TRIZ: Theory of Inventive Problem Solving
Understanding and Introducing It

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Abstract

"Theory of Inventive Problem Solving (TRIZ)" has been developed and systematized since 1946 in ex-USSR and has become known to the western countries after the end of the Cold War as a new methodology for technological innovation. It is based on the philosophy: "Improvements, innovations, and evolutions of technologies share some common aspects across their fields and their eras. Thus, by extracting such shared essences out of a large number of excellent cases, and by making them easy to retrieve after classification, we may reuse them for facilitating new development of technologies. Especially, excellent cases of technology innovation can be understood in a number of patterns of breaking through the contradictions in the problem; such patterns provide us hints for our own creative innovation."

The followings have already been established as a methodology system and applied in real parctice: (a) Trends of evolution of technical systems (b) Inverted database of science and technology which are retrievable from technical goals to various candidates of technical means (c) 40 "Principles of Invention" (d) "Contradiction Solving Matrix": corresponding to each element of a problem matrix of 39 improving aspects versus 39 worsening aspects, top four most-frequently-used Principles of Invention are quoted on the basis of an ellaborate analysis of world patents

Recently in USA, the TRIZ methodology has been implemented in software tools and rapidly become known to industries. In Japan, TRIZ has been introduced and promoted in a significant scale since last year.

The present paper describes an overview of TRIZ and points out the possible large impact of TRIZ on the future of world's technologies, industries, and education. It discusses how to introduce TRIZ to the practice of industries, and also discusses the necessity of introducing the TRIZ philosophy in education.

1. Introduction

As the global competition of technologies is becoming severe more and more, there is a great demand of creative ability in technology development. How can we generate creative ideas and innovative technologies? How can we obtain higher ability in our own creativity? These are serious problems. So far, however, the experienced processes of having reached creative ideas have been described simply as "enlightenment" by scientists at some uninteded moments after intensive thinking or as "by-products" of trial-and-error processes of experiments. Since these processes depend on luck, they give us only spiritual advices.

Lately, however, it became known to the western countries that a method formed in ex-USSR and called TRIZ, pronounced as /tri:z/, have had given much clearer solutions to these problems. TRIZ is the English spelling of Russian abbreviation of "Theory of Inventive Problem Solving". It claims that creative ability can be increased by extracting, systematizing, and learning the essences of real cases of creative technological innovations, and it actually have developed such a system. TRIZ already has a history of 50 years of research and wide-ranged application practices in Russia; it became known to the western countries after the end of the Cold War, and has started new phases of development for these few years. The methodology has reorganized the whole system of science and technology from a practical, yet having deep insight, stand point for achieving desired technological goals. It will give, in the near future, a great impact on the technology and industry of the world, and will urge serious reconsideration of the ways of education of science and technology.

The present author heard about TRIZ at the end of last May, 1997, for the first time in a lecture given in Tokyo by Dr. Mats Nordlund of MIT, and for these twelve months he has been endeavoring to study and introduce TRIZ, especially in Fujitsu Laboratories, where he was a staff until the end of March 1998. In the present paper, TRIZ is introduced to novice readers by describing how to understand it and introduce it in industrial practice.

2. History of TRIZ and its current situations

2.1 History of TRIZ

In 1946, Genrich Altshuller, who was at the age of 20 and engaged in patent reviewing, recognized typical thinking patterns in inventions and obtained the fundamental initial idea of the TRIZ theory. He sent a proposal to Stalin, but was rather sent to a camp in Ciberia, where he continued developing his ideas. Being released after 5 years, he published his work of TRIZ, and opened a number of TRIZ schools at various locations in USSR. His activities were prohibited again since 1974, but were allowed open in the years of the Perestroika. During these 50 years of development, a few thousands of researchers/engineers have got involved in the study and development of TRIZ, to analyse patents of the world, i.e. 2.5 million patents in total as sometimes being claimed, in its technological semantics and to establish the system of the TRIZ methodology.

Since 1980s, especially after the end of the Cold War, a number of ex-USSR TRIZ specialists emmigrated to the western countries and brought in TRIZ. Sweden, USA, and Israel were active in receiving them. Particularly in the United States, some companies have started developing software tools of TRIZ, many consultant firms their activities of promoting TRIZ, and manufacturing companies their trial introduction of it. In Japan, introduction/promotion activities have been started in a significant scale only since 1997.

