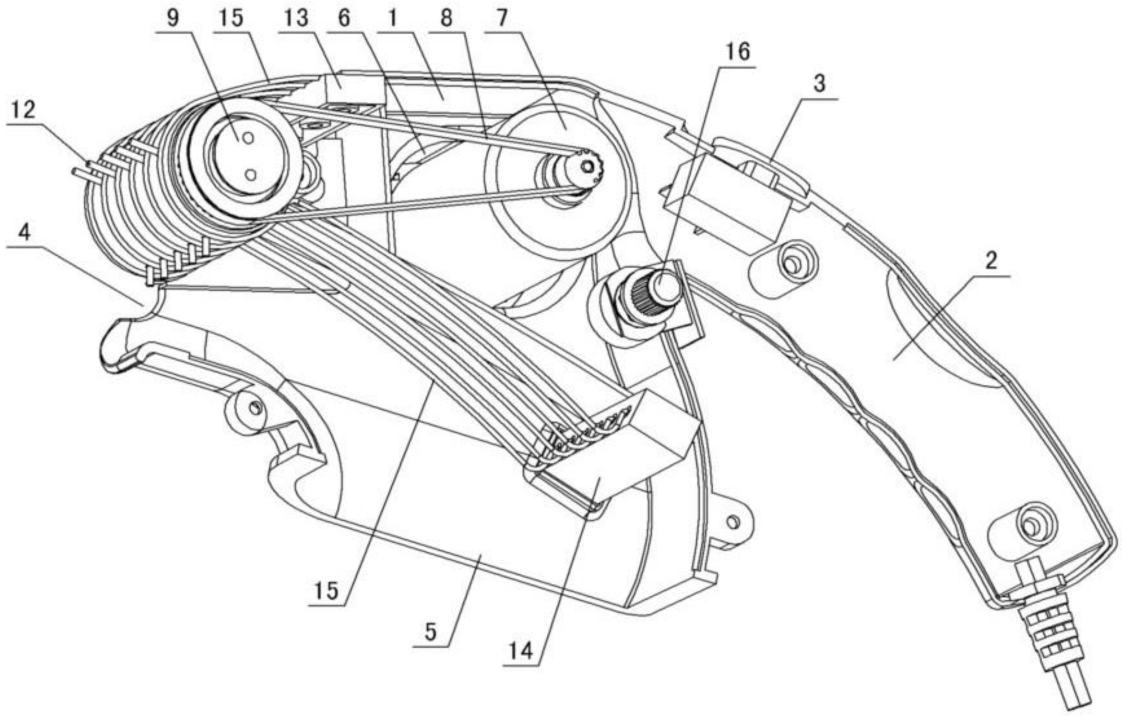


圖 4 可攜式手持采棉機示意圖

建立采棉機的主要功能關係：

表 4 可攜式采棉機組件的主要功能關係

組件	作用	對象	功能類型	功能等級
殼體	固定	電源開關	協助工具	滿足
	安裝	電機	基本功能	滿足
	安裝	擋棉鐵絲	協助工具	滿足
電機	驅動	皮帶	協助工具	滿足
皮帶	驅動	滾筒	協助工具	滿足
滾筒	安裝	鉤棉針	基本功能	不足
鉤棉針	提取、引導	棉花	基本功能	滿足

