

TOC and TRIZ: Using a dual-methodological approach to solve a forest harvesting problem.

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ABSTRACT

Although cut-to-length forest harvesting with harvesters and forwarders is hardly used in some parts of the world, it has many advantages over conventional harvesting systems. Research has shown that the core reason for the low adoption of CTL in the southeastern USA is the complexity of the equipment to optimize value recovery. In this paper we delve deeper into this problem by investigating the technical and physical contradictions responsible for this situation. A dual-methodological approach was followed to analyze and solve the problem using the Theory of Constraints (TOC) and the Theory of Inventive Problem Solving (TRIZ). A solution is to apply one of the innovative principles of TRIZ: Mechanics substitution. We believe that this dual-methodological approach can be used to great effect to solve many more technical and non-technical forest operations or other problems.

Key words: Theory of Constraints, TRIZ, forest harvesting, cut-to-length

INTRODUCTION

The focus of this study is on cut-to-length (CTL) harvesting systems consisting of harvesters and forwarders. The harvester (**photo 1**) is used to fell and process trees at the stump, while the forwarder (**photo 2**) is used to extract the logs. During processing, the harvester head (**photo 3**) and log optimization system (**photo 4**) cut the stem into logs with the objective to optimize the value recovery from the stem as different parts of the stem have different values (e.g: the logs at the bottom of the stem may be worth US\$ 35/ton while the upper logs may be worth only US\$ 2.50/ton). Machine operators should take care during the optimization process as value losses due to sub-optimization can range from 1 to 68% in harvester/processor operations [1]. In a study Conradie *et al.* conducted in the southeastern USA the value loss with three harvesters ranged between 6 and 10% [2].



Photo 1. Harvester



Photo 2. Forwarder

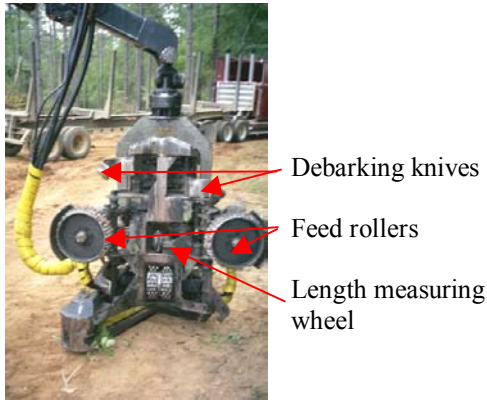


Photo 3. Harvester head



Photo 4. View from the harvester's cabin with the screen of optimization computer system is the lower left corner of the photo.

Currently, most harvester/processor heads use mechanical sensors to measure lengths and diameters [3]. The length measuring systems consist mostly of a small spiked wheel (**photo 3**) in the belly of the head that runs along the stem during processing. Diameters are normally measured by the amount of opening in the debarking knives or the feed rollers (**photo 3**). Murphy and Marshall [3] reported that productivity can decrease by as much as 30% and logging costs can increase by up to 55% if the current mechanical scanning equipment are used more thoroughly to increase value recovery (i.e. do a full scan of the stem before starting the optimization). It is not only the machine that makes some “measurements”, the harvester operator is responsible to make an assessment (“measurement”) by eye of the defects (knots, rot, sweep, etc.) on the stem and then make the decision to override the suggested cutting pattern made by the optimization system. The harvester operator is therefore an integral part of the log optimization process. According to Gellerstedt [4] harvester operators indicated that they already have problems seeing defects while processing stems at the current feeding speeds of 4m/s. It is therefore doubtful if the speed of current value recovery technologies can be increased without adversely influencing value recovery – a breakthrough innovative technology is required to do the diameter and length measurements, and to detect defects.

In Sweden and Finland almost 100% of wood is harvested by cut-to-length (CTL) systems while in North America between 20 to 30% of logging is done this way [5]. Brink [6] determined that the global trend is to replace feller-bunchers and skidders with harvesters and forwarders. Heidersdorf [7] reported that the primary advantages of CTL are lower environmental impacts and higher fiber recovery. The trend towards more CTL operations has not yet been observed in the southeastern USA as a survey conducted in 1997 found that CTL accounted for less than 1% of logging in Georgia, a state in the southeastern USA [8] There is no evidence to suggest that the situation in the southeastern USA has changed since then. According to a root cause analysis Conradie performed using the Current Reality Tree from the Theory of Constraints, the core problem for the low adoption of CTL in the southeastern USA is the complexity of the equipment the harvester uses to optimize value recovery [9, 11]. Complexity is seen as the number and diversity of elements and element interrelationships within a system, as well as the difficulty of mastering the system [10]. Ease of operation is also seen as a measure of complexity (simplicity). large number of steps in an operation also normally makes it less easy. “Hard” processes have low yield, and “easy” processes have high yield; they are easy to use [10]. Conradie *et al.*'s [11] general direction to solve the complexity problem is to “*Manufacture simple, cost effective CTL equipment that can mass produce and optimize value recovery*”.

According to Savransky [12] problems in engineering design are of two kinds: maxi and mini-problems. A maxi-problem is a change to the system as a whole while a mini-problem is a change to a sub-system. In this paper we address a mini-problem with the emphasis on finding a solution that will in particular satisfy the needs of loggers in the southeastern USA although we believe that such new equipment will be universally accepted. We will identify our specific problem using the Theory of Constraints (TOC) and TRIZ (TRIZ is the Russian acronym for the Theory of Inventive Problem Solving), then relate our specific problem to a TRIZ general problem and finally relate the TRIZ general problem to the TRIZ general solution (**Figure 1**). It is beyond the scope of this paper to go into the detail of the specific solution.

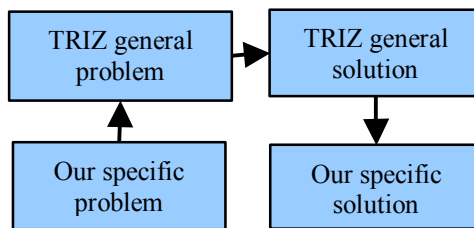


Figure 1. The general TRIZ problem solving model.

In this paper we first discuss TOC and TRIZ, including their weaknesses, strengths and synergies. In the methods section we describe how TOC and TRIZ can be used to solve a mini-problem systematically. In the results section we apply the methodology to the CTL mini-problem. In the discussion and conclusion section we relate our general solution to actions the industry is taking to overcome this problem.

THE TWO THEORIES: TRIZ AND TOC

What is TRIZ?

The development of TRIZ was started in 1946 in the former USSR by Genrich Altshuller (a scientist and inventor) and his colleagues. Since then it has expanded and is today being developed and practiced throughout the world. Classical works of Altshuller include: *Creativity as an Exact Science* [13], and *And Suddenly the Inventor Appeared* [14]. TRIZ research hypothesizes that there are universal principles of invention that form the basis for creative innovations in technology. If these principles could be codified, they could be taught thereby making the invention process more predictable. TRIZ researchers examined, classified, and analyzed over 3 million patents to identify the principles of innovation [15]. The three key discoveries of TRIZ are as follows: (1) Problems and solutions were repeated across industries and sciences; (2) Patterns of technical evolution were repeated across industries and sciences; and (3) Innovations used scientific effects outside the field where they were developed.

Nakagawa [16] summarized the essence of TRIZ as the “*recognition that technical systems evolve towards increased ideality by overcoming contradictions mostly with a minimal introduction of resources. Thus, for creative problem solving, TRIZ provides a dialectic way of thinking, i.e. to understand the problem as a system, to image the ideal solution first, and to solve the contradictions*”. Technical contradictions are the classical engineering tradeoffs – the desired state cannot be reached because something else in the system prevents it. When a technical contradiction exists an action is simultaneously useful and harmful (i.e. as speed increases so does friction). A physical contradiction exists when one object has contradictory/opposite requirements (i.e. it must be hot and cold, it must be fast and slow).

TRIZ tools and techniques include, but are not limited to: Functional analysis, problem formulation, the ideal final result, locating the zones of conflict, 40 principles of inventive problem solving, contradiction matrix, separation principles, the trends of evolution and 76 standard solutions. Traditionally TRIZ was mainly used to design products and processes at the mini-problem level. However, in recent years, TRIZ practitioners have developed new matrixes including ones for business and software problems.

According to Domb and Dettmer [15], early research indicated that inventors using TRIZ experienced an improvement of 70 to 300% or more in the number of creative ideas that they generated for solving technical problems and in the speed with which they generated innovative ideas.

What is TOC?

According to Gillespie *et al.* [17] TOC is a management philosophy that defines a set of problem solving and management tools, which have had a significant effect on businesses throughout the world. TOC was originally developed in the early 1980's by Eli Goldratt (an Israeli physicist). He illustrated his production scheduling concept in a novel, *The Goal* [18]. Since then many others have contributed to TOC.

The problem solving tools of TOC, better known as the Thinking Process, was first taught by the Goldratt Institute in 1992. These logic tools of the Thinking Process were published in 1994 in the novel, *It's Not Luck* [19] and consist of Evaporating Clouds, Current Reality Trees, the Negative Branch Reservation process, Future Reality Trees, Prerequisite Trees and Transition Trees. These tools can be used to solve most problems by building causal trees or diagrams. Some authors prefer to refer to the Evaporation Clouds as Conflict Resolution Diagrams (CRD). In this paper we used the CRD terminology. The CRD and Current Reality Trees are used to identify the core conflict and core problem respectively (What to change?). The Negative Branch Reservation and the Future Reality Tree can be used to construct and test possible solutions (What to change to?). The Prerequisite and Transition Trees are useful in building effective solutions and implementation plans (How to implement the change?). The Thinking Process is therefore a complete problem solving process. TOC also has generic applications for operations, finance and measures, project management, distribution, marketing, sales, managing people, strategy, and tactics. TOC is regarded as a holistic (systemic) problem solving theory.

As TOC is normally used to solve business problems/conflicts, we were unable to find examples where TOC was used on its own to solve technical or physical contradiction problems. A possible explanation could be that technical or physical contradictions are normally very localized problems and TOC is normally concerned with problems blocking an organization as a whole from reaching more of its goal. The development of the TRIZ business matrix may strengthen the synergies between the TRIZ and TOC.

In *The World of the Theory of Constraints: A Review of International Literature*, Mabin and Balderstone [20], reported the following average results from TOC implementations: a mean reduction in lead time of 70%, mean reduction in cycle time of 65%, mean improvement in due date performance of 44%, mean reduction in inventory of 49%, and mean increase in throughput of 63%.

Strengths, weakness and synergies

In 1997, Rizzo [21] briefly commented on the synergies between TOC and TRIZ. Later, the same year, Domb and Kowalick [22] stated in passing that TOC could help TRIZ in the problem identification phase. In 1999, Domb and

Dettmer [15] showed with an analysis of the Challenger space shuttle accident how the two theories are complementary. Later in 1999, Moura [23] explained how the Current Reality Tree and the Conflict Resolution Diagram (CRD) can be used together with TRIZ. In 2000, Mann and Stratton [24], described three case studies that combined TRIZ and TOC. In 2002, Bergland [25] described a six step basic process of how TRIZ and TOC can be combined to exploit the strengths of both. His process includes a focused variant of the Problem Formulation Diagram of TRIZ that shows how the harmful and useful effects are connected. It also shows how a CRD is constructed that contains both the technical and physical contradiction. Recently (2003), Pfeifer *et al.* [26] proposed a model where TRIZ, TOC and 6 Sigma (DMAIC) could be combined. TOC and TRIZ can also be used with the LEAN manufacturing/enterprise philosophy.

According to Domb and Dettmer [15] the strength of the CRD is its superiority in structuring and graphically depicting the crucial elements of any conflict and its ability to assist in identifying the unspoken assumptions underlying the conflict. The purpose of the CRD is to identify the conflict and to generate ideas on how to break erroneous assumptions that can assure non-compromising “win-win” solutions. Cox *et al.* [27] states that a major problem with developing assumptions for the CRD is that there are no specific rules or criteria governing what is a good versus a poor assumption. A person therefore has to study each assumption in some detail and hopefully it will provide insight into how to solve the problem. Domb and Dettmer [15] state that the CRD is somewhat weak in stimulating idea generation [15]. To overcome this weakness Goldratt developed the idea of a reference or alternative environment where the conflict does not exist. Many people find this approach difficult as it presupposes that you can think of such an alternative situation. Fortunately, TRIZ can be used to provide a structured approach to the generation of ideas [15]. One of the synergies Rizzo [21] sees between TRIZ and TOC is the 40 inventive principles that can help TOC practitioners to generate ideas for solutions that break the inventor's underlying assumptions about the problem. He also states that it is more difficult to define the conflict in TRIZ without the CRD. The two together make for a powerful combination as the CRD provides clarity on the conflict and the inventive principles provide many possible solutions to break underlying assumptions. According to Mann and Statton [24], the CRD offers a simple yet highly effective means of defining and understanding a conflict. They also state that the CRD provides more focal points where assumptions can be challenged.

METHODOLOGY

Conradie [9] used the Current Reality Tree from the Theory of Constraints (TOC) to identify the core problem why CTL is not the system of choice in the southeastern USA. His analysis revealed the complexity of the harvester's value recovery sub-system as the core problem. We used this as the starting point for the analysis phase. During the analysis phase we took the core problem and used an adapted version of the Problem Formulation Diagram of TRIZ to identify the technical and physical contradictions after which we constructed the Conflict Resolution Diagram (CRD). A CRD consists on five entities (**Figure 2**), including two requirements B and C which are necessary (but not sufficient) to achieve the common objective (A). The prerequisites D and D' are necessary (but not sufficient) to achieve the requirements B and C respectively. The physical contradiction is used as the two prerequisites (D and D' in **Figure 2**) and the contradicting features of the technical contradiction are used as the two requirements in the CRD (B and C in **Figure 2**). From the technical contradiction we verbalized a ideal final result (IFR) and used it to formulate the common objective in the CRD (**Figure 2**). It is beyond the scope of this paper to teach how to construct the CRD. Several texts [28, 29] provide detailed procedures on how to do it.

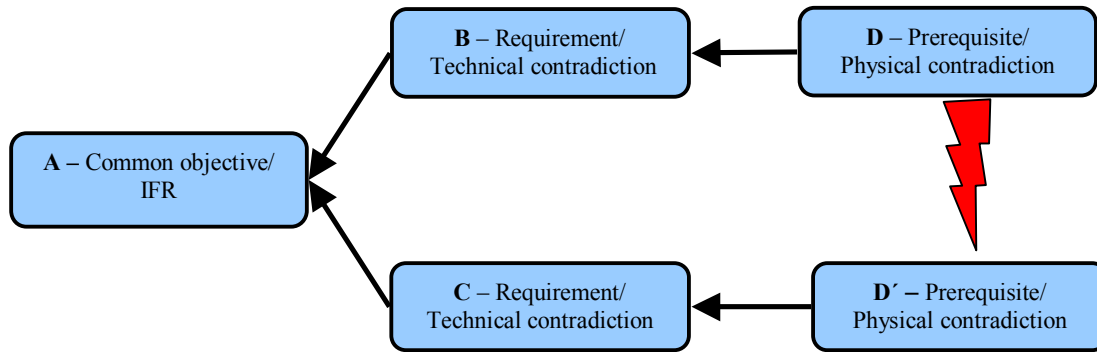


Figure 2. Conflict Resolution Diagram (CRD)

Altshuller’s research was focused on finding the common characteristics of breakthrough solutions. He found that patents fell into 40 generic inventive principles and that the solutions in these patents resolved some contradiction. He identified 39 contradicting features which he used to construct his contradiction matrix [30]. The 40 inventive principles [31], a description of the 39 contradicting features [10], and the contradiction matrix [www.triz-journal.com/archives/1997/07] is available in the TRIZ journal.

The contradiction matrix is used as follows. The contradicting features are shown as rows and columns in the matrix (**Table 1**). The row shows the improving feature while the column shows the worsening feature (example: when ease of operation improves, device complexity worsens). In this example, the intersecting cell (**Table 1** in bold) contains the numbers of the 40 principles that are probable solutions to this specific contradiction; the intersecting cell shows that principles 32, 26, 12 and 17 are the “most probable” solutions, although no solutions are guaranteed. Some TRIZ practitioners prefer to look at all 40 principles to find possible solutions, not only the “most probable” ones.

We used the contradicting features we identified in the problem analysis phase as the entering arguments into the matrix. Thereafter, we used the contradiction matrix and the 40 inventive principles to solve the technical contradiction, while we used the separation principles to solve the physical contradiction. The 40 inventive principles may also be used with the separation principles to solve a problem. Mann and Stratton [24] explain how the inventive principles relate to the separation principles. The following separation principles may be used to solve a physical contradiction: separate opposite requirements in space, in time, between the whole object and its parts, or through changing conditions, satisfy the contradiction and alternative ways (sub-system, super-system, alternative and inverse).

Table 1. Part of the contradiction matrix showing five improving and worsening features.

Improving feature \ Worsening feature	Speed	Measurement accuracy	Device complexity	Ease of operation	Productivity
Speed	+	28, 32, 1, 24	10, 28, 4, 34	32, 28, 13, 12	
Measurement accuracy	28, 13, 32, 24	+	27, 35, 10, 34	1, 13, 17, 34	10, 34, 28, 32
Device complexity	34, 10, 28	2, 26, 10, 34	+	27, 9, 26, 24	12, 17, 28
Ease of operation	18, 13, 34	25, 13, 2, 34	32, 26 12, 17	+	15, 1, 28
		1, 10,	12, 17	1, 28,	+

Productivity		34, 28	28, 24	7, 10	
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RESULTS

Analyze the problem

In order to get from the core problem to the physical and technical contradiction we adapted the mini-problem formulation of TRIZ and the focused variant of the mini-formulation described by Bergland [25]. We called it the Dynamic Problem Formulation Diagram (DPFD). As a starting point we needed to identify why the complexity of the value recovery sub-system is undesirable from a physical contradiction point of view. The physical contradiction is that the complexity influences the operating speed of the value recovery sub-system. High speed and low speed is needed to fulfill some requirements – so on the one hand we want to increase the operating speed while on the other hand we want to decrease the operating speed (D' and D in **Figure 3**). The useful effect of increasing the operating speed (D') is increased productivity (C) but this causes the harmful effect that measuring accuracy decreases (B') – C counteracts B'. When measuring accuracy decreases, we feel pressure to decrease the operating speed. When we decrease the operating speed, the measuring accuracy increases (useful effect) but productivity decreases (harmful effect). When productivity decreases we feel pressure to increase the operating speed. The cycle starts all over again. We are therefore in a chronic conflict between D and D' (the lightning bolt in **Figure 3** represents the conflict).

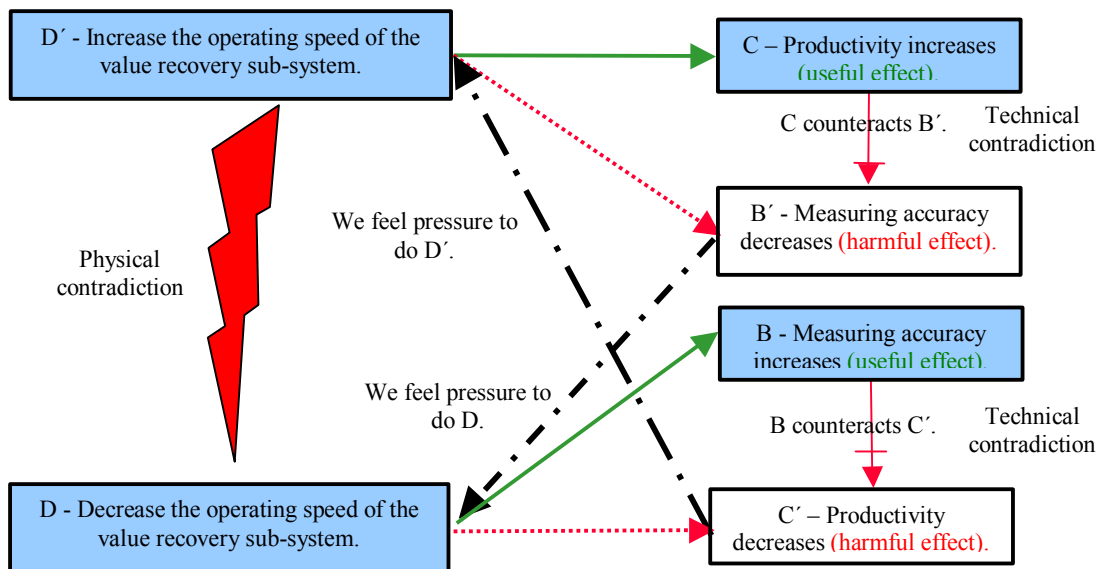


Figure 3. The Dynamic Problem Formulation Diagram (DPFD).