2.2 Textbooks, References, and WWW information on TRIZ

Textbooks of TRIZ are very limited in languages other than Russian. In English, published are two Altshuller's textbooks [1,2], an introductory textbook [3], and a training material [4], and maybe some others. Under this situation, one should note information offered through WWW [5-8]. In particular, a monthly electric journal, named "The TRIZ Journal"[5], was established in 1996 and has been publishing every month about five papers and articles, including case studies. In conferences in the field of quality control, TRIZ sessions have started; it is announced that the first international conference of TRIZ will be held in coming November 1998 in USA.

Introduction of TRIZ in Japanese was recently initiated by the article [9] in the April 1996 issue of a monthly journal, "Nikkei Mechanical". Near the end of 1997, three introductory TRIZ textbooks [10-12] were published in Japanese. Among these, [11] is the easiest to read. This is a Japanese translation of the textbook [1], which Altshuller wrote about TRIZ ideas readable even for highschool students (technological examples are dated only up to 1960s). Reading [10] next is recommended. It explains the overview of TRIZ in a more detailed and systematic way. Some parts of it are easy to read, but some others are difficult mostly because the materials are condensed too much. In the TRIZ theory, there are some core parts which are unfamiliar and rather contradictory to the common sense, just like Zen communications; this point is related to the fact that one can achieve any breakthrough only after breaking one's own conventional ways of thinking.

Textbook [12] by Hatamura et al is introductory but rather unique in containing appropriate criticisms of TRIZ. The part explaining TRIZ in [12] is a Japanese translation of the textbook by Fey and Rivin [3], which is written in a style similar to [10]. Their demonstration examples, however, are rather old (mostly describing the technologies used before 1970), and there are a number of patent cases which were apparently recorded as new ideas without engineering/commercial examinations. Hatamura and his group discuss and criticize these points in detail. Besides, Hatamura et al describe their own "Creative Designing Principles", which has some aspects similar to TRIZ but has been built up independently. Since [12] contains all these related but conflicting parts together, it seems very difficult for TRIZ novices to understand the book, or at least to realize the merits of TRIZ. After studying TRIZ for some time, one should read this [12] again to fully understand its messages.

2.3 Current situations of TRIZ software tools

Some TRIZ specialists of ex-USSR moved to USA and started implementing the TRIZ methodology into software tools; Invention Machine Corporation [13] is the leading company. IMC has developed and is marketing software packages, TechOptimizer and IM Phenomenon, which work smoothly on PCs with practical usefulness. Ideation International, Inc. [14] has also implemented their TRIZ training course into a software package. In Japan, Mitsubishi Research Institute [15] has been working as the general agency for IMC, forming a consortium to making a Japanese version of the software tool, and taking the leadership for introducing TRIZ to Japan.

3. Philosophy and Scheme of TRIZ

Since TRIZ has already formed a large system of methodology, it is difficult to introduce its whole aspects. Essence of its philosophy and scheme may be understood as follows:

3.1 Technology-oriented: concrete and yet abstract thinking

TRIZ deals with a very wide range of science and technology. Its philosophy is not based on academic approaches like "science" nor "engineering", but rather on a practical approach of "technology". By fully utilizing the well-established system of science and technology, we want to solve problems in technology and create innovative technologies; that's the goal for us to use the TRIZ methodology.

For this purpose, the way of thinking in TRIZ is concrete, practical, and widely spreaded. For example, the states of substances listed up in TRIZ include not only the typical three states (i.e. gas, liquid, and solid) but also a large number of in-between and compound states (such as aerosol, foam, powder, porous, and void (i.e. vacuum) states) and the states having special characteristics in thermal, electric, magnetic, and optical aspects. TRIZ takes all these states of substances into consideration in its problem solving. In opposite to the substances, TRIZ considers physical fields, forces, and interactions (these are sometimes called simply as "Fields" in TRIZ); they include mechanical, electrical, magnetic, thermal, and optical "Fields", as the main categories.