擋棉鐵絲	引導、阻擋	棉花	基本功能	滿足
蓄電池	提供	電能	協助工具	過剩
電能	驅動	電機	協助工具	過剩
電源開關	控制	電機	協助工具	滿足

繪製可攜式手持采棉機功能結構模型：

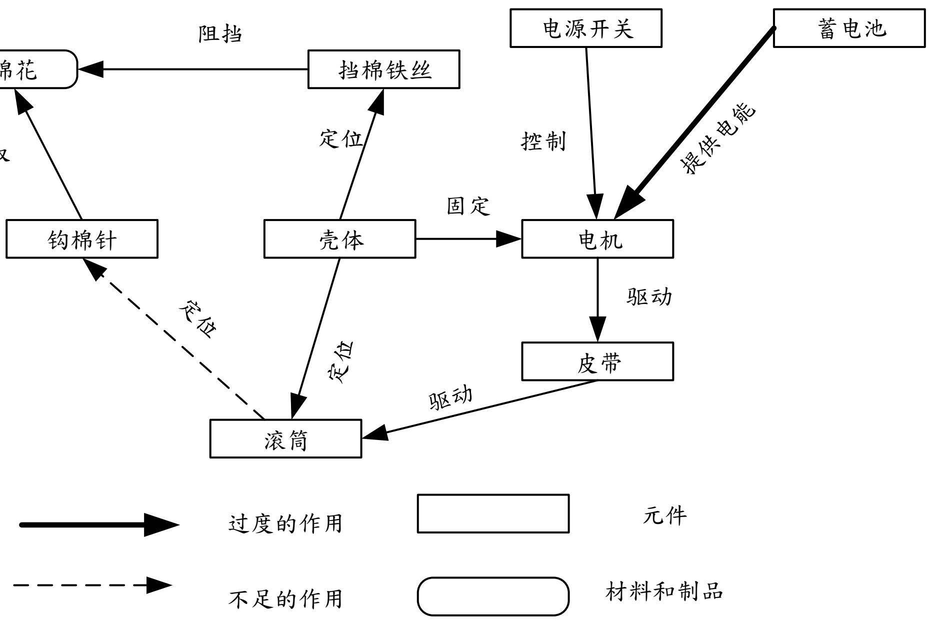


圖 5 可攜式采棉機功能模型

（2）功能裁剪

下圖中虛線表示裁剪的組件。

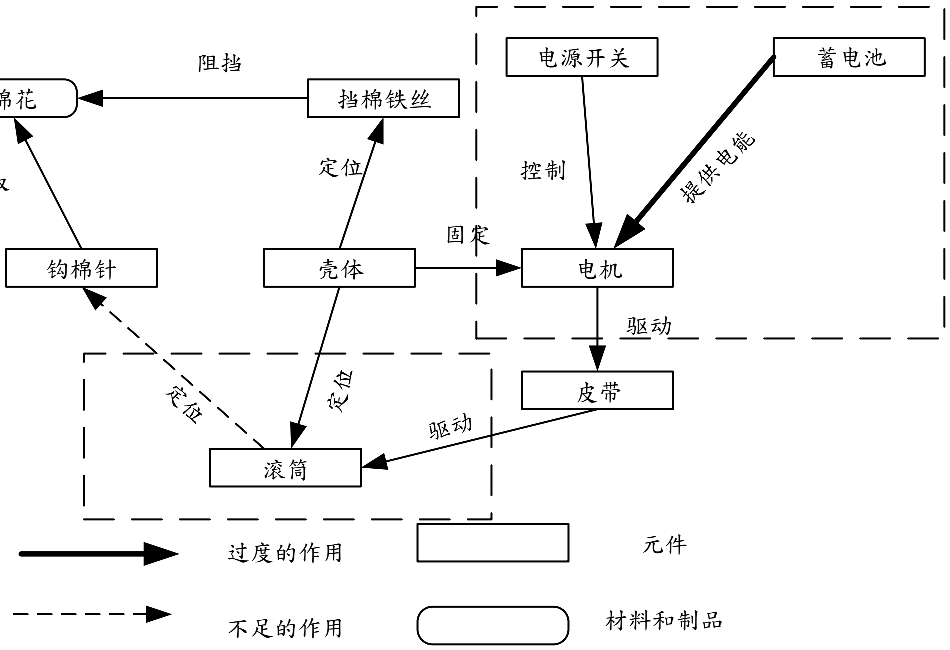


圖 6 可攜式采棉機預裁剪功能模型

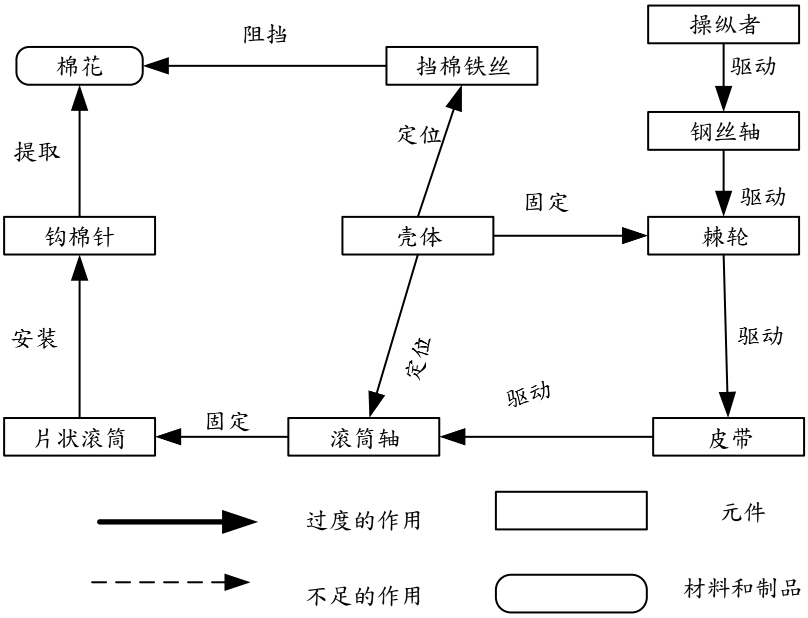


圖 7 可攜式采棉機功能裁剪變體模型

（3）根據目標專利進行方案設計

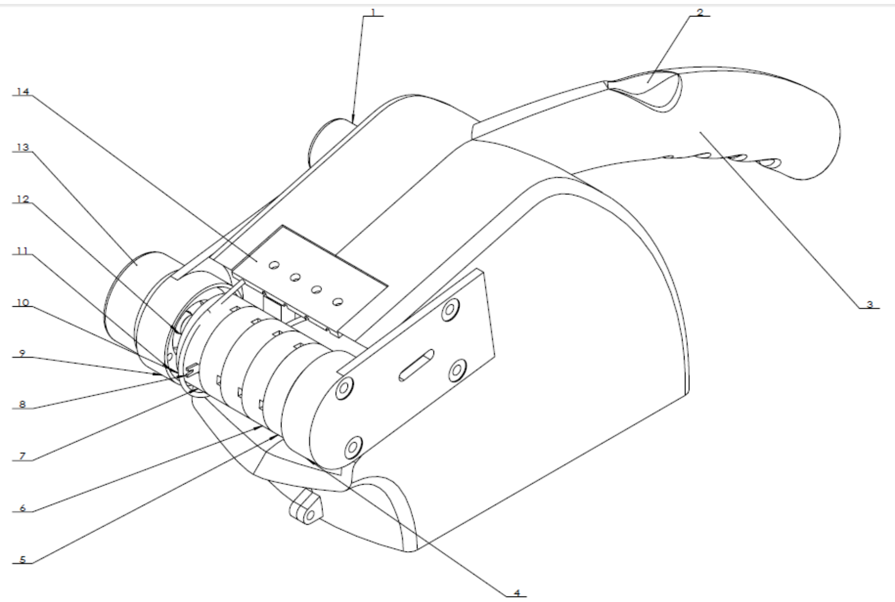