We used D and D' (the physical contradiction in **Figure 3**) as the basis to formulate the D and D' prerequisites of the Conflict Resolution Diagram (CRD) in **Figure 4**. We included the current and an ambitious target operating speed as prerequisites in the CRD. We later used the ambitious target speed to formulate the Ideal Final Result.

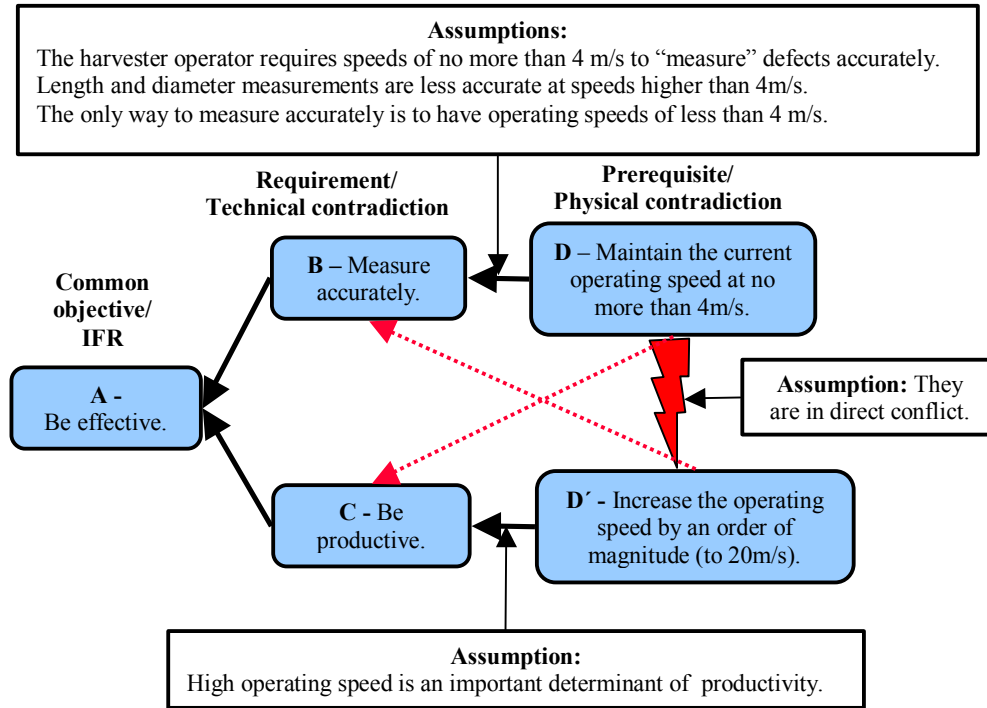


Figure 4. Conflict Resolution Diagram (CRD) with the technical and physical contradictions.

Next we wanted to know what requirements/technical contradictions are being satisfied by D and D'. D is required to “measure accurately” (the B-requirement). Measurement accuracy includes length and diameter measurements and the accuracy with which the operator can visually identify defects on the stem. D' is required to “Be productive” (the C-requirement). The useful effects in **Figure 3** are therefore used to formulate B and C in **Figure 4**. The measuring accuracy (B) and productivity (C) are the two contradicting features that will be used to solve the technical contradiction. TRIZ defines productivity as the output per unit time or the cost per unit output, and measurement accuracy is the closeness of the measured value to the actual value (reducing the error in a measurement increase the accuracy of the measurements). From the B and C requirements we formulated a TRIZ Ideal Final Result (IFR) to keep us focused on the problem. The IFR also helps to remove mental constraints of existing solutions and get people to think outside the box which help them to realize that they have been creating the box themselves [32]. In this case the IFR is: We want a simple, easy to operate value recovery sub-system, that operates at 20 m/s and an accuracy of 100% all of the time. A summary of the IFR is therefore that the harvester must be effective, which we used as the common objective of B and C (A in **Figure 4**).

The CRD is read as follow (**Figure 4**):

- *In order for the harvester to (A) “Be effective”, the value recovery sub-system must (B) “Measure accurately”. In order for the value recovery sub-system to (B) “Measure accurately” the value recovery sub-system must (D) “Maintain the current operating speed at no more than 4 m/s” because (AB assumptions) “The harvester operator requires speeds of no more than 4 m/s to measure defects accurately”; “Length and diameter measurements are less accurate at speeds higher than 4m/s”; “The only way to measure accurately is to have operating speeds of less than 4 m/s”.*

- *In order for the harvester to (A) “Be effective”, the value recovery sub-system must (C) “Be productive”. In order for the value recovery sub-system to (C) “Be productive” the value recovery sub-system must (D’) “Increase the operating speed by an order of magnitude (to 20 m/s)” because (CD assumption) “High operating speed is an important determinant of productivity”.*
- *On the one hand the value recovery sub-system must (D) Maintain the current operating speed at no more than 4m/s, while on the other hand the value recovery sub-system must (D’) Increase the operating speed by and order of magnitude (to 20m/s). We cannot have both simultaneously because (DD’ assumption) they are mutually exclusive/in direct conflict with each other.*
- (D) “Maintaining the current operating speed at no more than 4m/s” *jeopardizes* (C) “Being productive”.
- (D’) “Increasing the operating speed by an order of magnitude” *jeopardizes* (B) “Measuring accurately”.

Use the inventive principles to identify a solution for the technical contradiction

We used the B and C requirements in the CRD (**Figure 4**) as the entering arguments into the contradiction matrix (**Table 1**) with D being the improving feature (productivity) and D’ the worsening feature (measuring accuracy) in the matrix. The measuring accuracy therefore needs to be protected from degradation (or preferable increased) as productivity increases. The intersecting cell in the matrix shows that principles 1, 10, 34 and 28 could give us high productivity without counteracting measuring accuracy (**Table 1**). Tate and Domb [28], and Domb *et al.* [33] provides directions for solutions for each principle.

Table 2. The “most probable” inventive principles and directions for solutions.

Principle	Directions for solutions
1. Segmentation	Divide an object into independent/smaller parts. Use particles instead of the whole object. Divide the objects into parts, then make them flexible. Make an object easy to disassemble. Increase the degree of fragmentation or segmentation.
10. Preliminary action	Perform the required change of an object (either fully or partially) before it is needed. Pre-arrange objects such that they can come into action from the most convenient place without losing time for their delivery.
34. Discarding and recovering	Make portions of an object that have fulfilled their functions go away or modify these directly during operation. Conversely, restore consumable parts of an object directly in operation.
28. Replace mechanical system with fields	Replace a mechanical means with a sensor (optical, acoustic, taste or smell). Create a field that can be detected or measured. Use a field instead of a substance. Use electric, magnetic and electromagnetic fields to interact with the object. Change from static to movable fields, from unstructured to those having structure.

TRIZ provided us with many more options than the conventional TOC way of breaking assumptions. Example: To break the assumption in **Figure 4** that the only way to measure accurately is to have operating speeds at less than 4m/s, one could go through the following TOC mental process:

- Think of who “measures accurately” without doing it at low speeds. Without knowledge of what other industries do it is not so easy to think of alternatives. The danger is that most people intuitively look for solutions within a paradigm (i.e. the forest or forest products industries in this case).
- How do they “measure accurately” without doing it at low speeds.
- How can we have A, B and C without D.

It should be clear from the above example that TRIZ opens up a wealth of ideas on how to solve the problem. However, it takes time to understand how to use the principles as most of them are at first very abstract to most people.

It seems that principle 28 (Mechanics substitution – replace a mechanical means with a non-mechanical sensor or create a field that can be detected) is the most likely candidate to solve the problem. Principle 28 is also a candidate to increase productivity without counteracting device complexity or easy of operation (**Table 1**). We foresee that non-mechanical sensors or fields will be able to make accurate diameter and length measurements, and accurately recognize defects on the stem at the high speeds. This will lift the restriction (4m/s) the operator places on the operating speed. Such a value recovery sub-system will also increase measurement accuracy.

It is beyond the scope of this paper to investigate all the inventive principles identified in the intersecting cell of the contradiction matrix or any other inventive principles that could provide possible solutions.

Use the separation principles to identify a solution for the physical contradiction

To apply the separation in space principle we asked ourselves whether we need the speed to be low and high everywhere, or is it necessary in certain places only. Therefore, the speed can be high in areas of the stem where the harvester operator does not need to make decisions regarding defects (e.g. there are very few knots or there are so many knots that the decision is obvious) and it can be low in areas of the stem where the operator needs to make decisions. We believe that most operators are applying this principle anyway with the current equipment. However, this will not make current operations much more productive as the maximum speed on most harvester heads are in the 4 to 6 m/s range. Other solutions currently used by the industry that illustrates the separation in space principle is to separate the optimization of the stem from the felling and some other processing functions. In such cases a harvester is not used to fell, process and optimize the stem at the stump. The felled tree is processed and/or optimized by other equipment (not harvesters) at other places (on the landing, central processing plants, merchandising yards, etc.). This is also an application of another separation principle as the problem is moved from the sub-system to the super-system.

To apply the separation in time principle we asked ourselves whether we need the speed to be low and high at the same time, or is it necessary at certain times only? The operator only needs the low speed when decisions need to be made. In this case, it is therefore similar to the separation in space principle.

According to Mann and Stratton [24] one of the inventive principles that could satisfy the contradiction is principle 28 (Mechanics substitution). By using non-mechanical sensors or creating a field that can be detected we can eliminate the need for the differentiation between high and low speed. The operator is no longer the limiting factor. This is the same solution we identified to solve the technical contradiction.

Evaluate the solution

If we design a non-mechanical value recovery sub-system we can increase the operating speed by an order of magnitude and also increase both the measuring accuracy and productivity. We have therefore resolved the conflict. It is possible that the current stem feeding system might not be able to cope with an operating speed of 20 m/s. A similar analysis as we just did could be used to solve such a problem too.

DISCUSSION AND CONCLUSION

We have shown how TRIZ and TOC can be combined to systematically find solutions to engineering problems – finding a solution is not longer a question of luck or trial and error. By reducing trial and error approaches to product design it is possible to reduce product development time and control development costs – both being necessary conditions to stay ahead of the competition in today’s competitive forest equipment market. A systematic process, without compromise, also opens the door for breakthrough, quantum leap improvements – not the normal incremental improvements we are accustomed to. Nicholas Negreonte from the MIT Media Lab states that incrementalism is innovation’s worse enemy [34].

We identified that replacing the mechanical measuring system with sensors/fields as the mostly likely means to solve the conflicts. Some readers may be saying *yes but* at this point in time and asking, “..what about possible negative effects?” or “How can we overcome obstacles to put the idea in practice?” TOC also has tools to manage this process: The Negative Branch Reservation process and the Future Reality Tree are TOC tools to test a solution and trim any possible negative effects that could be forthcoming, while the Prerequisite Tree and Transition Tree are useful in identifying obstacles to implementation and developing project plans.

Over the last decade the forest industry has mainly been taking actions to improve measurement accuracy and productivity of harvesters incrementally (i.e. move the diameter measurement from the debarking knives to the feed rollers, find ways for the length measurement wheel to follow the contours of the stem better, find better ways to hold the stem in the feed rollers, increase the power in the feed rollers, use chains or spikes on the feed rollers for better grip, etc.). Some also see an investment in operator training as a simpler and more effective way to improve value recovery than investing in technology [3]. The abilities of operators to handle fast feeding speeds where complex log specifications are used is already limited at speeds of 4m/s. The learning curve for operators is also long (could be years). According to Murphy and Marshall [3] improving tree-form models are one of the ways being used to increased the accuracy of the measuring system but it does not work well in many cases. Other ways of improving value recovery is to use different combinations of how much of the stem is measured and how much is forecasted. Simulations have shown that value recovery can be increase but the draw-back is lower productivity [3].

Recently, a company in New Zealand developed a system that uses a non-mechanical means (lasers) to make length, diameter and sweep measurements. This system can scan and calculate the optimum cutting pattern in seconds. However, it is a separate unit used on the landing with a conventional (not a CTL) harvesting system – they did not incorporate the technology into the harvester head of the harvester. The information is transferred from the scanning unit to an excavator with a processor head that cut the stem into logs. This system does not automatically measure external defects (knots, rot, etc.) or cut the stem into logs. Another product has been developed in New Zealand that uses sound to identify internal (not external) defects. It has not been incorporated into a harvester head either. Optical equipment has also been used to identify defects.

In our opinion we need to investigate how measurements are done with sensors/fields in other industries and adapt it to forestry. TRIZ research has shown that innovations frequently use scientific effects outside of the field where they were developed (i.e. GPS and central-tire inflation used in forest operations were originally military applications). Brink [6] indicated that the worldwide trend is to replace tree-length with CTL systems – indeed a great economic incentive to solve the problem.

For people familiar with TOC it might be interesting to see that the CRD (Conflict Resolution Diagram) can also be used to solve technical contradictions as it is normally used to solve non-technical conflicts [15]. Many authors have shown that TRIZ can also be applied with equal effectiveness to a non-technical problem, although that was not the purpose of its inventor. In recent times TRIZ has been applied more and more to non-technical areas too. It is interesting to note that the inventors of both theories are scientists!

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TRIZ Development Model in China

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Abstract

This paper will discuss a newly developed model, reporting for the first time, called LEADS which is designed to implement TRIZ in China in various stages or phases. The model has been discussed among many local industries and applied in real cases. The author believes that TRIZ will gradually become popular and applied in China as the country is moving into establishing local branded products with local design elements across a wide range of industries. Once the reported success and experience of applying TRIZ in Korea and Japan is shared and made well known in China over the next few years of cultivation period, TRIZ will be starting to together local support and applications. However, the main important issue is to establish a local development model for TRIZ so that a systematic approach for applying the methodology can be referenced. The author will first discuss various initial hurdles in using TRIZ in China based on first hand experience. The various phases of the LEADS model will then be studied together with application to a real case example of a consumer optoelectronics based product. The author has applied various Inventive Principles, Contradiction and S-Field Model.

I Introduction

TRIZ is a powerful tool to generate innovative design. Although it is originated in engineering and technological areas, it is now gradually being applied and the concept being extended into non-technological areas. Despite the fact that TRIZ has been demonstrated as an efficient and effective method in solving problems innovatively, it is still new to many engineers in the world. However, with the gradual adoption in many industrial design applications in the world especially in Asian countries like Japan and Korea in recent years, it is believed that TRIZ will become an essential subject in engineering field within years. TRIZ has started its development in China in the last few years. However today, there are still very few people in China whom are aware of it. One of the main reasons is the lack of a systematic approach to learn and apply this powerful tool.

II Meeting Competition from Globalization with TRIZ

Globalization may bring in a lot of benefits including rapid growth in market size, more opportunity to obtain investment funds, quicker in knowing new technologies which are constantly evolving in the world, better communication to smooth out cultural differences and weakness, etc. However, globalization also brings in the following challenges:

- (1) Increases business opportunities also means an potential increase in competition
- (2) Since R&D and technology breakthroughs could occur everyday and everywhere, engineers are also competing for innovative level of their designs.
- (3) The constant demand for better products with ever lower cost is happening all over the world. Consideration of material used for products and functional capability of products are of essential important to success.
- (4) Time to market is getting more critical

TRIZ may be the only systematic tool that can help to meet some of the challenges stated above through the application of the methodology in order to achieve the followings:

- (1) Zero defect product at design stage
- (2) Innovative and valuable patterns in product / system design in order to bypass short-term and/or mid-term competitions
- (3) Patents generation to increase the value of a company, a product or an individual.
- (4) Upgrade in the functional capability of a product within short period of time

III Hurdles to use TRIZ in China

Despite the capabilities of TRIZ, there are hurdles to its educational development and application in China within short period of time. Some of these hurdles are outlined in below:

- (1) Learning mode in China

Most Chinese receive knowledge through tradition teaching which is characterized by collecting information / knowledge with minimum analysis of the philosophy behind. Westerners learn through analysis, analogy and brainstorming. Memorization is not an important part in Western mode of learning system. However, TRIZ requires people to be able to think out of local traditions, learn and work in the western style described.

- (2) Lack of systematic learning approach

In western countries, there are many courses aim at providing different levels of TRIZ education and training. In China, there are just a handful of courses on TRIZ and practitioners are extremely limited. At time of this writing, according to informal field information that there are less than 50 TRIZ “advocates” in the mainland with less than 10 TRIZ “advocates and practitioners” in Hong Kong

SAR. Open courses were only available recently.

(3) Lack of attention from executives

TRIZ receives little attention by chief executives because:

- (a) They do not know nor have time to understand TRIZ
- (b) Too much focus on “time-to-market” issues which reduces a key element in TRIZ, i.e. time for innovation
- (c) R&D people are not accustomed to TRIZ and hence reluctant to propose to chief executive on applying this methodology

(4) Lack of resources

TRIZ requires people to think outside the paradigm in problem solving. This requests some initial investment in time and fund from the company, organization or government, as well as individuals. Since TRIZ is new to China, the resources for TRIZ development are still very limited. Time-to-market is rated too important in a product cycle by many SMEs. This hinders many design professionals from trying new concepts because there are more uncertainties than following existing methods or references.

IV The Five-Phases Incorporation Model – LEADS

The fundamental philosophy behind TRIZ is to “jump over” hurdles which prevent a person to think creatively and solve problem innovatively. It is commonly acknowledged that it is vital for local Chinese companies with their design and management teams to become more competitive in the global market in the long run. In order to achieve this goal, TRIZ can be a vital platform for such Chinese companies to stay competitive.

But before we can surf in the arena of creativity, it is however important for us to first understand the cultural differences between the west and China in this context so that a localized implementation model of TRIZ can be realized. To this end, the Author has developed a model called LEADS which covers a five-phase process as below:

(1) **Learn**

TRIZ is simple from its appearance but the philosophy behind is very deep. Learn it by heart before one can really appreciate its power.

(2) **Evaluate**

Follow the rules and principles in the first place to solve simple problems so as to get the basic understanding of the algorithms in TRIZ. Learn how to appreciate TRIZ by analyzing the results.

(3) **Adapt**

Incorporate and live with TRIZ to unveil its philosophy. Once you know its philosophy, you may be able to release its real power. . The “Adapt” stage is to train the TRIZ learners to get accustom to solve daily problems with TRIZ that is

to become a basic instinct of the learner.

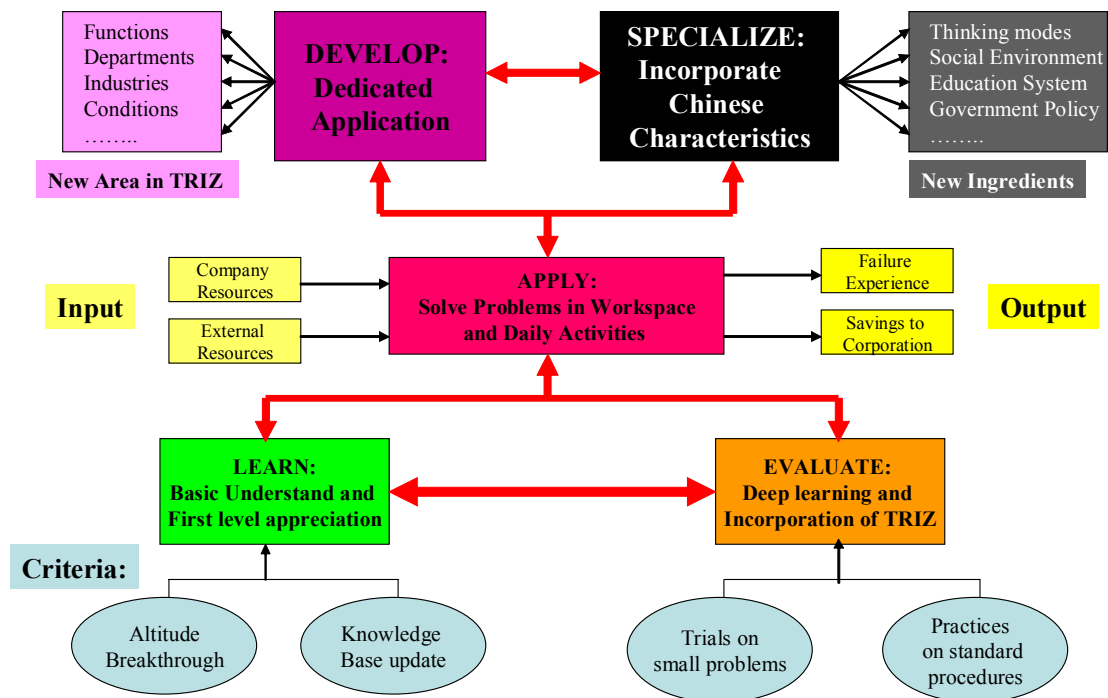
Develop

Tailor TRIZ for specific application segment so that you can modify it to suit the characteristics of yourself and your living environment.