To handle all these wide variety of substances and "Fields" in a well classified, ordered, generic, and unified way, TRIZ fully uses abstract thinking. For example, in handling the five main "Fields" mentioned above, TRIZ discusses inter-conversion of the "Fields" by using some characteristic substance system, "structuring" of the "Fields" (i.e. increasing/decreasing, reflection, transmission, refraction, difraction, etc. of the "Fields"), accumulation of the "Fields" (e.g. accumulation of mechanical energies), etc. Such introduction of concreteness and abstractness at the same time has made the TRIZ methodology unique and extraordinary. This feature of TRIZ is evident in all the following subsections.

3.2 Trends of evolution of technical systems

One of the insights by Altshuller is that all technical systems (or artifact systems) have a number of trends of evolution which are common across the fields and eras.

One of such trends is that one part, such as a functional part, in a system evolves into two parts, then into multiple parts, into many parts, and finally into one part at a higher level. An example of this type of evolution can be seen in the speaker system of a radio; a single speaker equipment evolved into a stereo system of two speakers, then a surrounding sound system of multiple speakers, and finally into a 3D sound system. Similarly, a gun with one bullet evolved into a double channel gun with two bullets, then a revolver pistol with several bullets, and finally into a machine gun with a large number of bullets in a belt.

Another common trend is the segementation of a working part of a system; a solid working part of a system (e.g. a metal ball in a ball bearing) evolved to divided solid parts (e.g. balls in a two-row ball bearing), then to many smaller parts (e.g. a micro- ball bearing), further to molecular scale parts (e.g. a gas bearing), and finally to the extreme of the parts using non-substance, i.e. a "Field" (e.g. a magnetic bearing system).

Adding further the trends of increasing flexibility, dynamization of time characteristics, etc., over a dozen of such trends of system's evolution have been recognized. TRIZ teaches us these common trends in technical system evolution at a highly abstract level, together with illustrations of concrete practical examples. It guides us to think along these courses of trends and to find futuristic technical innovations right now.

3.3 Inverted database of science and technology for finding means from goals

"Technology-orientedness" means that we want to achieve some technical goal by solving technical problems in front of us. Engineers wish to solve some problem or want to achieve some goal. They are struggling to find how to achive it; namely they are seeking for any means to achieve a goal. If the goal is achievable by some means which they know well and use often, the problem is easy. If the goal is inreachable by currently available means, or if a new task is given, engineers want to find new or higher-level means. They often meet problems which can not be solved by their personal knowlege nor even by the technologies currently known to their field of industry.

The system of science and technology should certainly be expected to give them the guiding principles for solving such technical problems; nevertheless, it is not easy for the engineers to effectively use it at the present situations. One fundamental reason for this difficulty is that the principles and theories in science and technology are stated in the basic scheme that "setting up a situation then comes the result", and their practical applications are also shown in the scheme of "from means to effects". Statements in these schemes have been accumulated in huge scales in each field of finely divided areas of sciences and technologies. For an engineer to find some suitable means to achive his goal, he has to learn the relevant fields of science and technology, and has to apply the knowledge to find any means (or rather a set of means) which can achieve his goal; thus during the process of his search he has to invert the knowledge scheme into "from a goal to means". Consequently, any engineer can think of means in relatively narrow fields of science and technology, and does not know whether the means he has found is appropriate for the solution in a wider scope. Thus technology innovation has been requiring difficult re-search work in trial-and-error.

For improving this situation, TRIZ has been building up an inverted database of whole science and technology, so as to be able to retrieve in a scheme of "from a goal to means 1, means 2, ...". The TRIZ approach was built not at a level of retrieval function of indeces to encyclopedias and to conventional scientific/technological databases, but at a level of much essential reorganization of the scientific/technological information. TRIZ has first classified various technical goals into a hierarchical system. The goal categories at the top level are:

substances (as object):	obtaining, holding, protecting, eliminating, moving, separating, measuring properties of, and changing properties of.
"Fields" (as object):	generating, accumulating, absorbing, changing in space arrangement of, measuring properties of, and changing properties of.

Representations of goals are further classified into lower level categories, such as "changing surface properties of a substance" and "separating a component in liquid mixture"; 283 categories are listed as goals. For each category of goal, applicable principles of science and technology and their practical examples have been compiled in an already-sorted scheme for easy access.