圖 8 可攜式采棉機規避設計方案示意圖

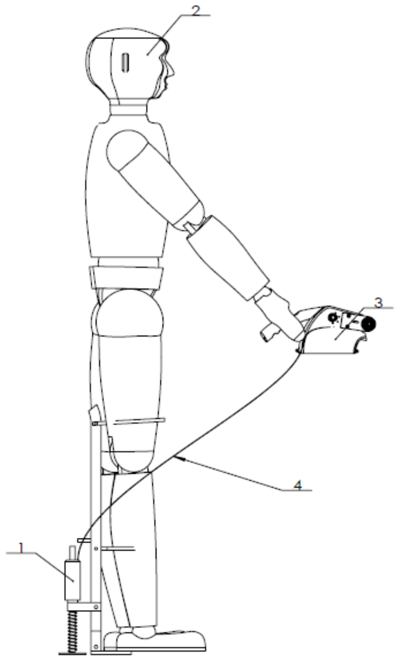


圖 9 可攜式采棉機規避設計使用示意圖

實例應用總結

借鑒他人的專利技術，並不一定就構成侵權，認真研究他人專利的權利要求和說明書，完全有可能把他人的專利技術拿來進行改進和創新。基於 TRIZ 理論的專利規避設計是將 TRIZ 作為突破專利壁壘的有效方法，通過應用 TRIZ 的分析工具確定出規避設計所要解決的問題，並指導設計人員在吸收現有專利技術優勢，採用 TRIZ 的知識工具集來解決問題實現持續性創新，並保證新技術不落入規避對象的專利保護範圍。

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