(4) Specialize

Aggregate and trim the modified TRIZ dedicated application environment that can be an individual, a company, an industry, a technical or non-technical arena, a science, a society, a country or even the entire world!

TRIZ Development in China – LEADS Model



V The LEADS Model in Detail

V.1 Learn

TRIZ is powerful tool that is developed by systematic analysis of millions of recorded patents in engineering problems as well as on the analysis of psychological and physiological behavior of human beings on “activities of invention”. It is the result of abstract philosophy with empirical proof. In order to acquire an in depth understanding of TRIZ, one needs to adapt different learning approach from philosophy to pure engineering science and with a heart felt trust of the methodology.

(1) The altitude

- (a) Be open minded

- (i) Chinese are usually more conservative in thinking. This is the main hurdle in learning phase on TRIZ.
 - Use more imagination
 - Use more analogy
 - (ii) Be open to ask, discuss and listen from the junior
 - Chinese seniors do not commonly appreciate the juniors
 - Chinese juniors usually wait for order instead of making proposal
 - (b) TRIZ is, fundamentally, a philosophy
 - (i) Technology evolution directly relates to human evolution
 - (ii) There are different forms of technology which implies that there can different form of “beings”
 - (c) TRIZ is still growing
 - (d) Everyone can be innovative
 - (e) TRIZ starts from Anthropic Principle because it is a study of the human inventive behavior and is evolving gradually to a philosophy on invention.
- (2) Thorough understanding on the basic TRIZ
- (a) The concepts on
 - (i) Creativity, innovation, ideality, contradictions and knowledge
 - (ii) Chinese pays too little attention to understand definition and focus too much on application level, which generate negative effects on innovation.
 - (b) The tools
 - (i) Methodology
 - (ii) Implementation
 - (iii) Application
 - Chinese usually follows application but less trial in new application. This will affect the level of appreciation and real understanding of TRIZ.
- (3) Keep updated with the knowledge in the area of interest
- (a) The sources of knowledge base
 - (b) The tools to access the knowledge base
 - (c) Use analogy to understand a knowledge from different field
 - (i) Chinese is less accustom to analogy
 - (ii) Chinese is less confidence on analogy because it usually means that there is not an existing application.

V.2 Evaluate

TRIZ focuses on releasing the ability on innovation of a person. Innovation is not necessarily to be great but must be useful. Therefore in order to build the appreciation of TRIZ power, one must first evaluate his level of understanding on TRIZ through:

- (1) The depth of understanding on a particular term, theory, methodology or part of TRIZ philosophy. The deeper the understanding, the more appreciation on TRIZ.
- (2) Incorporate the learnt knowledge (may be a small piece only) into daily life, not only just in workspace but also on other daily activities.
- (3) The ease of using TRIZ in daily activities reflects the level of incorporation of TRIZ philosophy. This can be self evaluated through the intention and number of occurrences of applying TRIZ in daily activities.

V.3 Adapt

It can be said that the level of understanding of a tool, a skill or a theory will be reflected from the level of application. However, most people, in particularly, Chinese, seldom share experience on failed applications.

- (1) Successful application provides positive psychological effects
- (2) Analysis on failure application provides knowledge effect because it can reveals
 - (i) Deficiency in analyzing the application conditions
 - (ii) Deficiency in the scope of application
 - (iii) Deficiency in the use of tools, methodology and/or theory
 - (iv) Deficiency in the tool, methodology and/or theory itself

Any deficiency reflects that there is room for improvement or further development. It also provides a direction for the improvement and future development. (This is also one of the reasons for the development of AFD which is a key methodology in TRIZ)
- (3) Sharing of experience in failure application accelerate the development of more TRIZ practitioners:
 - (i) TRIZ improvement through failure analysis
 - (ii) Improvement on application efficiency (no need to repeat the failures)
 - (iii) Save energy, time and resources
- (4) Apply TRIZ in daily activities to earn practical experience and confidence
 - (i) TRIZ application is not limited to solving difficult problems in the workspace but also simple application in daily life.
 - (ii) Daily life application of TRIZ provides a wider scope of application environment. This can widen the understanding on TRIZ in different arena. However, most Chinese may think that this is not “high level” enough to be an illustration or sharing with others. This traditional prospective and altitude on learning such a breakthrough, well proven concept must be re-educated.

V.4 Develop

TRIZ is very strong in problem solving and is nearly the unique approach to tackle very difficult design problem. However, the gargantuan scope in problems characterized by their functions, area of occurrences and condition of occurrences will

complicated the use of TRIZ by an individual user. Therefore, it is useful to develop standard model of using TRIZ procedures to use certain TRIZ tools or modified version of TRIZ and its tools in relation to the characteristics of problems:

- (1) By function
- (2) By department
- (3) By industry
- (4) By field in science
- (5) By fields in non-technological arena
- (6) By type of problem
- (7) By condition etc

Since solving problems with TRIZ requires the users to know both TRIZ and the specific knowledge involved within the problem, such standard models in dedicated area can then be further develop as a standard procedure or benchmarking criterion in the corresponding area, e.g. TRIZ in Health Care industry, TRIZ in Marketing and Sales, TRIZ in consumer product design etc.

V.5 Specialize

TRIZ originates from Russia and gradually improved by the western world. However, the thinking mode, behavior and culture are different between east and west. For example, many Japanese think that the classic TRIZ is too difficult to be used. Therefore, they developed local TRIZ version called USIT for Japanese companies and local people. [See Editor's note 1] The long histories of Chinese will complicated these areas. Therefore, TRIZ development in China can be in the following directions:

- (1) Add / amend the components of TRIZ to tailor Chinese
- (2) Add / amend the process of adopting TRIZ in China
- (3) Add / amend the tools for special application arena in China

VI TRIZ Case Study in China / HK

In 2003, a system company in Hong Kong went through the first three phases (Learn, Evaluate and Apply) of the LEADS model. In 2004, it successfully made use of TRIZ to develop a system project within one year. This system project included proprietary software at system level and a thin client terminal. This section shows how the company incorporates TRIZ in her project development.

VI.1 Introduction

Multimedia content is essential for recreation (e.g. movie, karaoke) and professional

training (all kinds of professional trainings, e.g. lectures on quantum computing). VCD and DVD are the most cost effective and common media to store the content. However from a royalty or intellectual property consideration, they are not good because they do not offer any content protection or interactive features. On the other hand, video streaming methodology from remote server using PC as user access terminal can achieve this content protection objectives but it, on one hand, relies heavily on Quality of Service (QoS) of the network (must be broadband), and on the other hand, require huge investment hardware and maintenance operation on service providers. Moreover, in order to cover the potential market all over the world, there is only one common communication network environment that can serve, i.e. PSTN telephone network system (ordinary telephone network). The project is to set up and demonstrate a system that can serve all these purpose cost effectively in such a way that the multimedia player is just of similar price as the general home entertainment multimedia players.

VI.2 Contradictions on System Level

(1) Ergonomic – Administration Conflict

The solution of the project must be cost competitive in two aspects:

- (a) On end user side, the access terminal must be of similar price structure to the ordinary multimedia player commonly found in the market, e.g. high grade DVD player despite the fact that the access terminal is an intelligent device that provides both normal multimedia functions as well as dedicated content royalty protection.
- (b) On system and content provider side, the initial investment on hardware and the future maintenance cost must be as low as an ordinary network commonly used by SME.
- (c) The whole system must be of high degree of automation but with minimum IT equipments and professionals, but at the same time to be flexible in operation.

(2) Technical Conflict

It has been shown that a broadband network can provide adequate QoS but it requires sophisticated network equipments, broadband network infrastructure and complicated receiver terminal for real time multimedia content access by end users. If the hit rate distribution of end users focus in the same three-hour period of a day (which is true for business deployment), there will be a huge waste of investment on network equipments. On the other hand, a normal multimedia player cannot have any protection on the royalty, and cannot have any interactive services to the end users.

(3) Physical Conflict

Physical conflict is caused by the need of royalty protection on multimedia content and the provision of interactive services with the QoS of broadband. The desired result is to have a broadband network system which can achieve all system requirements and without a broadband network system which requires huge initial investment and operation cost but in limited regions.

VI.3 System Analysis based on TRIZ Substance-Field Model

In system analysis phase, it is necessary to define clearly the problem statement so that all the subsequent design process can be moving in the right direction. This is the result through multiple discussions between the customer and the chief technical officer of the company. In this case, the problem statement is:

“Design a system that can handle royalty protection, interactive function and QoS same as broadband on multimedia content with ordinary PSTN telephone network which is same and cover every corner in the world”

(1) Step 1 : Identify elements in SFM :

System : Multimedia Player with Security Control over Internet

Tool : Multimedia player

Function: Access content, protect royalty, communication on Internet

Substance : Multimedia content player, internet, server system

Field : Electronics (data communication and control)

Environment : Person, display, telephone network

Final Result : Play the content after authentication with broadband quality

Benefit :

Cost :

Parameters :

Analogous Systems :

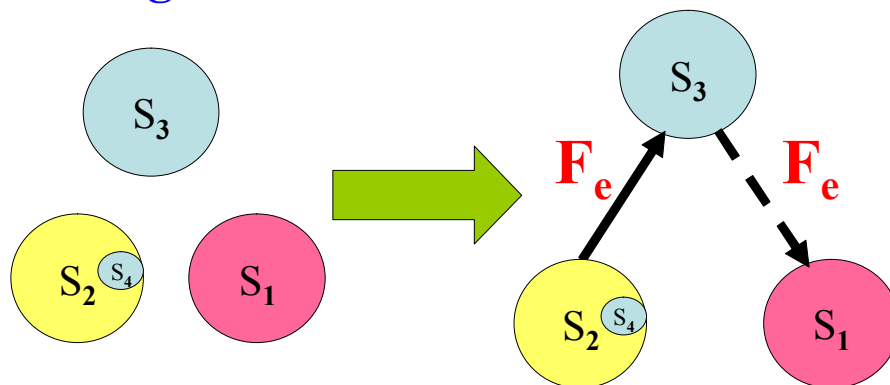
Figure VI.1 : Identify the elements

- Task – Convey content and control through the Internet
- Function – Convey content and control
- S1 : Multimedia Player
- S2 : Server
- S3 (Environment) : Internet



(2) Step 2 : Construct the SF model

Figure VI.2 : Construct the model

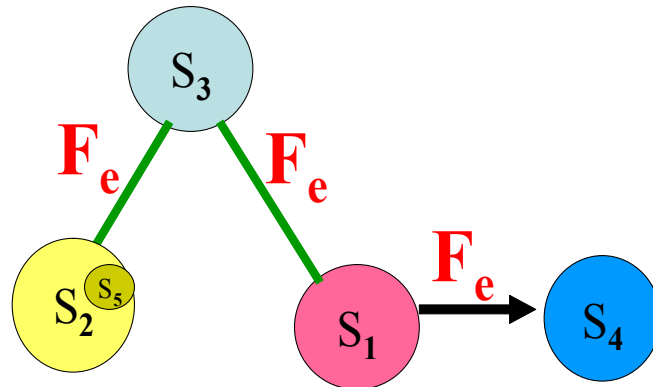


Remarks:

- The system is an ineffective complete model because the desired effect (QoS of broadband network) cannot be guaranteed from S₃ to S₂.
- F_e is the electrical force (in the form of electronic data).
- Initially, content is within S₂ (system), indicated as S₄.

(3) Step 3 : Check from the 76-Standard Solution

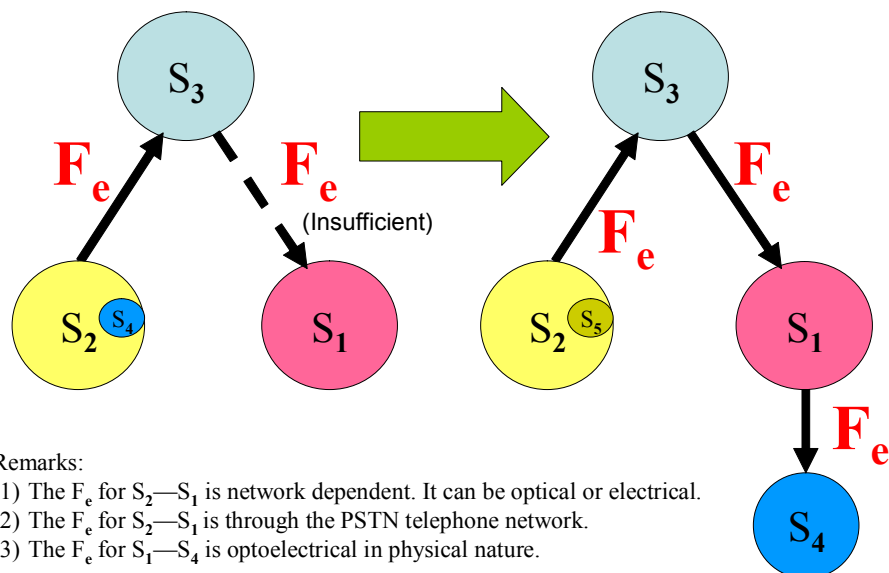
Figure VI.3 : Consider from 76-Standard Solutions



- Using 76-Standard Solutions to change the developed concept into a useful system:
- (1) Construction of inner complex SF (Class 1), $S_1—S_4$: First is to move S_4 from S_2 to S_1 because network environment cannot be modified
 - (2) Change in (1) will create an undesired effect, i.e. loss of royalty protection on the content.
 - (3) Adding substances at SF (Class 5), S_5 within S_2 : Introduce another element S_5 in S_1 to accomplish the loss of royalty protection in (1).

It is unnecessary to set the mechanism in detail at this stage. On the other hand, it is necessary to ensure the mechanism is useful complete system. The SFM model for such system is as follow:

Figure VI.4 : Useful Complete System



Remarks:

- (1) The F_e for $S_2—S_1$ is network dependent. It can be optical or electrical.
- (2) The F_e for $S_2—S_1$ is through the PSTN telephone network.
- (3) The F_e for $S_1—S_4$ is optoelectrical in physical nature.

- (4) Step 4 : Develop a concept to support the solution

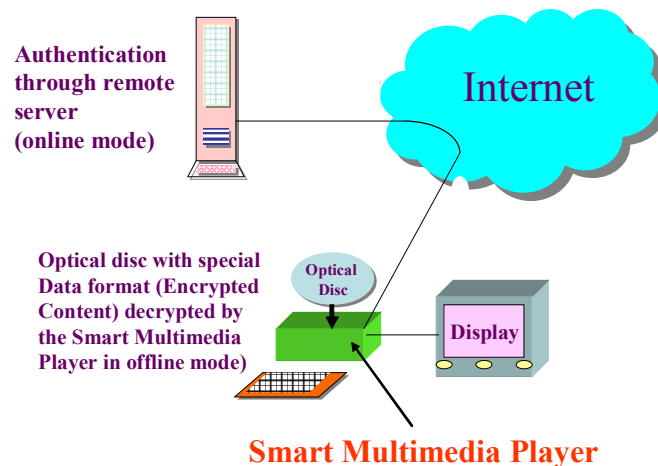
Checklist for the complete useful system is as follow:

System : Multimedia Player with Security Control over Internet
 Tool : Multimedia player

Function: Access content, protect royalty, communication on Internet
 Substance : Multimedia content player, internet, server system
 Field : Electronics (data communication and control)
 Environment : Person, display, telephone network
 Final Result : Play the content after authentication with broadband quality
 Benefit : Local content to reduce network dependence and authentication via internet to ensure royalty protection
 Cost : Proprietary encryption algorithm for content, decryption engine on multimedia player
 Parameters : Complexity of the multimedia player
 Analogous Systems : DIVX system, e-Media system

The system design based on SFM is as follow:

Figure VI.5 : Security Enabled Multimedia System



Challenges for the success of the system:

- (1) Cost of Smart Multimedia Player unit
- (2) Time to Market

The multimedia player is the focus of this paper. The next step is to define the specification of the player.

VI.4 Functional Specification of the Multimedia Player

- (1) Disk Type : DVD/VCD/CD
 - (a) VCD 1.0, 2.0 version
 - (b) CD-DA (common music laser CD)

- (c) CD-R, CD-RW
- (d) MP3 audio CD
- (2) Video Format : MPEG2 for DVD; MPEG1 for VCD
- (3) Audio Format : MPEG-1 Layers 1,2 and 3 (MP3)
- (4) Signal Output : SVGA
- (5) Read special format optical disc
- (6) Power voltage : AC 90V-AC240V
- (7) Power consumption : 25W
- (8) V.90+ 56K Modem
- (9) Keyboard

VI.5 Contradictions in the Multimedia Player Design

The immediate solution to such a multimedia player is using an ordinary personal computer. However, the contradictions using PC solution includes the following:

(1) Ergonomic – Administration

(a) Cost

The cost is too high because the application is dedicated in nature, which violates the versatile application nature of the PC. Therefore, a lot of waste is incurred if PC is adopted.

(b) Form factor

PC is of well-defined specification and hence the form factor is nearly fixed. However, for application specific consumer product, the case design is one of the critical factors for success.

(2) Technical

Compact design has to be employed in consumer product but the functionality needed is a versatile PC.

(3) Physical

The product specification requires a PC which is large and of standard casing however the application specification requires a consumer product which is small and of non-standard casing.

VI.6 Ideation Function

For an ideal Multimedia Player, it should have the functionality of a PC without being a PC. This will result in a consumer multiplayer player of proprietary casing but with a PC capability and with cost at the same level as the ordinary multimedia players in the consumer electronics market.

VI.7 Analysis based on 40 Inventive Design Principles

Through TRIZ, the 40 Inventive Design Principles are used to solve the technical

contradictions. These inventive principles were used by analogy, to arrive at possible solutions for the captioned problem along the waveguide.

Technical Conflict

Recommended Principles

- | | |
|---|--|
| (1) Versatile PC design versus application specific consumer electronics design | #3 Local Quality
#2 Extraction
#3 Merging
#17 Another Dimension |
| (2) Play general multimedia data format as well as proprietary data format | #1 Segmentation |
| (3) Standard casing versus proprietary casing | #15 Dynamicity
#17 Another Dimension |

VI.7.1 Analogy of the Inventive Principles

Employ analogy to match the principles to the current problem as follow:

- (1) #3 Local Quality
 - (a) Change from uniform to non-uniform structure for the PC related functions
 - (b) Change from uniform to non-uniform structure for the external environment, the casing
- (2) #2 Extraction
 - (a) Only the necessary part of the PC hardware functions are included, e.g. no Ethernet interface, no floppy drive
 - (b) Only the necessary part of the PC software functions are included, e.g. modify operating system (OS) for standard PC.
- (3) #5 Merging
 - (a) Bring closer together the PC operations in space
 - (b) Bring closer some of the records on system side to user side, e.g. user records on the proprietary content stored on the Multimedia Player instead of on the system side.
- (4) #1 Segmentation
 - (a) Separate the multimedia content from within the hardware to be external of the hardware and become a separate object.
 - (b) Separate the decryption engine from the engine of reading normal DVD or VCD to another program module.
- (5) #15 Dynamicity
 - (a) Replace flexible mechanical casing design for general upgrade to inflexible compact mechanical design

- (b) Remove all expansion slots for product upgrade
- (6) #17 Another Dimension
 - (a) Go from single layer to multi-layer, for circuitry and components
 - (b) Go from single storey to multi-storey on the subsystems

VI.7.2 Recommendations on Design based on the Inventive Principles

Employ analogy to match the principles to the current problem as follow:

- (1) #3 Local Quality
 - (a) Change from uniform to non-uniform structure -- from versatile design to embedded design using single compact microcontroller instead of several high performance processors for the PC main control.
 - (b) Change from uniform to non-uniform structure for the external environment, the casing – use proprietary case with form factors as specified by the customers as far as possible.
- (2) #2 Extraction
 - (c) Only the necessary part of the PC hardware functions are included, e.g. no Ethernet interface, no floppy drive – Remove all such circuitry from the host controller board
 - (d) Only the necessary part of the PC software functions are included, e.g. trim (also TRIZ tool) down the ordinary operating system (OS) for PC to a smaller and application specific OS.
- (3) #5 Merging
 - (e) Bring closer together the PC operations in space – e.g. the video driver, decoders and network interface all within the same host board.
 - (f) Bring closer some of the records on system side to user side, e.g. user records on the proprietary content stored on the Multimedia Player instead of on the system side – a separate and protected record data record area reside on the multimedia player for system operation only.
- (4) #1 Segmentation
 - (g) Separate the multimedia content from within the hardware to external to the hardware and become a separate object – Store the content in an optical disc. Access it only when needed.
 - (h) Separate the decryption engine from the engine of reading normal DVD or VCD to another program module – It is conditionally activated after confirming that the content within the optical disk is of the proprietary format.
- (5) #15 Dynamicity

- (i) Replace flexible mechanical casing design for general upgrade to inflexible compact mechanical design – Remove all the designs that allow user to open the case for any repair work.
- (j) Remove all expansion slots for product upgrade – Remove the circuitry for the all expansion slots not needed.
- (6) #17 Another Dimension
 - (k) Go from single layer to multi-layer for circuitry and components – e.g. design with the use of multilayer PCB for circuit routing and have components to be mounted on the top and bottom layer of the PCB.
 - (l) Go from single storey to multi-storey on the subsystems – e.g. stack up the host board, DVD mega and the memory assembly (three layers).