By using this inverted database, an engineer can easily find many technical means which he hardly think of from his own knowledge and speciality, and can use them as hints for his poblem solving. Not being limited by conventional thinking in one's speciality, but flexibly introducing knowledge and technologies of other fileds is a most important key for opening the door to technical innovations.

3.4 "40 Principles of invention"

Altshuller has extracted 40 "Principles of invention" through his semantic analysis of patents world-wide. Some example of them are:

Principle of invention, No. 1:	Segmentation (dividing an object, assembling of parts, and segmentation to the extreme)
Principle of invention, No. 2:	Extraction (taking our harmful parts, and extracting useful parts)
Principle of invention, No. 4:	Asymmetry (making an object asymmetric)
Principle of invention, No. 40:	Compound materials

These principles were extracted and formalized by Altshuller with his sense; they form one of the essence in TRIZ.

Among the principles of invention, some are seemingly natural and in common sense, but some others are unexpected. The principle of "Asymmetry" is an example of unexpected antitheses. Principles in science and technology often advise us to make symmetry of objects higher for better functioning; on the contrary, this principle in TRIZ points out that making objects asymmetic can be the key to a breakthrough. The primary barrier against technology innovation is the psycological inertia (e.g., preference to higher symmetry which is deeply installed in one's mind); this is the insight in TRIZ. Principles of invention are stated in abstract terms in order to be applicable to problem solving accross fields and eras. The most basic way for understanding TRIZ is to read the explanations and practical application examples of the 40 principles of invention, thouroughly to understand its implications. These principles of invention demonstrate their real usefulness in the "Contradiction Solving Matrix", as discussed in the next subsection.

3.5 Solving technical contradictions: "Contradiction Solving Matrix"

It is often the situation in technical problems that if one tries to improve an aspect of the system, one causes to worsen another aspect. Most typical solution in this kind of situation is to regard the problem as a trade-off between the two (or more) aspects and to take a compromise which chooses some acceptable but not satisfactory point in both aspects. A more sophisticated solution may be obtained by the "optimization" technique. Optimization requests the engineer to clarify the constraints of the given problem, to set up an objective function as the criterion for evaluating solutions, and to find out some means which makes the value of the objective function highest under the given constraints. Mathematical models and techniques are used in expressing the solution models in a form of function containing various parameters and in finding the model which gives highest value (in a practical sense) of the objective function. Even though the "optimization" technique is highly sophisticated with these mathematical representations, it often has fatal pit-holes in the setting up of the constraint conditions and in the representation of model functions as feasible solutions. These representations usually reflect the current technical system and the optimization searches a solution within such a current framework; thus optimization rarely proposes real breakthroughs.

TRIZ, on the other hand, regards such a technical problem as "technical contradiction". It tries to make the contradiction even clearer, and to find a break- through solution by really breaking the barrier posed by the contradiction. Not detouring but eliminating the contradiction is the key to new technical innovation; this is the fundamental standpoint of TRIZ. Such technical innovations have been realized many times in the history of science and technology. TRIZ has paid special attention to patents as the records of such technical innovations. By analyzing a huge number of patents, TRIZ has extracted typical solutions to "technical contradiction" problems, and has formalized in the following way:

First, for expressing technical problems, one is urged to describe which aspect of the current system he wants to improve and which other aspect becomes worse by such an improvement and causes an contradictory situation. To describe these aspects, TRIZ uses 39 standardized aspects, including weight of movable object, loss of energy, easy to use, reliability, etc. The matrix thus formed by 39 improving aspects and 39 worsening aspects is regarded as the ground for representing technical contradictions. Altshuller and his followers have analyzed the cases of technology innovation recorded in the patents; they classified the problem of each case on the 39 x 39 matrix and expressed the essence of the patent solution in terms of the 40 principles of invention. Accumulation of these analyses of patents has lead to find frequently-used principles of invention for each section of the matrix; top four principles have been listed for each section. The table of frequently-used principles of invention on the 39x39 matrix, thus obtained from such an ellaborate work, is called "Contradiction Matrix" or "Contradiction Solving Matrix". This forms a part of core results uniquely obtained in the TRIZ methodology.