VI.8 Anticipatory Failure Analysis and Trimming

AFD serves to predict the potential failure mode and their results within the system, and then conduct improvement evaluation when the system is still on the paper design stage OR during prototype stage only. It is based on AFD that the paper design or prototype can then be improved or re-designed in order to remove any potential failure modes which may occur within the system while it is still at design or prototype stage. Hence AFD is aimed to anticipate system failure before the system is put to real live deployment application.

- (1) Problem Statement: What are the ways to produce failure in the multimedia player?
- (2) Potential failure modes (Methods to produce failure):
 - (a) System Failure
 - (i) User cannot send ID to remote control server for the authentication due to modem failure.
 - (ii) Master controller for web serving services malfunctions.
 - (iii) Breakdown on the video stream from optical storage media (DVD, VCD or CD) to the MPEG decoder circuitry through the DVD loader.
 - (iv) MPEG decoder circuitry malfunction
 - (b) Inadequate function
 - (i) Dial-up modem interface limits the performance of general web serving.
 - (ii) Boot up time from flash memory will be very slow and may also destroy user data.
 - (c) Inadequate performance
 - (i) Single board design allows reduction of PCB cost by an amount of

US\$0.5 but rules out the possibility of standalone hardware platform to integrate with other network interface to form new products, which enhances cost reduction on the electronic components purchased.

- (ii) X86-based microcontroller (486 grade) simplifies hardware design and software programming but slow in speed, especially during bootstrap phase.

(3) Resources for the failure

(a) System failure

- (i) Modem chipset is not reliable and MTBF is short.
- (ii) Master processor is not powerful enough to serve those website that pump continuously refreshed video signal to the player, e.g. game website.
- (iii) DVD loader is noisy, not reliable and MTBF is short.
- (iv) MPEG decoder chipset malfunction or the S/N is too small in a compact environment.

(b) Inadequate function

- (i) Master processor is not capable enough to handle the service requested by the cable modem.
- (ii) Access time of Flash memory is too slow to handle the boot up sequence and subsequent manipulation on the high speed and tremendous data.
- (iii) Thin client miss the resource for possible future service upgrade through common user interface.

(c) Inadequate performance

- (i) Single board design cannot serve the need for product variances to low down the main cost of materials, i.e. processors and other ICs.
- (ii) The next generation x86-based microcontroller rolls out a year from the design deadline and is not 100% compatible with the current design.

(4) Hypothesis on the mechanism for the failure

(a) System failure

- (i) When master processor cannot handle the function properly, it will execute a hardware exception and come to a system halt.
- (ii) Since master processor cannot properly handle the graphics objects, program error arises or graphics objects are displayed as characters improperly.
- (iii) DVD loader generates noise that affects data integrity before and after MPEG decode. In addition, it may become malfunction during service warranty if its MTBF is too short.

- (iv) Too high ambient temperature, mechanical damage or electrical shock.
 - (b) Inadequate function
 - (i) Bandwidth of dial-up modem is too small to cater for the continuously refreshed video data pumping from the server side through the internet.
 - (ii) The boot up time is too long and will also introduce system instability.
 - (c) Inadequate performance
 - (i) When only the network interface is requested to change, need redesign of the schematic and whole PCB layout. It incurs excessive time and additional cost.
 - (ii) Using x86-based microcontroller will degrade the general web-surfing performance.
- (5) Hypothesis verification
- (a) System failure

Simulate the timing diagram for the master processor based on the function needs to perform, which include dial-up modem interface, data extraction from telephone network, data stream transportation for MPEG decode, 2D graphics decode, interface with flash memory for device setup etc. A good practice in estimation of the performance is to reduce the capability of the master processor by 30% and raise the loading of each function by 20%.
 - (b) Inadequate function
 - (i) Inadequate function item (i) cannot be solved with existing resources within the design.
 - (ii) Boot up time for flash memory can be calculated by simulating the timing diagram for the boot up sequence needed for the system. A good practice in estimation of the performance is to reduce the capability of the master processor by 30% and reduce the access time (Read and Write) for flash memory by 20%.
 - (c) Inadequate performance
 - (i) Estimate the cost difference based on 1000 sets of the boards.
 - (ii) Closely follow up with the supplier of X86 microcontroller for the new and more powerful microcontroller.
- (6) Corrections on failures
- (a) System failure

Replace the master processor with Pentium 2 core based micro-controller with built-in 2D graphics engine (e.g. P2 microcontroller from SGS Thomson). Estimated price will be U\$10 higher than the current design but the processor capability will be at least double. Such microcontroller is of Ethernet interface.

- (b) Inadequate function
 - (i) Stress on the application specific purpose of the multimedia player.
 - (ii) Use One-time-PROM (OTP) to replace flash memory for system software. Flash memory is used for user data only.
 - (iii) For additional user interface, add USB port for future hardware connection by end user.
- (c) Inadequate performance
 - (i) Use Separation Principle, Separation of Space, to separate the single board design into two, the backend (main board) and the front end (network interface) with Ethernet as the standard interface between them.
 - (ii) Replace by P2-grade microcontroller.

(7) Result Evaluation

The modified design is of the following features:

- (a) Master processor changes from 486-based X86 core to P2 core (200MHz).
- (b) Add the 3D graphic engine (to handle all common graphics objects)
- (c) Add interfaces (USB and IDE) for future hardware (e.g. printer and micro-drive) attachment.
- (d) Separate the design to backend and front end in such a way that by changing the network interface front end (e.g. cable modem, ADSL modem etc), the thin client can immediately serve other applications (versatile design). This can lower the component cost of the backend significantly.

VI.9 New Knowledge Acquisition – Enrich the Knowledge Base

At the end of the project, it is necessary to update the knowledge base learnt or obtained. Despite the fact that some of the Inventive Principles and/or recommendations are not actually applied in the final design, it is valuable to record down them so that it may be used or referred in the future through a feasible searching process from the knowledge base. It is worth to mark down the knowledge that has been tested and untested to distinguish the “depth on knowledge acquired”.

- (1) Various encryption and decryption engines
 - (a) Lossless Compression / Encryption Techniques
 - (i) Run Length Encoding (RLE)
 - (ii) Lemple-Ziv-Welch Encoding (LZW)
 - (iii) Huffman Coding
 - (b) Lossy Compression / Encryption Technique
 - (i) Scalar Quantization
 - (ii) Rate Distortion
 - (iii) Transform Image Coding Scheme

- Rectangular Wave Transform
 - Eigenvector-based Transform
 - Wavelet Transform
- (2) Communication Protocol Design
 - (a) Triple Data Encryption Scheme (Triple DES)
 - (b) GOST Scheme
 - (c) Message Digest 5 (MD5)
 - (3) Cryptography for authentication process
 - (a) Cipher System
 - (b) Data Encryption System (DES)
 - (c) Public Key Crypto System
 - (d) The Rivest-Shamir-Adelman (RSA) Scheme
 - (e) Stream Encryption System

VI.10 Design Project Conclusion

This project presents TRIZ application in electronics system design. The system is completely new to the Company. Despite the fact that only some of the TRIZ tools are employed. It is easily found that the system is a directly follow up of the customer requirements. TRIZ SFM is good for system modeling while upon reaching the product specification, Contradiction Principles and 40 Inventive Design Principles will become much useful to have the design become focus on to the application. Finally, the AFD and Trimming techniques are used to debug and modify the design to the real prototype which is very much close to the real product.

VII TRIZ Localization

It is out of question to suspect the effectiveness of TRIZ towards problem solving. However, some people find that TRIZ is difficult to use because there are no mathematical rules to guide the innovation process. This is true at user level. One of the reasons is that creativity and innovation are abstract human behavior. At user level, this is meaningless to present innovation by empirical formulae because if this confinement is added, designers cannot solve problem innovatively anymore. However, the philosophy aspect behind TRIZ can be presented by abstract mathematics, including set theory and topology etc.

On the other hand, there are specific characteristics within China that can affect the efficient implementation and application of TRIZ, e.g. learning habit, working style, environmental and situational differences, resources availability, cultural difference etc. Together with the fact that TRIZ is human behavior related, therefore, similar to Japan, TRIZ localization in China will be inevitable in the future.

VII Conclusion

TRIZ is a very effective and systematic methodology to train up people to use their inherent innovative capability to solve design problem. Chinese is characterized by their strong learning and adapting ability. Moreover, China has been the well known manufacturing bases of the world in the past decade. Nowadays, many manufacturers are seeking ways and opportunities to transform from OEM business model to ODM. The transformation requires breakthrough in design capability in multiple aspects from basic product design, manufacturing design and testing design to more sophisticated operation model design, marketing model design and financial model design etc. TRIZ is proved to be successful in many multinational corporations all over the world. With the specialized LEADS model described here for the first time, TRIZ can be deeply interwoven with the economic activities of China within years.

Acknowledgments

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Editor's Notes

1. *SIT was developed in Israel in the 1980's. USIT was developed by Ed Sickafus in the US <http://www.ntelleck.com>, and has been adapted for use in Japan by Toru Nakagawa (see his paper in this issue of the TRIZ Journal.) However, there are many companies in Japan using TRIZ, not USIT. See the November 2003 issue of the TRIZ Journal, for example, for a report on the 4th Invention Machine Users Group conference, and see the numerous papers from the Sanno Institute and from authors working at Hitachi, Fujitsu, etc.*

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3) CREAX, website information.

4) Domb, E., '40 Inventive Principles With Examples', TRIZ Journal, July 1997.

5) "17 Secrets of an Inventive Mind: HOW TO CONCEIVE WORLD CLASS PRODUCTS RAPIDLY USING TRIZ AND OTHER LEADING EDGE CREATIVE TOOLS", TRIZ Journal, Nov. 1996, by James Kowalick, Ph.D., P.E.\

6) "Beyond TRIZ Limits", TRIZ Journal, March 1998, Denis Cavallucci and Philippe Lutz

End...

The Integration and Strategic Use of TRIZ with the CPS (Creative Problem Solving) Process

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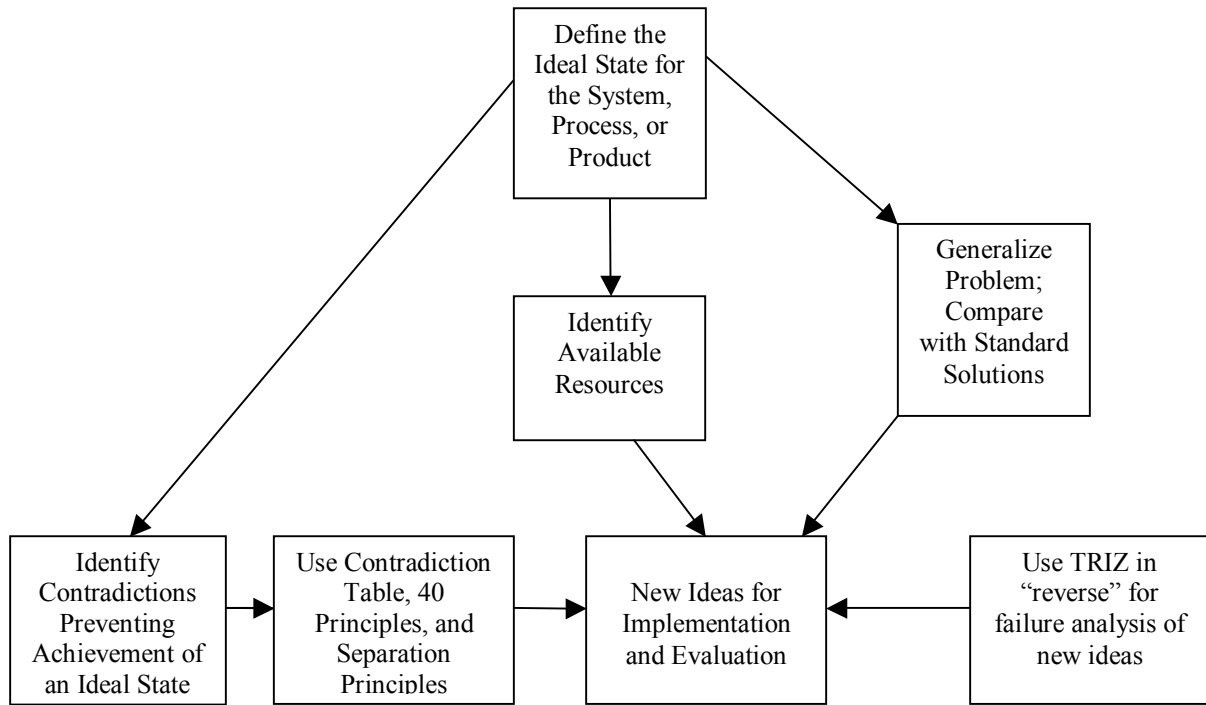
www.innovation-triz.com

When the TRIZ Inventive Problem Solving process and its tool kit are introduced into an organization, they invariably encounter a host of processes and tools already in place. While it has been relatively easy to integrate TRIZ with other enterprise tools such as Six Sigma (which have no inherent problem solving capability), it has been more difficult to co-ordinate TRIZ thinking with other psychologically based creativity and assessment tools. Users and trainers for these various tools tend to be very protective about each process and do not spend sufficient time thinking about ways to integrate or understand the value of all tools. In previous papers and presentations⁷, this author has reviewed the integration of TRIZ with DeBono's Six Hats™ and Lateral Thinking™ processes at previous TRIZ conferences (ETRIA, 2001) and in the TRIZ Journal (2/ 2002). This paper will review suggested ways to effectively integrate TRIZ innovation and problem solving principles specifically with the Osbourne-Parnes Creative Problem Solving process, frequently known as CPS.

Prior to the structuring of TRIZ by Altshuller and his associates, all of the improved creativity and inventive processes were based on psychological stimulation—changing the thinking patterns and attitudes already existing within the problem solving group in an attempt to generate ideas that were not seen earlier by these same individuals. These techniques bring no additional knowledge into the innovation session, but attempt to stimulate the knowledge already present within the problem-solving group.

It is assumed that readers of this article know the basics of TRIZ, but suffice it to say that TRIZ is a structured (“left brained”) approach to inventiveness and problem solving whose basis is that most problems we encounter have already been solved in a generic sense. There are a limited number of inventive solution principles and thus the focus of TRIZ problem solving is to model a problem in a basic, fundamental way and then to use the previously described principles (which apply to all inventive solutions) to solve it. An outline of one view of the basic TRIZ (not the more in-depth ARIZ algorithm) process is shown in Figure 1. As with TRIZ, there are different opinions and choices about the sequence and choice of how the various tools in the tool kit are used.

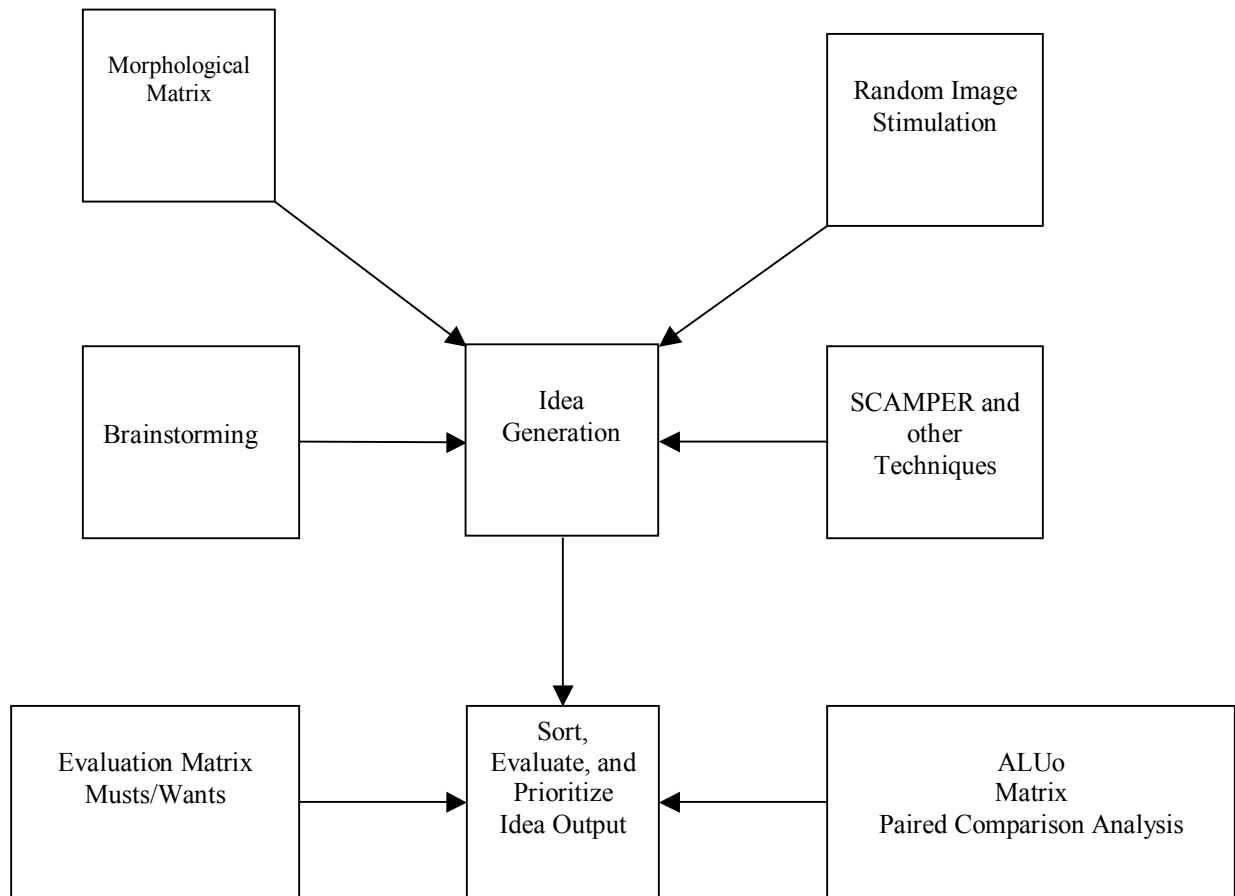
Figure 1
A View of the Basic TRIZ Process



Creative Problem Solving (CPS)

Creative Problem Solving (CPS), first developed in the 1950's by Alex Osborne, was an attempt to improve the simple process of brainstorming. An overview of one practiced version of this process is shown in Figure 2.