Engineers who want to solve their own technical problems are advised first to describe the problem in the scheme of improving aspect versus worsening aspect on the Contradiction Solving Matrix. Then the Matrix readily shows the engineer up-to-four principles of invention which were most frequently used in inventively solving such a type of problems. Engineers thus can use the principles and their application examples as valuable suggestions for solving their own problems.

The "Contradiction Solving Matrix" has offered us a method of "re-using" cases of innovations and breakthroughs achieved by preceeding pioneers, for the purpose of solving our current problems. Simple accumulation of those cases in the innovators' own words (i.e. original patent documents) does not allow easy retrieval or re-use for solving new problems. TRIZ has enforced, in describing the problems and their solutions, to use a fixed framework of such a set of abstract terminology, i.e. contradictions among the 39 aspects for the problems and the 40 principles for solutions. This enforcement has allowed to represent and classify a huge number of patents in a standard way, and has resulted in a very condensed set of know-hows in a form easy to reuse.

3.6 Standard menthods for improving systems

For innovatively improving a technical system, TRIZ advises engineers to functionally analyze the system and to focus the attention onto the essencial part of the system. The essencial part is represented in either of the following two simple schemes:

(a) Object 1 ---- (Action) ----> Object 2   (b) Object -----> Property to be measured

For each of these simplified systems, standard methods of problem solving have been classified and shown in abstract schemes. At the top level, the standard methods are:

For solving (a): Methods by use of interactions with additives (either substances or "Fields")
Methods of generating/eliminating/multiplying "Fields"
For solving (b): Methods of using marks for measurment
Methods for detouring

These methods are further classified into 76 standard methods in total. The standard methods are explained with shematic figures and many examples.

3.7 Algorithm for solving inventive problems (ARIZ)

TRIZ has developed many more techniques for problem solving. They include:

Consideration of Final Ideal Result: To consider an extreme ideal system satisfying the objective, to think of barriers prohibiting the realization of it, and to clarify the technical contradictions.

Substance-Field Analysis (or Su-Field Analysis): To represent the function of the current object system in a symplified scheme of "substances" and "Fields", and to consider ways of system improvement by using transformations of the scheme representation. (Related to the method discussed in the subsection 3.6.)

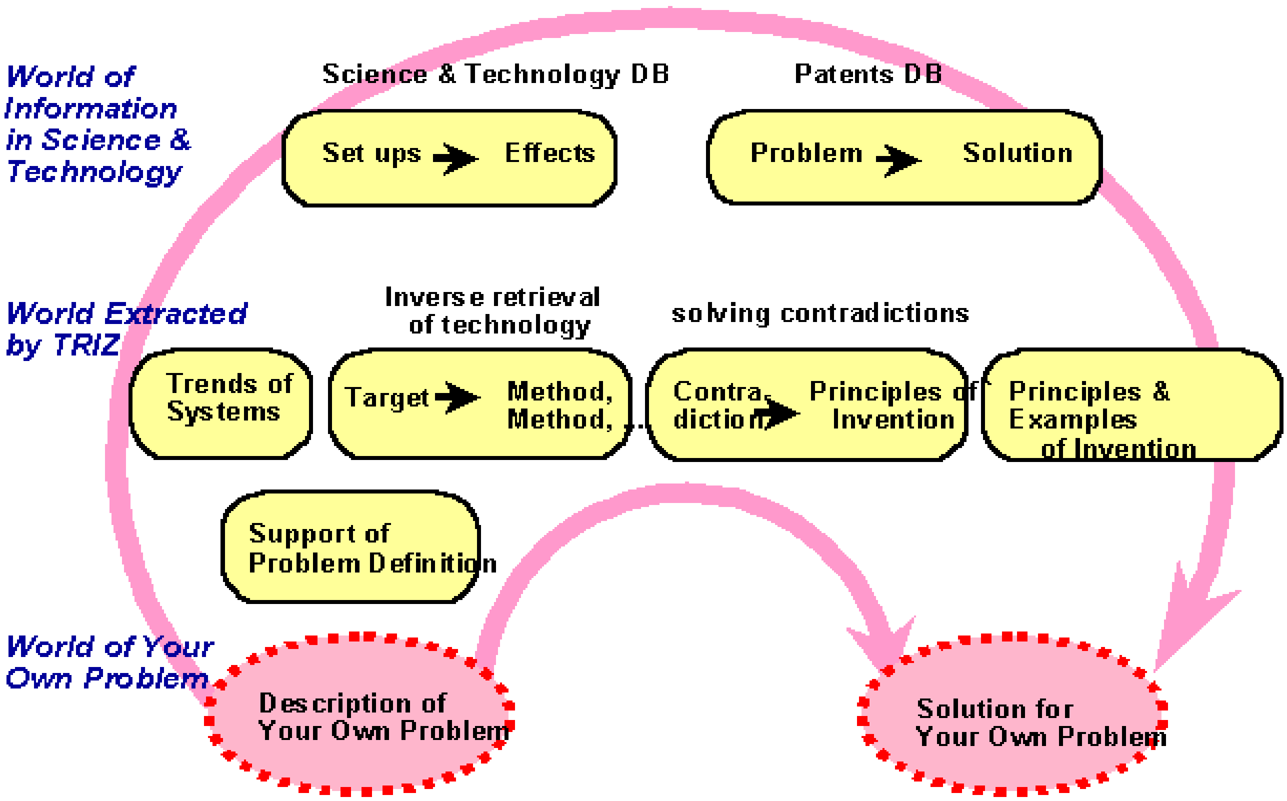
Physical Contradiction and its solution: The problem of the technical system may further be analyzed to reach a logical dilemma (or called "Physical Contradiction" in TRIZ), such as "seen" and yet "not seen". For these "Physical Contradictions", TRIZ has already found a number of standard ways of solution; they typically include spatial separation and time separation of the contradictory states.

Furthermore, containing all the methods described above in sections 3.1 through 3.7, an overall method for problem solving in TRIZ has been presented and named **"ARIZ"** (i.e. "Algorithm for Inventive Problem Solving"). It is a complex method having many iterative steps. ARIZ has several versions which have been modified and transformed little by little during its history of development. The present author is wondering whether these ARIZ algorithms are indeed effective and whether such complex systematization and formalization is appropriate for real applications; thus the author will not discuss here on them any further.

3.8 Summary of the TRIZ methodology of problem solving

Summarizing the above discussion of problem solving methods in TRIZ, the overall structure of the TRIZ methodology can be illustrated by the scheme shown in Fig. 1.

TRIZ Methodology for Problem Solving



The upper row in the figure shows the world of information formed by the whole system of science and technology in the traditional way. The world accumulates a huge amount of information (or databases) of the principles, expressed in the scheme of "from settings to effects", in a wide range of fields of science and technology. It also accumulates a huge volume of individual records of technical improvement/innovation, which are described in the scheme of "from a problem to a solution"; they typically include patent databases and paper reference databases.

The bottom row, on the other hand, represents the world of an individual engineer facing his own technical problem. The engineer has his specific problem which he wants to solve. The first task for him is to describe his system in the problem and to clarify the problem itself. Then he wants to find appropriate solutions for his problem; how can he proceed?

For this situation, TRIZ has offered several important methods as the keys to the problem solving, as shown in the middle row of Fig. 1. They include: - recognition of the trends of technology evolution, - inverse retrieval of technological means from goals, - expressing the problem as the contradiction between two aspects and obtaining principles of invention as hints by using "Contradiction Solving Matrix", and - principles of invention and practical examples of their applications. TRIZ also offers methods to support the engineer to make his own problem clearer and to guide him to the world of the TRIZ methodology. By offering all these methods, TRIZ encourages the engineers to solve their own technical problems by fully utilizing the information of the world of science and technology.

4. Software Tools for TRIZ

4.1 Invention Machine's TechOptimizer

The present author have used and mastered a software tool, TechOptimizer Professional Edition Version 2.51 developed by Invention Machine Corporation. This software works smoothly under Windows95 on a notebook PC, and implements all the features of TRIZ discussed in the subsections 3.1 through 3.6. Its component modules are listed below with brief description of their functions:

Prediction Module:	trends of evolution of technical systems (see sections 3.1 and 3.2), standard methods for improving a system (see section 3.6)
Effects Module:	inverted database of principles (or "effects" in TRIZ) in science and technology and their application examples (see section 3.3)
Principles Module:	principles of invention and their application examples (see section 3.4), Contradiction Solving Matrix (see section 3.5)
TechOptimizer Module:	functional analysis of a system, management of problem solving process, and reporting
Feature Transfer Module:	tranferring features between systems