Figure 2
The Basic CPS Process



Summaries of the process and the various tools in its tool kit are available⁶. The major improvement made by CPS compared to the general “brainstorming” process, was to separate the idea generation phase of the process from the idea evaluation process in order to maximize the number of ideas generated and not allow idea criticism in parallel with idea generation to overly restrict the final output of a creativity session. The number of ideas generated in a CPS session is a primary measurement of success used by many CPS facilitators. The assumption here is that the more ideas generated, the more likely it is to generate the “best” ideas for further pursuit. The separation between idea generation (the divergent phase) and idea combination, critique, and evaluation (the convergent phase) allows the generation of ideas without fear of criticism or preliminary evaluation from other participants. This process, over time, has also developed a number of idea generation tools to improve the quality of the ideas produced during the divergent phase⁶. One of the fundamental differences between CPS and TRIZ is that TRIZ does not insist on a linkage between the need to generate a large quantity of ideas to generate the “optimum” solution. TRIZ has the capability to produce an optimum solution without the need to generate and analyze a large magnitude of original ideas.

Looking at more detail of the various aspects of the CPS process:

Idea generation and divergent phase--- using brainstorming (assisted by many supporting resources such as image stimulation). Another CPS tool is the use of the SCAMPER idea generation (Substitute, Combine, Adapt, Modify, Eliminate, Put to other Uses, Reverse) tool, used as a specific idea stimulation tool. For example, how could we substitute for this part or function? A morphological matrix, where a few basic properties of a system or product are varied deliberately, can also be used to stimulate ideas. An example of a morphological matrix is shown in Figure 3. Each major attribute of the system under consideration and the group lists possible parameters or characteristics of each parameter. Randomly combining each of the entries of the matrix can generate a large number of ideas.

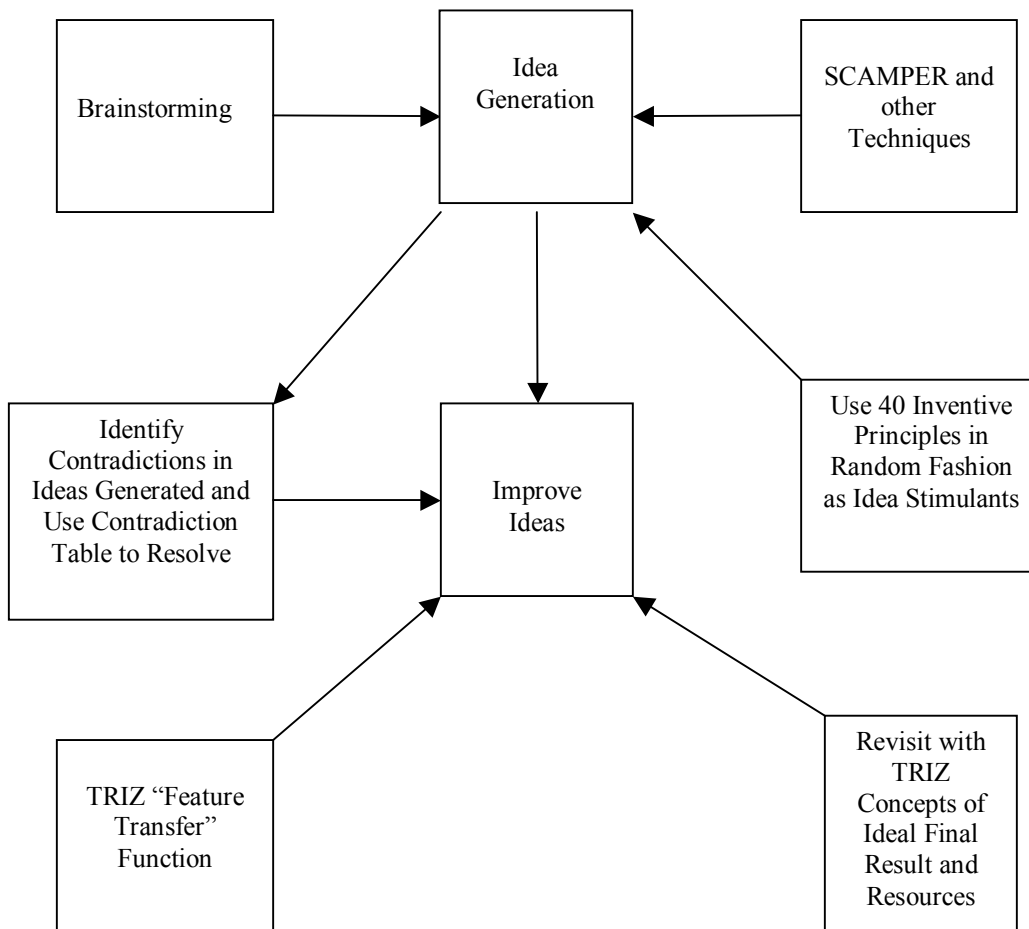
Idea analysis and convergent phase--- Once a list of ideas has been generated by the divergent phase of the CPS process, these ideas are narrowed and focused by a number of different tools

- Focus and evaluation--- use of an evaluation matrix, comparison against criteria, prioritization against absolute needs, etc.
- Idea analysis using ALUo—this focusing tool asks the participants to analyze each idea in terms of its Advantages, Limitations, Unique qualities, and overcome limitations to assist in idea optimization, prioritization, and selection.
- Idea Evaluation Matrix—this tool lists the ideas selected for final evaluation against evaluation criteria established by the problem solving group or its organization. In a table, the ideas are listed vertically and the criteria listed horizontally. At each intersection, a rating or relative ranking is made, assisting in the final decision making of the group.

Using Creative Problem Solving (CPS) as an Umbrella for the Use of TRIZ

CPS can be used as an “umbrella” under which to incorporate many of the simple TRIZ problem analysis and problem solving tools, if desired. (Figure 3).

Figure 3
A CPS UMBRELLA FOR TRIZ



The details of this overall diagram and structure will now be discussed.

TRIZ and CPS professionals both respect separation of the idea generation from the idea evaluation phase of an innovation process. In fact, TRIZ consultants frequently make a point of noting individual statements said during a problem solving session, such as “that won’t work because...”, to illustrate and take note of a contradiction for later consideration. TRIZ adds more emphasis on the problem definition aspect. In the idea generation phase of CPS, the emphasis is on quantity of ideas on the assumption that the ratio of ideas generated to potentially valuable ideas is a constant. TRIZ argues that a well defined problem eliminates the need for a high ratio of ideas generated to useful ideas, but if this is the desired goal, this is how TRIZ principles can be used to improve the CPS process, assuming that it is the overriding general process to be used.

TRIZ Tools for the CPS Idea Generation Phase

A simple way to introduce part of the TRIZ tool kit into CPS is simply to use the original 40 principles randomly or each of the 40 principles on a Post-It™ note and distribute them among the group and ask for ideas via that stimulus as part of a brain writing exercise.

The SCAMPER idea generation tool mentioned previously has some strong overlaps with parts of the TRIZ tool kit. For example, asking the “E” question “eliminate? I.e. can we leave it out? Have fewer parts? Make it lighter, shorter, etc. are all examples of questions that would be asked by a TRIZ facilitator while focusing on the question of “resources” (which from a TRIZ perspective is a much larger list). Similarly, the SCAMPER “A” question relating to “Adapting” (What could I copy? Does the past offer a parallel?) would allow a knowledgeable TRIZ participant to suggest a more formal review of parallel industries that might have similar problems. The “R” question is a restatement of one of the basic TRIZ principles, “do it in reverse”.

TRIZ Tools for the CPS Convergent Phase

The ALUo analysis, previously described, will generate a list of limitations to which the TRIZ contradiction table, 40 principles, and separation principles can all be applied, as opposed to simply brainstorming solutions to the problems identified. The CPS evaluation matrix is an excellent tool for graphically displaying contradictions. The TRIZ tools used for contradiction resolution, 40 Principles and separation principles can be used to analyze and attack these contradictions. Paired comparison analysis is similar to a TRIZ technique (not mentioned previously) called “feature transfer” where we ask what good features of a known good idea (or one good aspect of an overall poor idea) can be transferred to another idea to make an overall better idea. The CPS process of identifying why a particular idea does not meet the criteria, can be supplemented with TRIZ problem solving tools to improve the suggested ideas.

Figure 4
Idea Generation Morphological Matrix⁶

Overall Product Framework or Challenge

Parameter 1	Parameter 2	Parameter 3	Parameter 4	Parameter 5
Value A	Value A			
Value B	Etc.			
Value C				
Value D				
Value E				
Value F				

Concept: Each value is combined with all other values to generate an idea

In summary, when TRIZ is entering an organization already using the Creative Problem Solving process, it can take its first steps toward adoption by using the CPS framework as an umbrella to introduce a number of the unique TRIZ problem analysis and problem solving tools. As its tools become better known and their credibility established, curiosity about the entire TRIZ process will generate interest in the entire TRIZ algorithm and tool kit.

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40 principles as a problem finder

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1. Introduction

For a problem solving, TRIZ is the very useful tool. It began from 1946 by G.S. Altshuller in Russia. In early stage, it used for technical problems, but expand the using areas to economy, politics, software etc.

It is not rare that one tool is using for many areas. Brain Storming by Alex Osborne and Mind Map by Tony Buzan are using in many areas from education to technical problems. How they are able to use for many areas? It's up to simplicity of that method. They are very simple and easy to learn. So many people easily used it for their problems. But if method is becoming complex, it is hard to apply to other areas. For example, FEA(finite element analysis) can't apply to political or social problems because it designed for specialized complex engineering problems.

Most people already know that TRIZ is not easy and simple methodology. Even though how TRIZ can apply to such a many areas? That's why TRIZ knows the primary source of problems. Thousands of problem solving methods are already made. But only three methods are reaching at the real origin of problems. 'The Art of War'¹⁾ by Sontsu, 'Right 8 way'²⁾ by Holly Budda and 'TRIZ'. 'The Art of War' is used for war problems, but nowadays it used for marketing, politics, business etc. 'Right 8 way' is used for religion, but it is using for medical, psychological problems in Korea. They are different to TRIZ because they have different process and method. But they are similar to TRIZ because they are reaching at the real origin of the problems.

TRIZ is just the problem solving method? During study of TRIZ I realize more than that. Most people use TRIZ for problem solving. But if we use TRIZ in other way, not only for problem solving but for problem finding though it doesn't happen.

2. Level of problem solving

Is problem solving the best strategy? The strategies of problem solving are classified into 4 types. 'Elimination', 'Transfer', 'Solving' and 'Evasion'.³⁾ 'Elimination' means deletion of problem itself, so we don't need to solve it. 'Transfer' means changing the problem from hard to easy or from given to remake. Sometimes solve the remaking problems are more efficient than solve the given problems. 'Solving' means to solve the given problems. 'Evasion' means run away from given problems. 'Let it be' is the keyword of this strategy. There are no royal rules that which strategy is always right. All of these strategies depend on problem types and situation.

But one thing is clear, if we find the problem in advance we can prevent or delete the problems.

In ancient China, there was a famous doctor. His name is 'Hwata'. Legend is still that he cured all of patients except one who never believe him. He got two brothers. They were also doctor. His first brother cures semi-illness. What is semi-illness? That is early warning system of human body for health. Do you think that people get a cold suddenly? It never happens. There may be a lot of early warnings before cold. Such as little headache, feel tired, a slight fever and so on. If you feel like that, you must get a rest, sufficient meal, and deep sleep. Doing that your body returns to healthy state from semi-illness. But if you ignore these informs you going to be real-illness from semi-illness. His first brother cures these kinds of patients. So his name was not famous because most people thought they never got a disease. Why semi-illness comes to people? They are up to behavior of peoples. Greed, Overeat, heavy drink, over sex, insufficient sleep, constipation, diarrhea make people weak. So if you prevent doing these things you never get disease. This calls potential-illness. His second brother cures potential-illness of peoples. Therefore in his village, no patients were there. And peoples never thought he is a doctor. It is not important that story is real or fiction. It defines what is the problem solving. Hwata solved problem, his first brother prevent the problem, second brother delete the root cause of problem. Who is real great doctor? I prefer his second brother.

Problem solving is important. But prevention is more. And elimination is most. Because problem happened once, we have to spend lot of times and materials to solve it.

The problem fining can be possible in advance? If can, what kind of work is defined as a problem? Answer is 40 inventive principles.⁴⁾

3. 40 Inventive principles and problem finding rules

40 Inventive principles are using for solving a technical contradiction as initial stage of the TRIZ. And it still using for many technical problem solving. There are 40 kinds of principles for problem solving. For example, inventive principle 1 'Segmentation' divides the present

situation for problem solving. And Inventive principle 4 'Asymmetry' breaks the balance of the present situation for problem solving.

If we change the viewpoint of these principles, we are able to get the rules of problems finding. Inventive principle 1 'Segmentation' solves the problems by divide. Therefore if something is not divided, that means that is problem. For example, you have one million dollars in cash. It's not safe that money holding in your room. So you deposit all of that in one Bank. Is that a problem or not? It is problem by inventive principle 1. What happened on bankruptcy? You never get nickels from that Bank. So most of rich peoples divide their wealth such as financial budget(ex. Bond, Stock), gold, real estate. Is that a problem or not if you have one job? It is also a problem. If you fired or your company is bankrupted how can you get the money?



Figure 1. Glass bottles



Figure 2. PET bottles

Let we think about inventive principle 15 'Dynamics'. It solves the problem to give them a flexible property. If it is like that, no flexible thing means problem. Look at figure 1. They are glass bottles. Are they problems or not? As you know, Glass bottles are hard and fragile. If you drop one, it breaks into pieces. Look at figure 2. PET bottles are very flexible. Even falling on rocks, it never brakes. So glass bottle is defined as a problem by inventive principle 15

Let we think about inventive principle 29 'Pneumatics and hydraulics'. Figure 3 is normal furnace. It made by steel outside, and refractory bricks inside. The inside temperature of furnace is very high, sometimes higher than 1,200 °C. No steel can resist on that high temperature. So engineer uses refractory bricks inside made by clay or ceramics. Even using refractory bricks, corrosion and contamination of bricks are happened by high temperature. So they have to change it regularly. If we increase the temperature of furnace, it comes to more thermal efficient. But even refractory bricks, it can't resist more than 1,500 °C. Figure 4 is a newly developed furnace. As you can see, the temperature of furnace is reach at 2,000°C. And there are no bricks

inside. Instead, it uses incoming air as a thermal insulation bricks. Incoming airs are changed into tornado on the side of furnace. It prevents the overheating of furnace wall. And heated incoming airs are increasing the combustion temperatures of furnace. And level of the NOx is lower than 20ppm. It is the same level as low temperature furnace. So new furnace satisfied the rules of inventive principle 29.



Figure 3. Normal Furnace

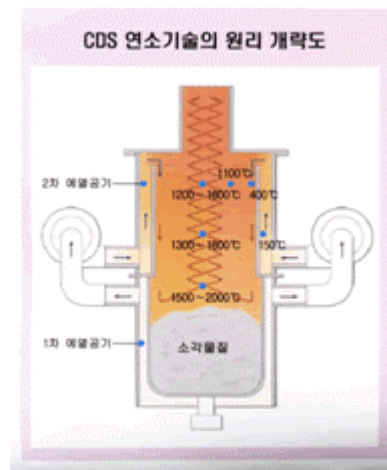


Figure 4. New concept furnace

Like this way we can get the problem finding rules by using the 40 inventive principles. All of rules are summarized in Table 1. Some principles are overlaped, so there are 15 rules for problem finding not 40.

Inventive principle 1. ‘Segmentation’, 2. ‘Taking out’, and 3. ‘Local quality’ are divide the problem for solving. That means undivided things are problem.

Inventive principle 5. ‘Merging’ and 6. ‘Universality’ are concentrate the problem for solving. That means segmented things are problem.

Inventive principle 7. ‘Nested doll’, 17. ‘Another dimension’, 9. ‘Preliminary anti-action’, 10. ‘Preliminary action’ 11. ‘Beforehand cushioning’ are find the resources(ex. Time, Space, Field) for problem solving. . That means lack of resource is the problem.

The inventive principle 40 is reducing the weight and increasing the strength by using composite materials. So heavy, weak strength are defined as a problem.

Like this way, low efficiency, strict or static, insufficient feedback, insufficient control, insufficient measurement, difference, insufficient strength, harmful, hard to direct handling, different condition, balance and unbalance are rules for problem find.

40 Principles	Method for problem solving	Rule for problem find
1,2,3	Dividing	Undivided
5,6	Undivided	Dividing
7,17,9,10,11	Find Resource	Lack of resource
16,21,27,34,18,27,28, 29,34,35,36,37,38,39	Increase efficiency	Low efficiency
15,29,30,31	Dynamic or flexible	Strict or static
23	Increase feed back	Insufficient feedback
23,25	Increase control	Insufficient control
26,32	Increase measurement	Insufficient measurement
33	Homogeneity	Difference
14,15,29,30,31,40	Increase strength	Insufficient strength
21,22	Remove harmful	Harmful
24,26	Indirect handling	Direct handling
12,13,19,20	Change condition	Different condition
4,8	Asymmetry, Symmetry	Balance, Unbalance
1,8,25,28,29,30,31,40	Decrease weight	Heavy weight

Table 1. 40 principle and rule for problem finding

Low efficiency means present efficiency is low than 100%. If you have a gas cooker please check the label of that. Maybe thermal efficiency of gas cooker is lower than 50%. So we can define that is the problem.

Strict or static means something is strict or static. Remember the glass bottle.

Insufficient feedback means lack of feedback. Compare the cannon ball and missile. Compare the success company and failed company.

Insufficient control means lack of control. Imagine the no steering wheel car.

Insufficient measurement means lack of measuring. Think that you are walking in the dark without lamp. If you can't measure, you can't feedback and control. So that calls problem too.

Difference means different between things. What is the reason for the race problem and War of Religion.

Insufficient strength means weakness. Please search the web what's happening in Tacoma bridge, Mihama nuclear plant, DH Commet the first commercial jet plane. Many problems occurred by weakness.

Harmful doesn't need explain. Environmental pollution, noise, waste, disease, crime are

harmful problems.

Hard to direct handling means you want to do directly but can't. Imagine that you are holding the hot kettle without tools.

Different condition is error of problem choosing. You got the right answer of wrong problem.

Balance and unbalance means current status is balanced or unbalanced. Sometimes balanced thing make problem, but in any situation unbalanced thing make problem too.

If you use 40 principles like this way, you can find the many problems in advance. It makes you more powerful in problem solving.

4. Conclusion

TRIZ is most developed and rational method for problem solving. TRIZ will evolve continuously. And the way of evolving is not only for problem solving but also for problem finding. If we find the problems before a thing takes place, we can prevent or delete it. Therefore we can save lot of money and time for problem solving.

So we have to developing the TRIZ theory for problem finding not just problem solving. 40 inventive principles can apply to finding because it deals the source of problem. And the other method of TRIZ, such as Effects, 76 Standards, System Operator, also can apply to the problem finding. So we have to study more the TRIZ for problem finding.

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USIT OPERATORS FOR SOLUTION GENERATION IN TRIZ: CLEARER GUIDE TO SOLUTION PATHS

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Abstract

The biggest reason for slow penetration of TRIZ into industries in Western countries is that very rich contents of TRIZ knowledge bases and individual methods of problem solving have been tried to teach without clear overall procedure/structure for problem solving. It has been traditional that principal solution generation methods in TRIZ, including Inventive Principles, Inventive Standards, and Trends of Evolution, are applied separately on the basis of their own problem analysis methods. Present paper demonstrates, on the other hand, that Unified Structured Inventive Thinking (USIT) is a simplified and unified version of TRIZ which has overcome the above-mentioned weak-point. All the solution generation methods in TRIZ have been reorganized into a unified hierarchical system of USIT Solution Generation Operators. On this basis, USIT has a clear procedure for creative problem solving process as shown in a flowchart and also has a clear structure, as shown in a dataflow diagram, of transforming problem information stepwise into solution information. User's specific but vague problem is (1) first converted into a 'well defined problem' at the problem definition phase, then (2) further converted into the understanding of the problem system in terms of objects, attributes, functions, space, time, ideal actions, and ideal properties at the problem analysis phase, (3) modified by applying the USIT Operators into pieces of ideas of a new system in the solution generation phase, (4) constructed into conceptual solutions on the basis of user's technological background capabilities, and (5) finally implemented into user's specific solution(s) in the implementation phase. USIT guides at the steps (1) through (4). USIT has been taught fully in 2-day training seminars at the level of solving real industrial problems by the participants themselves.

Keywords: Solution generation, models, USIT, analogy, problem solving, TRIZ.