This software implements principles and application examples in a wide range of field in science and technology; they include: geometrical, mechanical, thermal, optical and electoro-magnetic wave, electrical, magnetic and electro-magnetic, substances and materials, interaction between substances and "Fields", chemical, and elemental particles. The examples of technical application mostly describe those in old days before 1970, but in the field of micro-electronics a large number of examples of up-to- date techniques have been newly added to the Version 2.51. Oldness of the examples in TRIZ documents has been criticized very often; in commercial software tools, however, the examples have recently been and is now being made up-to-date ellaborately. (IMC's new software, i.e. IM Phenomenon, should also be noted in this context.)

TechOptimizer works so smoothly that users do not need to wait in retrieving various information. Each principle, effect, or example contains a color illustration and is explained in a plain and concise way. (The software now uses English language; a Japanese version is scheduled to be on sale at the end of this year 1998 [15].) Users may feel the contents of the databases unsatisfactory in the fields of their own speciality, but can learn very much from those in the fields beyond their speciality.

4.2 Experiences of trials and applications

The present author learned this software tool by himself for about a month, trying various functions and reading the contents of databases, and then tried to apply it to solve a real problem. One problem was chosen from several real problems suggested by a number of research groups for their possible trials. "How to cool a heat- generating component connected with a hinge" was the problem. This was not in the field of the author's speciality. Actually working on the problem on the tool for full one day, I found good and widely applicable solutions, which I suppose would contain some patentable ideas. And after spending half a day for writing, I handed a proposal report to the manager of the relevant research group. In this actual experience, the TRIZ software contributed to me especially in the following three ways: - it guides me to the essence of the problem through the functional analysis of the system, - it teaches me the principles and application examples of the heat-pipe cooling method (which I was not so familiar) through the databases, and - it stimulated me to reach a solution by reading a large number of principles and examples even though most of them are not so much relevant to the present problem. Through this actual experience of application, I definitely realized that the TRIZ software tool, i.e. TechOptimizer, was indeed useful in real applications and that the TRIZ methodology was offering us a solid base for technical problem solving.

5. Introducing TRIZ into industry

As discussed so far, TRIZ offers us a new and important methodology for technology development and technological innovation. However, if we try to introduce it into industry, we meet much difficulties mostly because TRIZ is hardly known yet in Japan. Questions and skepticisms which we often meet in the actual fields in industries are listed below, together with some advices for overcoming them.

(a) Though being upraised as "super-invention method", isn't it just a propaganda without any real usefulness? ---

TRIZ is not a trick. For resolving this kind of skepticisms, we need to show such people introductory articles and basic textbooks and to achieve steady penitration of basic ideas of TRIZ.

(b) Isn't an technique developed in USSR during the days of the Cold War too old to be of any use today?! --

The fundamental idea of TRIZ is important and useful as a framework of methodology. Since no practical means have been established in the western countries for improving technical creativeness, the TRIZ methodology is fresh and unique. It is important even now to understand and introduce the essence of TRIZ.

(c) If the databases do not contain the descriptions and examples of up-to-date techniques in our own speciality field, they will not be useful for ourselves. --

The main purpose of using TRIZ is not learning new technologies but obtaining or generating new ideas for solving our own technical problems. Examples in other fields, especially basic and typical examples, are valuable for this purpose. It is of course desirable and necessary to make the technology explanations up-to-date in the whole area ; this improvement should be achieved not only by the developers of TRIZ software tools but also by the user industries.

(d) We have rarely seen reports of successful applications of TRIZ to real problems. Has TRIZ been verified? --

Since the experiences of TRIZ are still short in the western countries, and since the firms do not like to publicize their proprietary technical innovations, good case-studies are reported very rarely. Nonetheless, there appeared some reports in TRIZ user meetings and conferences. For example, the case-study paper reported by Ford Mortor Company [16] is excellent to learn. In this case, they eliminated the noise (i.e., squeeking and buzzing noises) at the moldings (or sealing) of the windshield glass of an automobile. This problem remained unsolvable for several years, and was finally solved by applying TRIZ. This paper describes in detail the overview of the project and the thinking processes for the problem solving.