1. Introduction

Theory of Inventive Problem Solving (TRIZ) [1, 7, 9, 2] is a powerful methodology for creatively solving problems in a wide range of technological (and many other non-technological) fields. It has established knowledge bases (KBs) of technological facts with various useful indexing systems and of principles for inventive thinking and has also developed a large number of methods for problem definition, problem analysis, and solution generation. These KBs have been constructed by extracting world best solutions in science and technology, and the problem solving principles in TRIZ are at a high level of abstraction so as to be applicable to a wide range of problems.

In spite of expectations by TRIZ experts, however, TRIZ has not been spreading so widely and rapidly in the Western countries since its exposure in early 1990s. The present author [3] observes,

as many would agree, that the penetration of TRIZ has been slow not because it is poor but because it is so rich in contents. 'How to choose an effective principle' and 'how to apply a principle properly to the user's specific problem' have been the issues for TRIZ users. Most TRIZ specialists have tried to teach the rich contents of TRIZ KBs and thinking methods in more or less orthodox forms, but most engineers in industries and engineering students cannot understand them up to the level being able to apply them to their real problems. Some specialists may say 'It is a problem of the students and the training period', but the position of the present author in this paper is 'It is a problem of the teachers and the system of TRIZ itself.'

Basic model and overall structure of TRIZ should be reviewed and discussed in this context. It is generally understood that TRIZ is based on the four-box scheme of problem solving [2] shown in Fig. 1. Instead of trying to solve user's specific problem directly to specific solutions staying at the concrete level, TRIZ advises to go around at a higher abstraction level using standard models which show generalized problems and their generalized solutions. TRIZ has adopted this scheme from the sound basis of science and technology.

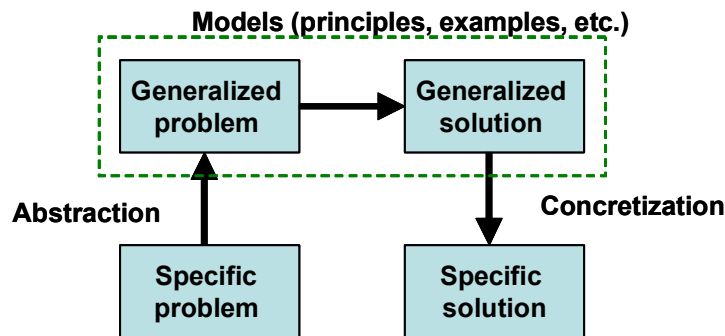


Fig. 1 Four-box scheme of problem solving

All the TRIZ KBs (such as Effect database, Inventive Principles, Inventive Standards, Trends of Evolution, etc.) have been built with the intention to let them serve as different models at the abstract level in this scheme.

Once models are established, the process of problem solving may be reduced to the following issues:

- Abstraction: How can we transfer the specific problem to the generalized problem in some known model? Do we need different abstraction methods for different models?
- Selection: Which model should we use among a number of models?
- Concretization: How can we transfer the generalized solution suggested by the model to a specific solution to our problem?

Generally speaking, these issues are not well understood unfortunately in many fields of science and technology. In each topic of a specialty field, one model is chosen and taught with a few examples. Then the students have to learn, study, drill and practice many times to understand by themselves that the model is useful for some kind of problems after some kind of abstraction.

TRIZ has developed a number of procedural methods of problem solving in technology, for the purpose of guiding us in the abstraction and selection (and little in the concretization) processes. These methods in TRIZ (such as 9-Window Method, Substance-Field Analysis, Technical and Physical Contradictions, etc.) are often very unique and powerful in the areas where no other effective methods and ways of thinking exist. Nevertheless, the overall procedure of problem solving in TRIZ has not been well established yet and is in a confusing situation for users.

In the present paper, the current situation of the TRIZ methodology is summarized briefly in this four-box scheme. Then I will demonstrate that Unified Structured Inventive Thinking (USIT) [8], i.e.

a simplified and unified version of TRIZ, has established a clear structure of problem solving procedure by extending the four-box scheme into more meaningful six-box scheme. The key to this structure is the USIT Solution Generation Operators, which have been obtained earlier by reorganizing all the TRIZ principles and methods for solution generation [4, 5].

2. Current Scheme of Problem Solving in TRIZ

The current situation of the overall scheme of problem solving in TRIZ may be roughly summarized as shown in Figure 2 in the framework of Figure 1. TRIZ KBs are shown in a box at the top and various TRIZ methods are shown in ovals according to the phases in problem solving. These components are established well [1, 7, 9, 2] and are summarized in the following subsections first and the overall structure will be discussed next.

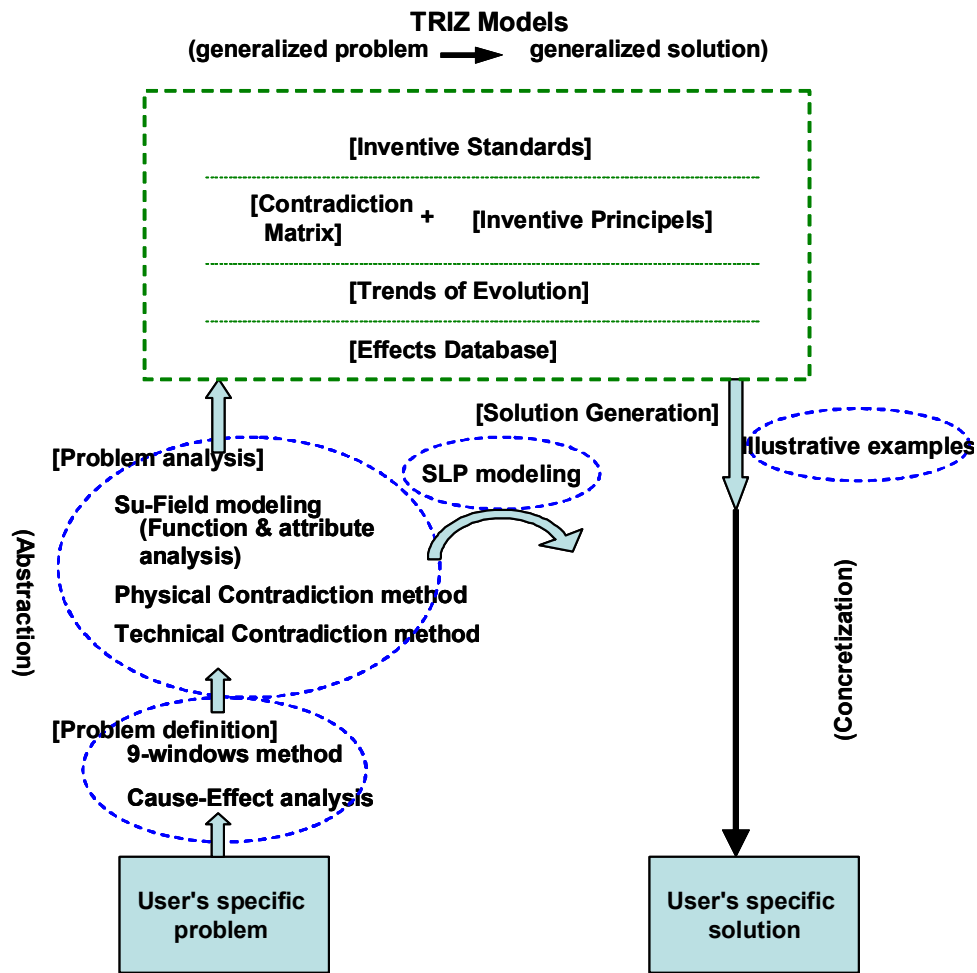


Figure 2. Overall Structure of Problem Solving in Traditional TRIZ

2.1 TRIZ Knowledge Bases of Principles and Facts

First type of KBs in TRIZ is the accumulation of facts and technical means, especially:

- Effects Database: facts database of physical, chemical, and mathematical effects and technical means

This type of KB is useful to learn various facts and means known in different fields of science and technology and to apply them to our own fields in novel ways. Reorganizing the KB in the explicit hierarchical system of functions has been a major contribution of TRIZ.

Second type of KBs in TRIZ is at a higher level of abstraction of the principles for inventive thinking and has been the most important contribution of TRIZ. They include:

- 40 Inventive Principles: essence of ideas in inventions
- Contradiction Matrix: information of which Inventive Principles have been most frequently used in which type of problem expressed in the Technical Contradictions
- 76 Inventive Standards: standard solutions corresponding to the situations expressed by the Substance-Field model
- Trends of Evolution of Technical Systems: patterns of evolution

These are the major models in TRIZ in the four-box scheme and provide problem solvers with generalized solutions for generalized problems. For each item in these KBs, examples of typical cases of application are accumulated and linked (e.g., to the Effects Database and to patent databases) and used for illustrating and stimulating users' analogical thinking. It should be noted that these KBs are presented to users as parallel alternatives, separated (and more or less overlapped) with one another, as shown with the separating broken lines in Figure 2.

2.2 Individual Methods and Techniques for Problem Solving in TRIZ

In the area of methods and techniques for problem solving in technology, Classical TRIZ has developed a number of unique and effective methods. Major ones are summarized below briefly with particular comments on their relationships to the TRIZ KBs:

- 9-windows method: to think over the problem in the 3 x 3 framework of system hierarchy (i.e., super-system, system, and subsystem) and time (i.e., past, present, and future). This is a general method to be used in the early stages of problem definition and problem analysis. It is loosely related to the usage of the KB of Trends of Evolution.
- Substance-Field modeling: to model the problem system with two substances (i.e., product and tool) and its functional relationship. This serves as the problem analysis procedure (i.e. an abstraction process) for using the KB of Inventive Standards.
- Technical Contradiction method: to model the problem in the scheme of a Technical Contradiction where the problem solver wants to improve one aspect (or parameter) of the system but another aspect of the system gets worse and preventing the improvement. This is a special method in the abstraction process for using the Contradiction Matrix (in the selection process) and then a few selected Inventive Principles.
- Physical Contradiction method: to model the problem in the scheme of a Physical Contradiction where two opposite requests exist simultaneously on one aspect of the system, and then to use the Strategy of Separation of the opposite requests. This strategy guides the solver to several selected Inventive Principles.
- Smart Little People's modeling: to imagine that a part of the system is composed of a crowd of smart little people who can and do perform any desirable action. This method stimulates to think of ideal solutions first and then to figure out solutions in feasible, technical terms. It does not utilize any KBs.

Recent works in TRIZ have added some more methods, including:

- Cause-Effect analysis: to model a network of cause-and-effect relationships in the problem, and to suggest a large number of smaller and more specific problems of preventing some harm or enhancing some good in the original problem. This serves in the problem definition process.

- Function and Attribute analysis: to model the functional relationships in the system (releasing the 'two-substance restriction' in the Substance-Field modeling) with some inclusion of attributes of objects.

2.3 Overall Procedure of Problem Solving in TRIZ

The above description of the components of TRIZ KBs and TRIZ methods and their positions shown in Figure 2 are basically agreed in the community of TRIZ specialists [1, 7, 9, 2]. The overall procedure of problem solving in TRIZ must further specify the recommendation of 'which methods and which KBs should be used in which order in which situation of problem.' This is the issue on which many TRIZ leaders have proposed and applied in many different ways, and is still under a confusing situation as follows:

Altshuller [1] who developed all the individual methods and KBs in Classical TRIZ also developed the overall procedure in the name of ARIZ (Algorithm of Inventive Problem Solving). Intending to make ARIZ more and more powerful for solving ever harder problems, he constructed various versions of ARIZ having complicated procedure of using various individual methods and their corresponding KBs. He recommended to use ARIZ after at least 80 hours of training, and for solving simpler problems he advised to use more standard methods (i.e., some appropriate individual methods).

Yuri Salamatov, in his orthodox TRIZ textbook [7], recommends to try several individual methods listed above and use ARIZ later only when no satisfactory solutions are obtained. Boris Zlotin and Alla Zusman [9] have proposed TRIZ Tool Map and recommended to use different individual tools depending on the type of sub-problems which are suggested by the cause-effect analysis.

Darrell Mann in his recent textbook [2] proposes a four-stage process composed of 'define the problem', 'select the solution tool', 'solve the problem', and 'evaluate the solution' stages. Though his explanation of individual methods is excellent and insightful, his overall process seems to contain two problems: Methods for problem analysis, i.e. the main part of the abstraction process in the four-box scheme, are described separately in the 'problem definition' and the 'problem solving' stages. In the 'tool selection' stage, he shows 19 situations of judging the results of the 'problem definition' stage and recommends for each situation up to four tools to select in the 'problem solution' stage. The selection table is too large and complicated to summarize here.

Thus these overall procedures of problem solving in the traditional TRIZ have in common the following weak points:

- The models of solution generation in TRIZ, especially the three principal models consisted of Inventive Standards, Inventive Principles, and Trends of Evolution, are placed separately and in parallel.
- Corresponding to the separated models for solution generation, the problem analysis phase provides separate methods of analysis, and usually carries out only one for each.
- Because of separated pairs of analysis and solution generation methods, the problem is analyzed only partially for each TRIZ model. This partialness is the origin of insufficiency in the power of the TRIZ procedure, and requires a complicated sequencing of selected methods.

3. Unified Structured Inventive Thinking (USIT) as a Simple and Unified TRIZ

USIT is a simplified and unified version of TRIZ, having reorganized all the TRIZ methods for problem analysis and solution generation, having constructed a clear full procedure for problem solving, and having a clear scheme of problem solving.

3.1 Main features of USIT

USIT was developed by Ed Sickafus [8] at Ford Motor Co. in 1995 by adopting and enhancing Israeli Systematic Inventive Thinking (SIT), which was a much simplified method of TRIZ developed in early 1980s. USIT has the following features:

- USIT provides a unified and simple procedure for the whole process of problem solving in technology. The process is characterized with three phases, i.e., problem definition, problem analysis, and solution generation phases.
- In the problem definition phase, users are requested to well define a problem with statements of an unwanted effect, the target and task stated in one or two lines, a simple sketch of the problem, plausible root causes, and minimal set of relevant objects.
- The system in problem is analyzed with the basic concepts of objects, attributes, and functions. The current system is analyzed in the functional analysis for clarifying the original intention of the system design and also in the attribute analysis for revealing as much factors relevant to the unwanted effect.
- With the Particles method, i.e., a refined version of Altshuller's SLP modeling, ideal solution is imagined first and is broken down to feasible technical solution concepts.
- Time and space characteristics of the problem are examined.
- Only five solution generation methods are used; they are Pluralization of objects, Dimensional change in attributes, Distribution of functions, Transduction, and Generalization of solution concepts.
- USIT procedure guides the group work of problem solving by stimulating people in unconventional views of the problem, for obtaining multiple conceptual solutions to real industrial problems. USIT does not depend on any handbook, knowledgebase, or software tools.

The present author [3-6] introduced USIT into Japan since 1999 and further refined it. The main features of refinement are:

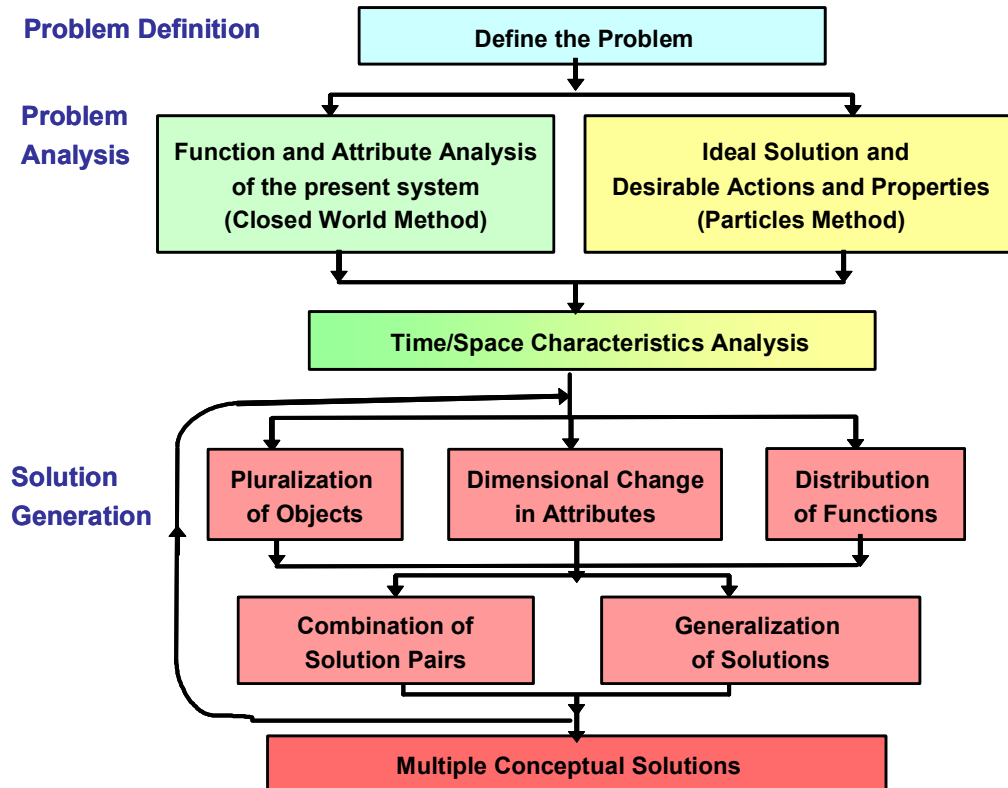
- All the TRIZ solution generation methods, which are mostly represented in the principles in the TRIZ KBs, are shuffled and reorganized into the USIT solution generation methods.
- Thus USIT has a unified and simple hierarchical system of solution generation methods, expressed in the form of operators. The five principal methods for solution generation in USIT are: (1) Pluralization of objects, (2) Dimensional change in attributes, (3) Distribution of functions, (4) Combination of solution pairs, and (5) Generalization of solutions. There are 32 sub-methods in total, which are expressed in the form of operators with simple guidelines.

3.2 Problem Solving Procedure in USIT

The whole procedure in USIT is expressed in the flowchart [3] as shown in Figure 3. Problem solving in USIT is done in three distinguished phases, i.e., problem definition, problem analysis, and solution generation. In the problem analysis phase, we have three principal methods, i.e., (a) the Function and Attribute Analysis of the current system, (b) the Particles Method for considering an ideal solution first, and (c) Space and Time Characteristics Analysis. Using either (a) or (b) depending on the nature of the problem is all right, but using both (a) and (b) for any problem is highly recommended from recent practices. Sequential use of (a), (c), and (b) is the typical current practice. In the solution generation phase, the five USIT operators are applied repeatedly onto possible operands in the system or in the solution space.

The flowchart representation of USIT has been used since the initial days of USIT development. It is quite natural because the group work of problem solving in USIT is actually conducted in sessions following this flowchart. Typically, Session 1 for the problem definition phase, Sessions 2 and 3 for the problem analysis phase using the methods (a)+(c) and (b), respectively, and Sessions 4 and 5 for the solution generation phase.

3.3 Overall Structure of Problem Solving in USIT

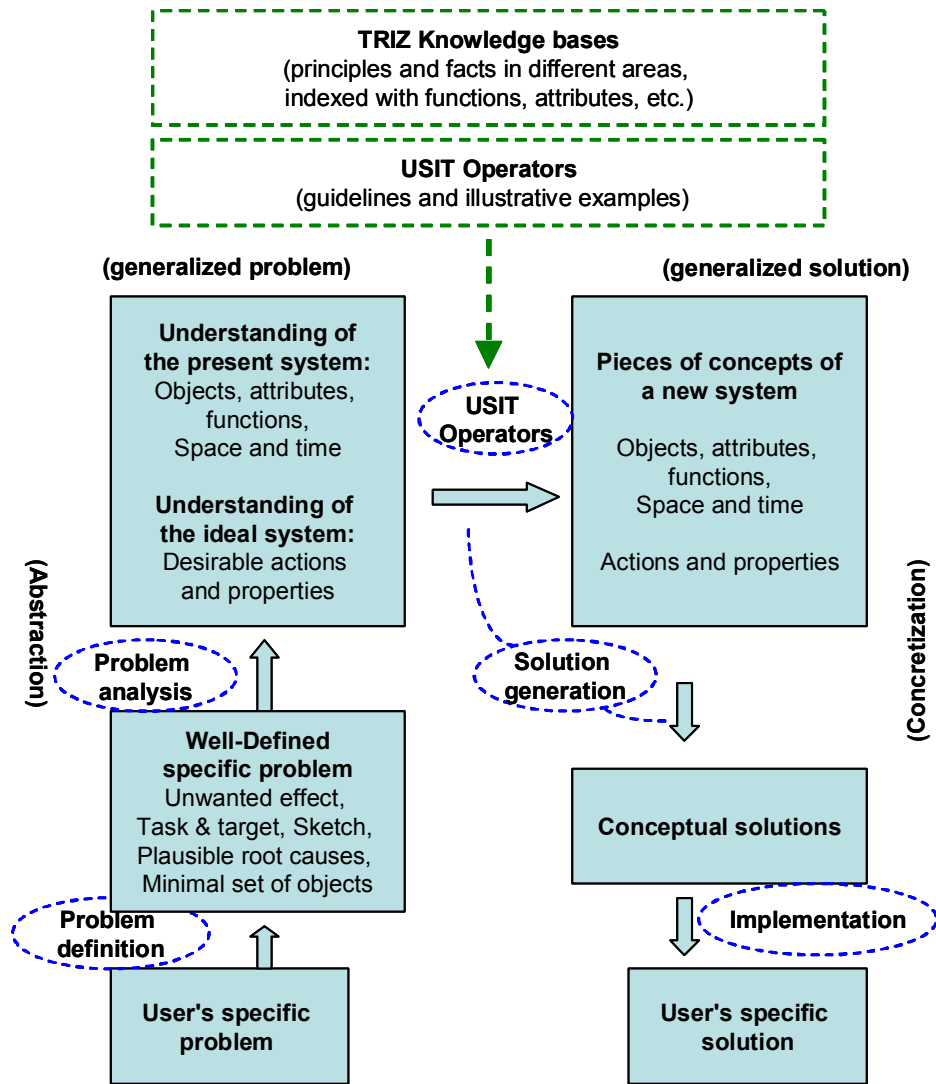


Now let us consider to map the USIT process onto the basic four-box scheme of problem solving shown in Figure 1. It is important to notice that the four boxes represent not the processes (or methods) but the information (or data) and that the arrows represent the processes. Thus we are going to draw, in terms of information science, a 'dataflow diagram' of problem solving in USIT:

This dataflow diagram of the problem solving process in USIT demonstrates (and claims) the following points:

Figure 3. Flowchart of Problem Solving Procedure in USIT

- Abstraction is first performed in the 'problem definition' phase of USIT. A user's specific problem, which is often understood vaguely without a sharp focus by the user him/herself, is converted into a well-defined specific problem having the information stated above.
- Abstraction is further performed in the 'problem analysis' phase of USIT. Understanding of the present system in terms of the basic concepts of objects, attributes, functions, space and time, and also understanding of the ideal system in terms of desirable actions and properties are obtained. The information thus obtained is a generalized problem model (or an abstract problem).
- USIT has the models for problem solving in the forms of 'USIT Operators for Solution Generation'. The guidelines of USIT Operators tell to pick up any possible operands (i.e., objects, attributes, functions, and solutions) in the system/problem and to transform them into modified operands so as to obtain pieces of concepts (or ideas) for a new system.
- Thus, in the solution generation phase of USIT, the USIT solution generation operators convert the operands in the generalized problem model into modified operands which form some parts of concepts in a new system.



- In the solution generation phase of USIT, the pieces of concepts of new system(s) are further built up into conceptual solutions on the basis of background technological capability of problem solvers. This is a part of concretization process.
- The final step of concretization is the implementation of conceptual solutions into user's specific solution(s). This step is usually performed outside the USIT process, by filtering conceptual solutions with technological and business criteria, designing a new system, carrying out experiments, etc.

Figure 4. Dataflow Diagram to Show the Overall Structure of Problem Solving in USIT

Since the USIT Operators form the key process in this scheme of creative problem solving, the nature of them is illustrated and discussed some more detail in the following section.

4. USIT Solution Generation Operators

USIT Solution Generation Operators (total 32 sub-operators)

(1) Pluralization of Objects

- a. Eliminate
- b. Multiply into 2, 3, ..., ∞
- c. Divide into 1/2, 1/3, ..., 1/ ∞
- d. Unify
- e. Introduce or modify
- f. Introduce from the environment.
- g. From solid to powder/liquid/gas

(2) Dimensional Change in Attributes

- a. Deactivate a harmful attribute
- b. Activate a useful attribute
- c. Enhance a useful or suppress a harmful attribute
- d. Introduce a spatial attribute or vary in space
- e. Introduce a temporal attribute or vary in time
- f. Change the phase or the inner-structure
- g. Attributes at the micro level
- h. Properties of the system as a whole

(3) Distribution of Functions

- a. Reassign to a different Object
- b. Divide the compound Functions and assign them separately
- c. Unify multiple Functions
- d. Introduce a new Function
- e. Vary the Function in space, use space-related Functions.
- f. Vary the Function in time.
- g. Detection/measurement Function.
- h. Enhance adapting/coordination/control
- i. With a different physical principle

(4) Combination of Solution Pairs

- a. Combine functionally
- b. Combine spatially
- c. Combine temporally
- d. Combine structurally
- e. Combine at the principle level.
- f. Combine at the super-system level

(5) Generalization of Solutions

- a. Generalize/specify
- b. Hierarchical system of solutions

4.1 The hierarchical System of USIT Solution Generation Operators

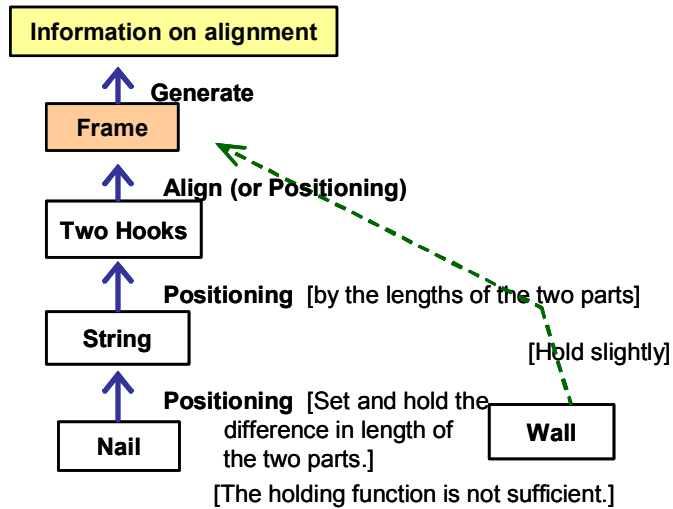
The USIT Solution Generation Operators [5] form a hierarchical system as shown in Figure 5. There are 5 principal operators which may be further classified into 32 sub-operators in total.

Figure 5. The Hierarchical System of USIT Solution Generation Operators

4.2 Illustration of Applying USIT Operators in a Simple Case: Picture Hanging-Kit Problem

Before discussing the nature of the USIT Solution Generation Operators, we better have some illustrative examples in a simple case study [6]. Let me use the Picture Hanging-Kit Problem [8]. Our task is 'To improve the ordinary picture hanging-kit composed of a nail, a string, and two hooks so that the picture is not apt to tilt'. Let us skip the description of the processes of problem definition and problem analysis (see Ref. [8, 3, 6]). As the generalized problem model in this case, we have the following pieces of information among others.

- The equilibrium position (or tilt angle) of the picture frame is determined essentially by the lengths of left and right parts of the string as divided by the nail.
- The functional relationships in the current system may be illustrated in Figure 6.
- When the frame tilts, the string slips on the nail. If the friction between the nail and the string or between the frame and the wall is large enough, the frame may be kept at a non-equilibrium (and possibly the 'straight-up') position temporarily.



- Making the friction between the nail and the string large is desirable for holding the string tightly, but not desirable for adjusting the string (and hence the frame) at first.
- The nail has attributes such as length, diameter, surface smoothness, shape, material, etc.

Focusing on the nail, for example, let us apply various USIT Operators. A part of such application results are demonstrated in Figure 7.

Figure 6. Functional Analysis Diagram for the Picture Hanging-Kit Problem [6]

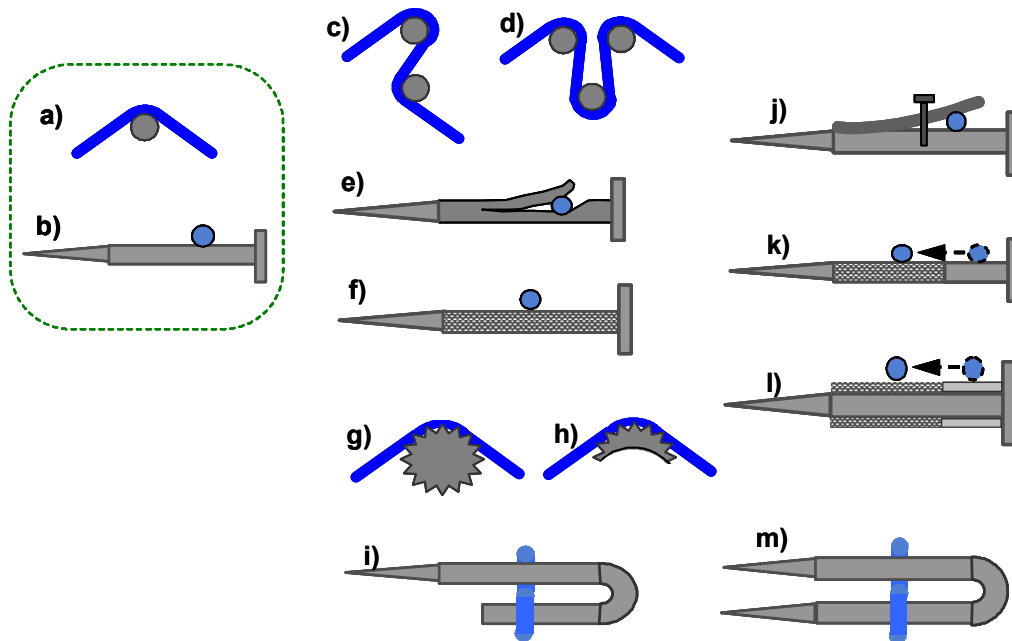


Figure 7. Illustrations of the Results of USIT Operators on the Nail in a Picture Hanging Kit

Figures a) and b) show the original nail with a string. The 'Multiply' operator (1b) is the simplest case of Object Pluralization (1), and gives solutions c) and d) with the intention of increasing the friction. 'Division' (1c) is also a form of Pluralization, and gives an idea shown in e) with the intention of holding the string tightly at the narrow slit. If we want tighter holding function after adjustment, we may attach a screw as shown in j).

The second principal operator advises 'Dimensional Change in Attribute', and f) is a simple response where the smoothness attribute of the nail surface is changed into a much different value, i.e. making the nail surface rough. Since rough surface is not good for adjusting, we have an idea shown in k) where only half of the nail is made rough whereas the other half is left smooth; this guides us the idea of adjusting the string at the smooth part of the nail and holding the string at the rough part. The idea l) is to use a collar having rough and smooth parts around the nail body. The surface of the nail may be changed not just rough but rugged, suggesting to change in the cross-sectional shape as shown in g). Since only the top part of the cross-section is actually used, we may change the cross-sectional shape and size more drastically as shown in h). The operational idea of 'changing shape' of the nail gives us another solution shown in i), which effectively has two nail bodies. When I noticed that the nail i) is apt to be turned by the string tension, the idea of two-footed nail m) came up. This may be regarded as the result of 'Unify' operator (1d) applied on the two nails shown in c).

You may notice in the above explanation that other 3 principal USIT operators have not appeared explicitly. But don't worry. Many of the above solutions are explainable as the results of other USIT operators as well. For example, the idea k) can be explained to have been obtained in different ways as follows:

- Operator (1c): The nail is divided into two parts, and then one part is made rough while the other smooth, and they are used together.
- Operator (2d): The smoothness of the nail surface is changed to be rough and smooth at the two different parts of the nail.
- Operator (3b): The nail's two functions, i.e., to adjust and to hold the string, are divided and assigned to two different parts of the nail.
- Operator (4b): The two opposite ideas of making the nail surface smooth for easier adjustment and of making it rough for tighter holding are combined spatially by using different parts of the nail.
- Operator (4c): The two opposite ideas of making the nail surface smooth for easier adjustment and of making it rough for tighter holding are combined temporally by pushing the string forward to the rough place after the adjustment.

In this manner, different USIT operators sometimes (or often) guide us to the same conceptual ideas. This shows the intended redundancy in the USIT solution generation operators.

For obtaining an idea, these operators may and may not be in mind explicitly beforehand. But it should be noticed that the reflection of any ideas in the general terms of these operators is important for understanding the solutions in its essence. For example, among the five ways of interpreting the idea k), the interpretation with the 'Operator (4c): Combination in time' is found to be most essential in this problem. This operator, in its essence, corresponds to the application of the strategy of Separation in time to a Physical Contradiction, in the orthodox TRIZ terms. Thus recognizing the idea k) in terms of this Operator of 'Combination in time' can lead the user to recognize the Physical Contradiction at the core of this problem and its possible elimination with the Separation in Time. With this understanding, the user will be able to generate many more novel solutions easily.

4.3 Guidelines of the USIT Solution Generation Operators

The USIT Operators for solution generation have their guidelines (i.e., brief instruction accompanied by a schematic diagram) at the 32 sub-operator level and at even more detailed levels. They reflect various TRIZ principles and have been reformulated in a much useful way [4, 5]. By the example, let us discuss about the 'Divide an object' operator (1c) in USIT. This operator has been derived from several TRIZ principles including:

- TRIZ Inventive Principle 1. Segmentation:
 - 1A. Divide your object into independent parts.
 - 1B. Divide your object into parts so that some its part can be easily taken away.
 - 1C. Increase the degree of the object's fragmentation.
- TRIZ Inventive Principle 2. Taking away
 - 2A. Take away an interfering pat of your object.
 - 2B. If some property of the object is undesired, find out what part of the object is a carrier of the undesired property and separate it from the object.
- TRIZ Inventive Principles 3. Local quality
 - 3C. If two functions are to be performed by the same object but this causes problems, divide the object into two parts.
- TRIZ Inventive Principles 15. Dynamicity
 - 15B. Divide your objects into parts capable of moving relatively each other.
- TRIZ Inventive Standards. 2.2.2 Evolution of SFM.
 - Increase the segmentation of the Tool substance.
- TRIZ Inventive Standards. 5.1.2 Introduction of substances under restricted conditions.
 - Introduce a new field.

In deriving the USIT guidelines from TRIZ principles, we have chosen the following stand points:

- To use the basic USIT concepts of Objects, Attributes, and Functions in the description.
- To choose a proper level of abstraction consistently, not too abstract and not too specific.
- To describe intentions, conditions of application, applicable cases, specific examples, etc. at the level lower than the guidelines of USIT sub-operators.

Thus the guideline for the USIT Operator (1c) is described as follows:

- USIT (1) Pluralization of Objects
 - (1c) Divide the Object (into $1/2$, $1/3$, ..., $1/\text{infinity}$):
 - Divide the Object into multiple parts ($1/2$, $1/3$, ..., $1/\text{infinity}$),
 - modify the parts (slightly, or differently for different parts),
 - and combine them for using together in the system.

Some more examples of guidelines in USIT are shown for other four operators which appear in the previous subsection:

- USIT Operator (2d) Introduce a spatial attribute or vary in space:
 - Introduce or enhance an Attribute related to the space, or activate an Attribute (or vary the Attribute's value) depending on different places in space (or different parts of an Object).
- USIT Operator (3b) Divide the compound Functions and assign them separately:
 - Divide the compound/multiple Functions present in the system and reassign the divided Functions to different Objects (already present or newly introduced) or different parts of Objects.
- USIT Operator (4b) Combine spatially:
 - Combine multiple solutions in respect to the spatial positions to apply; for instance, at different places (for avoiding the mutual interference), at distributed places, side by side, in front and back (in sequence), on top and bottom, at the same place alternatively, inside of the other, as an inner-structure of the other, etc.
- USIT Operator (4c) Combine temporally:
 - Combine multiple solutions in respect to time to apply; for instance, in sequence (one after another), beforehand of the other, simultaneously (in parallel), afterwards of the other, in the reverse order, alternatively, in pulses, periodically, from time to time, interrupting/switching corresponding to the situations, etc.

From these examples of guidelines in USIT, I hope the readers understand that a number of TRIZ principles (including Inventive Principles, Inventive Standard, Trends of Evolution, etc.) are smoothly unified in these USIT Operators, and that the solution examples shown above are easily obtainable by applying these USIT Operator guidelines.

Usefulness and intended redundancy of USIT Operators are based on the USIT concepts of Objects, Attributes, and Functions. The USIT Operators on Objects (as shown in case of (1c)) take some Objects as the operand, apply the specified operation on the Objects, and then further apply modifications onto Attributes and Functions of the operand Objects according to the guideline descriptions. Situations are similar in the USIT Operators on Attributes and on Functions. This type of extension in the USIT guideline descriptions guides the problem solver in a way easier to follow than most TRIZ principles. At the same time, the mentioning of Objects, Attributes, and Functions in each guideline description is the source of intended redundancy, i.e. overlapping, of the USIT Operators.

4.4 Experiences of Teaching and Applying USIT

Experiences of teaching and applying USIT in Japan have been reported in [3, 6]. A lecture of 2 hours can cover the overview of TRIZ and USIT. Typically, two-day USIT training seminar is held in a company with 15-25 participants of engineers. After the overview lecture, 3 real industrial problems are brought in by the participants and are tried to solve in parallel group practice following the USIT procedure. 5 sessions are carried out, where each session is composed of a short lecture of the process, parallel group practice, and presentation & discussion. Usually each group generates 20 to 40 ideas which may be further concentrated into several conceptual solutions worthy of further consideration for implementation. Thus engineers, who were novice of TRIZ/USIT, can have the experience of solving an industrial problem with USIT by themselves, and can understand the full USIT procedure with 3 real case studies. This shows the easiness and effectiveness of learning USIT in comparison with learning TRIZ.

5. Concluding Remarks

In the basic four-box scheme of problem solving, generalized models of TRIZ (and many other scientific/technological theories) are expressed by the generalized problems and their corresponding generalized solutions, and are supposed to be used with analogical thinking. Abstraction is for mapping the user's specific problem to the generalized one in the model, while concretization is for mapping backwards. These mapping processes, however, are often not well explained in the procedural manner.

The present paper proposes a different scheme of problem solving, as summarized in Figure 8.

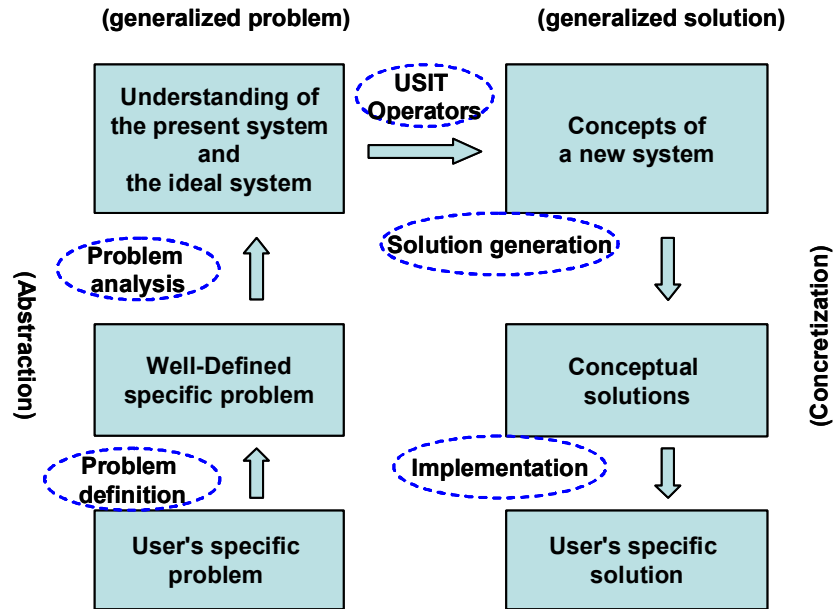


Figure 8. Scheme of Problem Solving in USIT Using the USIT Solution Generation Operators

Abstraction is done in two steps; the problem definition step converts the user's specific but often vague problem into a well defined specific problem and the problem analysis step converts it further into the abstract understanding of the current and ideal systems. This abstract understanding of the system is expressed in the basic terms of objects, attributes, functions, space, time, desirable actions, and desirable properties, etc. and is in place of the generalized problem of the four-box scheme. Then the Solution Generation Operators in USIT transform the elements of the abstract system into modified elements of a new solution system; this is the key step in the whole problem solving. Then conceptual solutions are formed on the basis of technological thinking, and finally user's specific solutions may be designed in technology.