(e) Does TRIZ work without a software tool? --

Understanding the essence of TRIZ is more important than using a software tool. If you master the ideas of TRIZ, you can actively use it without a software tool and without being restricted to the formal process. A software tool is of course helpful and effective, as discussed in section 4.2.

(f) Even though a software tool is installed in our company environment, we do not have time to learn how to use it effectively. --

It is more appropriate to train people to understand the essence of the TRIZ methodology first. Good textbooks and manuals of the tools are necessary. And, from a more practical view, the existence of pioneer(s) in the same company is most helpful for reducing this kind of barrier.

(g) In the daily development activities, we are too busy to introduce new technical methodology. --

It is important and necessary to bring up a few core members in a company, as pioneers for introducing new technology. These members should challenge to solve some suitably selected real problems with TRIZ; such an experience of success is most convincing in the company.

(h) Is TRIZ useful in research laboratories or in manufacturing departments? --

It can be and should be used at any place where people want to solve technical problems. TRIZ can be useful at various phases of R&D including - initial planning stage of a technical project, - design generation stage, - the stage of problem solving for fixing any technical trouble, - patent application preparation stage for making the patent wider and stronger. For these different stages, TRIZ should be used with some proper adjustment in practice.

(i) Is TRIZ really helpful? --

Yes, helpful! The people who ask this kind of question after lengthy discussions, however, will not believe TRIZ unless they really experience it by themselves. The present author listened and read about TRIZ to understand it, and actually tried to apply it, and now believes in the effectiveness of TRIZ. If you feel some interest in TRIZ, why don't you listen and read about TRIZ, and try to apply it by yourself? The firms should set up proper trial environments.

Reviewing the questions and difficulties discussed above, the present author notices that they are not the problems for individual persons or companies who are going to introduce TRIZ. We should solve them in a wider scope.

The TRIZ methodology offers a powerful method and guiding principles for the technology innovations in the future. The movement of introducing and promoting TRIZ will give as great an impact on the technology and industry as the quality control movement have given so far for these several decades. A part of big industries in USA already have a few years of experiences of introducing TRIZ, and have begun to generate successful applications. (In Ford Motor Company, for example, its quality control team have the experiences of four years of using TRIZ, and by forming a project team joint with object technology specialists have solved real problems [16].) Now, in Japan, we should also bring up pioneers, make textbooks, make good software tools, form good real application projects, make successful real cases, and set up open forums of information exchange; as an overall effect of all these endeavors we should make the general understanding of TRIZ higher.

6. Education/Research and TRIZ

TRIZ is also going to give an important impact on the education and research in science and technology. The target of education of science must not only for students/pupils to understand what they are taught but rather for them to observe the world, think and generate ideas, and do experiments and trials for themselves. The education should guide them to use science and technology for solving problems around them, for challenging new tasks, and for creating something new by overcoming contradictions. The "technology-oriented" philosophy of TRIZ is indeed suitable for the students and pupils to build up such attitude and to master such ways of thinking.

One point of warning should be worthwhile in applying TRIZ. It is not an intention of TRIZ to apply tables and software tools of TRIZ for problem solving in a 'mechanical' way. If one regards the results of TRIZ achieved so far in the history as solid, unchangeable doctorines, the problem solving with TRIZ would never be creative and would turn into thoughtless, non-creative work. One should understand the real essence of TRIZ, and then use it with liberated, flexible, and creative mind. The real aim of learning

TRIZ is to study the cases of creative technology developments in the history and to train oneself to be able to think by oneself in creative ways on such a basis.

Further research tasks of TRIZ should include the followings:

(a) To extend the application fields of TRIZ into the fields related to information, biology, and social activities such as services. (b) To re-examine the frameworks and classification categories in TRIZ, especially in relation to the above extension of application field. (c) To implement wider range of TRIZ methods in software tools, (d) By comparing and combining TRIZ with various problem solving methods and designing methods, to make it an even more effective methodology. (e) To establish a leading philosophy for the movement of introducing and promoting TRIZ for technology innovation.

In the current situations of increasingly hard competition in technology development in the global scale, these research tasks should be important; the future of technology and industry will depend on how people utilize and extend TRIZ.

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