It should be noticed that the vagueness in the analogical thinking disappear in the new scheme. Knowledge expressed in the 'Models' in TRIZ (and problem solving methods in general) has been concentrated into the USIT Operators. And hence all the procedures of creative problem solving are now expressed in much clearer terms and procedures.

This unification and simplification of TRIZ can help people understand TRIZ more easily and widely and apply TRIZ to their real problems, as demonstrated earlier.

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This article will also be published in the April 2005 issue of the Australian magazine, Manufacturers Monthly. Dr. Ahmed offered it to the TRIZ Journal to be used by people who need a short explanation of what TRIZ is, and what it can do for an organisation. We look forward to future articles on applications.

ANALYSIS MANAGEMENT: TRIZ and Systematic Innovation - An Overview

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TRIZ is a structured collection of solutions to technology problems found in diverse industries at any level of complexity. These solutions have been extracted over the past 40 years from the worldwide patent pool into a small set of rules and methods. The beauty of TRIZ is that it is a style of thinking as well as a set of methods and that the essential knowledge base of TRIZ is available free of cost in the public domain.

Is TRIZ the next wave of technology hype? Consider that it originated in the 50's and 60's as a systematic study of high quality patents from around the world to discover a common reasoning process behind the inventions. Pioneering work initiated by the visionary G. Altshuller (1926-98) in Russia continues to gain momentum worldwide. TRIZ has now evolved into a proven innovation system and has gained wide acceptance with key manufacturers in the USA, Europe, Korea, Japan and China.

How does TRIZ work?

Any industrial problem requires us to cope with complex issues within the limits of our expertise and the technical knowledge base available to us. TRIZ greatly enhances these resources.

We begin with a clarification of the problem by narrowing our focus from the large systems level, to the sub-system, to the component, to the function, and finally to the parameter level. Now the problem can be studied in its most basic form. In the second stage we use TRIZ methods such as 40 inventive principles or 76 standard solutions (all obtained from world wide patent analysis) to generate a number of feasible solutions matching best of class patents in other industries. In the third stage the most promising solution is transformed from a elementary concept and detailed back into a usable form. This last stage is extremely important as it forms the competitive advantage of a company in how well a solution direction is converted by the users into a new product, process or invention in their field of interest. The domain knowledge and process experience of the users closely interact with TRIZ at this iterative development stage.

Some further aspects of TRIZ thinking are:

- ◆ Every product, process or technology follows predictable trends of evolution. Situational awareness of position on this trend is critical to strategy and planning.
- ◆ The concept of ideality is found throughout TRIZ, being gain over pain or the quest for increased value obtained at ever decreasing costs. Over time, every system evolves towards increasing ideality.
- ◆ Unique approaches are used to enhance mental agility, including imagining perfect solutions of maximum ideality, thinking at microscopic levels of functionality, and studying the time, space and sub-assembly interactions within a task.
- ◆ Functions are the currency of TRIZ. Harmful, missing or excessive functions are also considered simultaneously with the required functions within a system.
- ◆ In TRIZ any input not fully utilised is considered a valuable resource. An aggressive, continuous approach to resource management includes the modification of harmful

effects into good and emphasis on problem solving within strict confines of existing resources.

- ◆ TRIZ actively encourages the user to utilise known scientific and engineering phenomena / effects that may provide a needed break-through. Systematic, indexed knowledge banks are part of TRIZ software.

The applications of TRIZ in routine or innovation activities of a company:

Long Term Strategy: Using on-going TRIZ analysis of technology evolution provides management with an understanding of the company's competitive position and its future growth potential. At the mature end of the cycle, it can help indicate the future direction for a paradigm shift in technology based on similar industry data.

NPD Opportunities: TRIZ provides evolutionary trends for common design parameters based on which the untapped potential of a product design can be seen. Generally shown as a radar-plot, this is an excellent visual representation of hidden opportunities for new product development and refinement. TRIZ has several tools to initiate and sustain NPD programs.

Lean Manufacturing: TRIZ at heart is pure lean thinking. At the higher level, it strives to drive the system towards ideality where increasing output is obtained from fewer resources (money, space, manpower, time). TRIZ also provides the tools to study the process at the mechanism level and to continually develop innovative solutions to production and logistics issues.

Six Sigma: The use of TRIZ is a standard recommendation for the Improve stage in the DMAIC cycle and forms an essential part of the Design for Six Sigma process.

Innovation and R&D: This is the core activity of TRIZ and one where TRIZ provides more features, capability and methods than any other methodology. It is a quick way to begin innovation programs at any level. Qualitative reasoning utilises the instinct and experience of the user. It does not require high-level mathematical or scientific training.

Rapid Changeover and SMED: Many of the methods developed by S. Shingo for rapid changeover at Toyota have remarkable parallels in the independently developed TRIZ.

Continuous improvement: The constant switching in TRIZ reasoning between the larger picture view and minute details ensures that improvements are carried out efficiently. The quest for increasing ideality provides the long-term motivation for sustaining such programs within the organisation.

There is a wealth of information on TRIZ and systematic innovation on the Internet which interested readers should access. TRIZ is an ideal approach for SMEs and large organisations to gradually develop a deep culture of innovation and continuous improvement in their existing set-ups at an affordable cost.

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Integrating TRIZ And Bionical Enginereeng

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Abstract

Bionics and TRIZ are two important issues at the center of all disciplines of Science and Engineering. They also play strategic roles in the development of research and innovation. They are very powerful tools for Creative Problem Solving, Innovation, Invention, Quality Development, and Productivity in all industrials. Industries are assisted in achieving their goals through their application. In this paper, combining TRIZ with Bionics is considered and developed so that the Inventive Principles are made more effective.

Introduction

TRIZ was developed by Genrich S. Altshuller, who born in the former Soviet Union in 1926. His first invention, for scuba diving, was when he was only 14 years old. His hobby led him to pursue a career as a mechanical engineer. Serving in the Soviet (Baku) Navy as a patent expert in the 1940s, his job was to help inventors apply for patents. He found, however, that often he was asked to assist in solving problems as well. His curiosity about problem solving led him to search for standard methods. During the next few years, Altshuller screened over 200,000 patents looking for inventive problems and how they were solved. Of these (over 1,500,000 patents have now been screened), only 40,000 had somewhat inventive solutions; the rest were straightforward improvements. Altshuller more clearly defined an inventive problem as one in which the solution causes another problem to appear, such as increasing the strength of a metal plate causing its weight to get heavier. Usually, inventors must resort to a trade-off and compromise between the features and thus do not achieve an ideal solution. In his study of patents, Altshuller found that many described a solution that eliminated or resolved the contradiction and required no trade-off. Altshuller categorized these patents in a novel way. Instead of classifying them by industry, such as automotive, aerospace, etc., he removed the subject matter to uncover the problem solving process. He found that often the same problems had been solved over and over again using one of only forty fundamental inventive principles. If only later inventors had knowledge of the work of earlier ones, solutions could have been discovered more quickly and efficiently. In the recent development of TRIZ research, much effort has been put in extending TRIZ to a broader application. So far several TRIZ tools have been found to be equally effective in problem solving. Examples of this are ARIZ and the 40 Inventive Principles which have been applied in quite a few new areas such as: business (Mann, et al., 1999), quality management (Retseptor, 2003), and others. This obviously signals the viability of using TRIZ in more areas, and the promising future of TRIZ development. The

general pattern of problem solving with TRIZ is shown in figure 1.

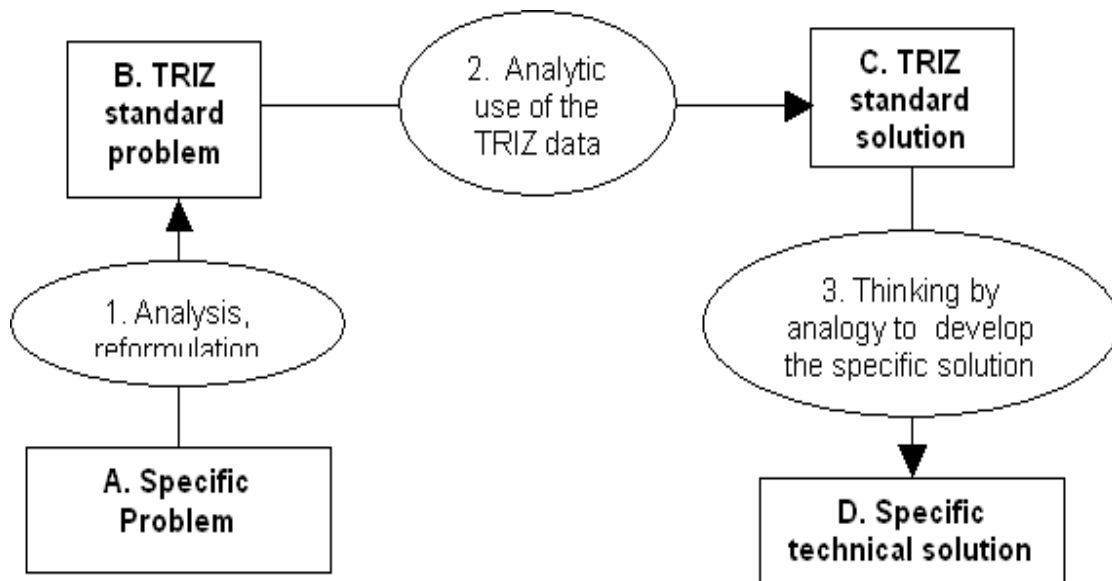


Figure 1: TRIZ general model (Domb, 2001)

TRIZ could increase problem solving cooperation across many industries and centers. This paper introduces the Integration of TRIZ and Bionical Engineering and the effects of this integration. TRIZ are tools for engineers, researchers, managers and etc, and help them for problem solving. Bionical Engineering is modeling and inspiration of principles from nature for problem solving. Interactivity of TRIZ and Bionical Engineering is important for developed and evolution of TRIZ and increased principles of TRIZ by principles of bionics and improvement of these tools.

Bionical Engineering

Biology has had to solve engineering problems since the appearance of life on earth. Design and function in plants and animals have been optimized under evolutionary pressures over millions of years a small step at a time. These long lead times do not fit easily with the more frenetic pace of the engineering world of today but the solutions cannot be dismissed on these grounds.

Time scales may be different but design constraints and objectives are very similar: functionality, optimization and cost effectiveness. Therefore, it is not surprising that engineering has always admired biological structures and often been inspired by them, therefore we can appreciate their esthetical attributes as well as their engineering and design content.

Bionics as a scientific discipline deals with the technical transformation and application of structures, procedures and developmental principles of biological systems.

Originally, the word Bionics derives from the terms bio and technique. Nowadays, the word is more generally used for a young and interdisciplinary

research field that combines biology with the sciences of engineering, architecture, and mathematics.

Bionic: an approach for determining the aim, the method used and the solution to a problem or opportunity.

Nature, with its great variety of efficient structures, is suitable as a source for the stimulation of possible ecologically sound and ergonomic solutions to problems and opportunities.

Examples in nature can become a creative element within the process of producing a solution to a problem. The rules of biological evolution can be used both for determining the aims and the principles of functions of structures and organizations as well as providing a model for determining solutions. The Bionic approach is seen as reducing the gap between the man made world and nature. Examples are included which show how technological solutions were developed based on analogies, or models, of biological systems (example: Velcro, Eiffel Tower and etc).

Principles of nature are the abundant source of inspiration for products and materials, a futurist researcher who believes that principles of nature are worth more as a source of ideas than as a source of raw materials.

Bionical engineering is innovative modeling or learning from nature. This science is a principle of design that looks at suitable solutions for human problems and problems of R&D. Using natural principles permits engineers to use that creativity in the development of: materials, design, and processes.

Many older inventions are based on the study of natural mechanisms. Structures in nature that are important in the micro and macro levels are used for modeling and inspiration.

There is no strict procedure available to ensure that the correct abstraction is made or that the organism mimicked is the most suitable. This means that there is a need for a methodology to formalize the process of Bionical engineering designs that is shown in figure 2.

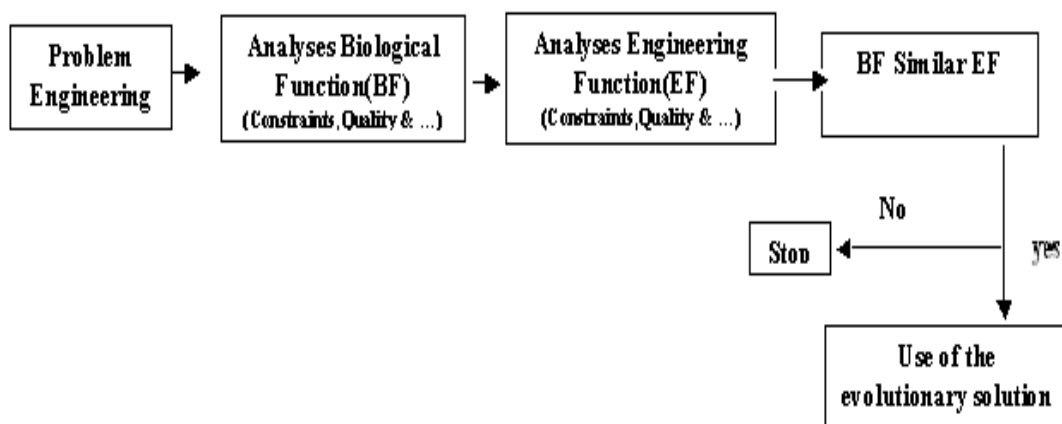


Figure 2: Bionical Engineering general model

Integrating TRIZ and Bionical Engineering

In this section, a proposed method for the integration of TRIZ and Bionical Engineering is represented as a general model that achieves integration as a model for problem solving. This model uses all of the TRIZ tools and Bionical Engineering principles. This proposed model shown in figure 3.

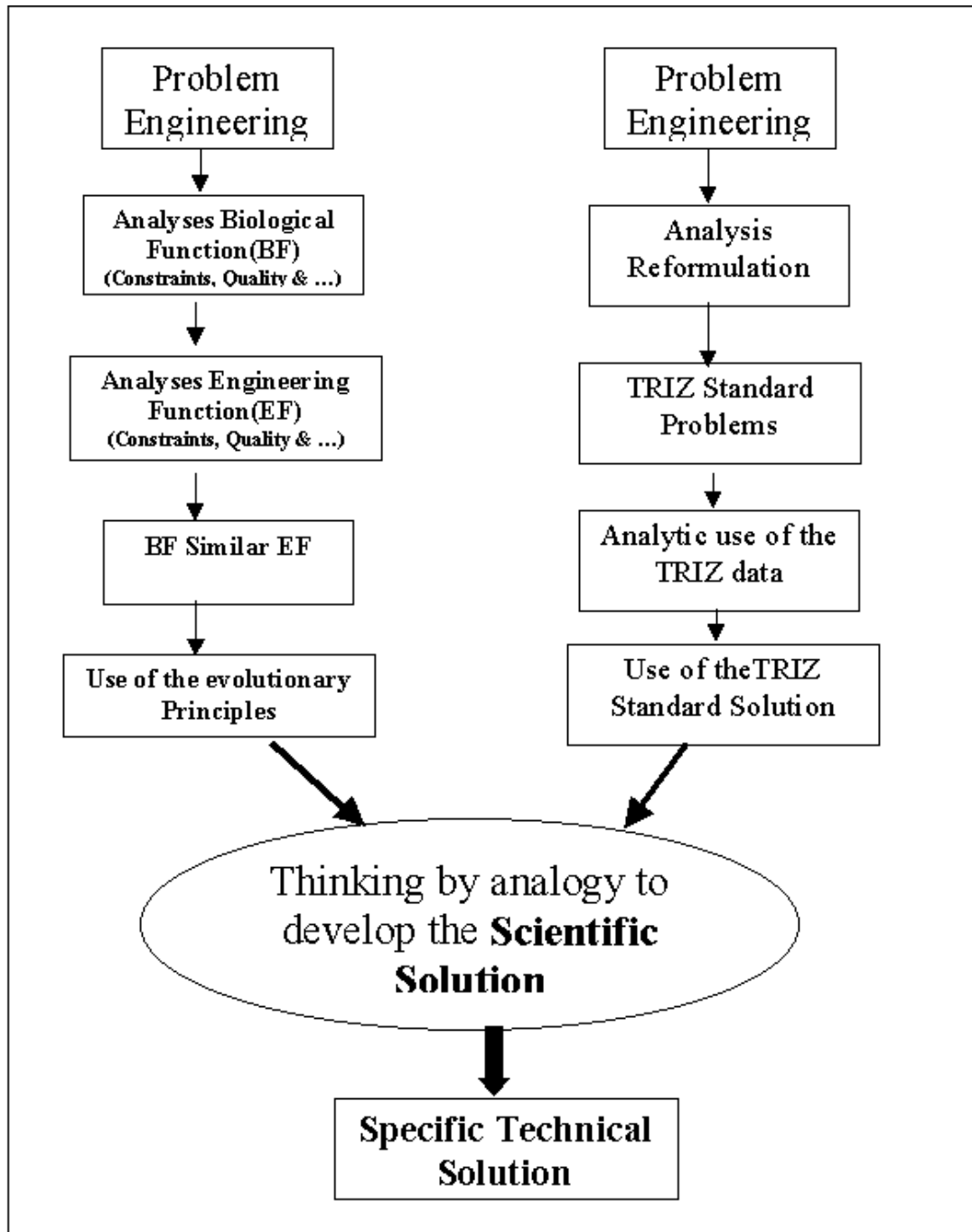


Figure 3: TRIZ and Bionical Engineering general model
This model is a powerful tool for solving of more problems.

Conclusion and prospective

A TRIZ-based methodology is developed to help the search for engineering principles for the design and technical problem solving, and limited in investment capacities. The development of the methodology is very important and Bionical Engineering could increase the ability of this. In this paper purposed The TRIZ concepts are coupled with the evolutionary principles of nature. The integrated approach of both methodology combines and a model purposed. This model is stronger of any of them, which guide the users toward the most suitable principles and existing applications. The development of this methodology is necessary. The integration of more scientific information such as the principles of nature into this methodology is believed to further nurture creativity and the generation of new principles.

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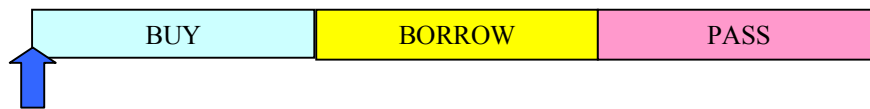
Book Review: **Principles of Survival (A Theory of Everyday Creativity)**

by Gennady Kizevich

Reviewed by Michael S. Slocum, Ph.D., M.B.B., T.Sc.

Details: 352 pages, paperback edition available from Amazon.com for \$17 US (a bargain). This book was published by Washington House in March of 2004.

Editor's note: So that our readers may judge how they might be able to benefit from this new book we used the buy/borrow/pass meter as indicated below (as you can see—a very strong “buy” recommendation:



This book is divided into 5 chapters:

1. Secrets of the Pyramid or Popular Theory of Systems
2. Skills to Remain Alive
3. To invent is to Forsee
4. The CAR of the 21st Century
5. How to Convert a Possibility into Money

Throughout the book there are many sections that are considerably interesting and these have been identified with their page numbers below:

Law of Efficiency	p. 1
The Steam Engine Is 2000 Years Old	p.18
The Space of Purpose	p.44
Super-methods and Super-principles	p.64
The Formula and the Paradox of Beauty	p.98
The Secrets of Toys	p. 149
Secrets of Art	p.153
The Theory of the Smile	p. 194
The Birth of a New Product	p. 218
To Sell a Dream	p. 219

This book was dedicated by the author to Forest Gump and is for people with a sense of humor and wonder as well as those who are serious about the pursuit of success and are looking for principles and laws to aid them in conquering the world we live in.

This is an absolutely fascinating book that is full of principles and laws to describe phenomenon that we usually take for granted. The perspective deepens as different examples are discussed that explain the principles in the book and describe useful

applications of them in the real world. A few sections in the book describe the authors views on Altshuller's work and reduces some of the key tenants of TRIZ into a set of principles: Altshuller's First Paradox, Altshuller's Second Paradox, and Altshuller's Precept. The insights are new and invigorating and that makes this book a valuable edition to your creativity library.