Accelerate Innovation with TRIZ

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"Keep on the lookout for novel ideas that others have used successfully. Your idea has to be original only in its adaptation to the problem you're working on".

Thomas Edison (1847-1931)

Today, evolution of science and technology has reached tremendous rate. Major breakthroughs in sciences, technology, medicine, and engineering make our everyday life more and more comfortable. Today it is nearly impossible to find an engineer who does not use complex mathematical tools for formal modeling of design products, CAD systems for modeling and drawing, electronic handbooks and libraries, and the Internet to find necessary data, information, and knowledge.

But what happens when we need to invent a radically new solution? To generate a new idea? To solve a problem when no known problem solving methods provide results? To predict and roadmap future generations of products and technologies? What tools and methods do we have to cope with these situations?

When it comes to producing new ideas, we still rely on thousands-years-old trials and errors method. It is good when a new brilliant and feasible idea is born quickly. But what price usually we have to pay for it? Wasting time, money and human resources. Can we afford this today, when competition is accelerating every day and capability to innovate becomes a crucial factor of survival? Certainly, not. But if there is anything that can help?

Fortunately, the answer is “yes”. To considerably improve innovative process and avoid costly trials and errors, leading innovators use Systematic Innovation: a scientifically-based methodology build on TRIZ. Relatively little known outside the former Soviet Union before the 1990^{th}, TRIZ has quickly gained popularity at world-leading corporations and organizations, among which are DSM, Hitachi, Mitsubishi, Motorola, NASA, Procter & Gamble, Philips, Samsung, Siemens, Unilever, to name a few. This paper presents a brief overview of TRIZ and some its techniques with focus on technological applications of TRIZ.

TRIZ origins

TRIZ (a Russian acronym for the Theory of Solving Inventive Problems) was originated by the Russian scientist and engineer Genrich Altshuller. In the early 50^{th}, Altshuller started massive studies of patent collections. His goal was to find out if inventive solutions were the result of chaotic and unorganized thinking or there were certain regularities that governed the process of creating new inventions.

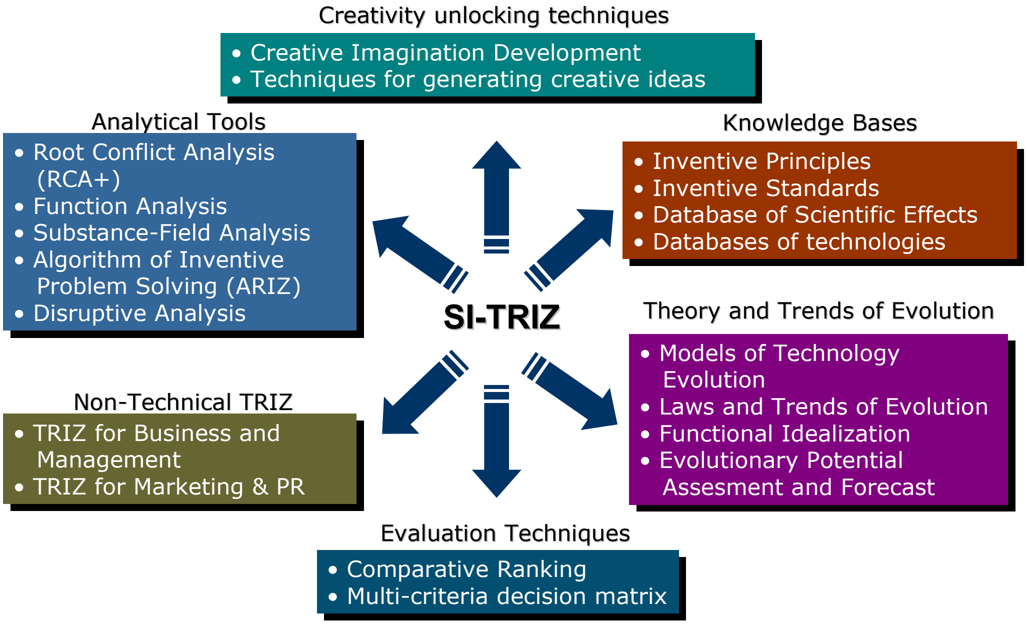
After scanning approximately 400.000 patent descriptions, Altshuller found that only 2% of all patented solutions were really new, which means that they used some newly discovered physical phenomenon – such as the first radio receiver or photo camera. 98% of patented inventions used some already known physical or technological principle but were different in its implementation (for instance, both a car and a conveyer may use the air cushion). In addition, it appeared that a great number of inventions complied with a relatively small number of basic inventive principles. Therefore, 98% of all new problems can be solved by using previous experience - if such experience is presented in a certain form, for instance as principles or patterns. This discovery had given impact on further studies which let to discovery the basic principles of invention.

More than thirty years of research resulted in revealing and understanding of origins of an inventive process, and formulation of general principles of inventive problem solving. At the same time, the first TRIZ techniques were developed.

Later, many researchers and practitioners worldwide united efforts and largely extended Altshuller's approach with new methods and tools. Today, a number of companies and universities worldwide are involved to enhancing TRIZ techniques and putting them to the practical use.

Modern Systematic Innovation

Modern TRIZ offers a number of practical techniques, which help to analyze existing products and situations, extract core problems, reveal potential opportunities for evolution, and generate new solution concepts in a systematic way. In addition, the use of the techniques and tools is organized in Systematic Innovation Process, which structures the use of the techniques and tools according to the desired outcome.



Modern Systematic Innovation is undoubtedly a large volume of knowledge. It includes both techniques for situation analysis and idea synthesis, such as Root Conflict Analysis, Evolutionary Potential Analysis, Function Analysis, Inventive Principles, Patterns of standard solutions, Databases of physical, chemical and geometrical effects, Trends and Patterns of technology evolution and Algorithm of Solving Inventive Problems (also known as ARIZ), etc.

Systematic Innovation is not easy to learn, and it takes considerable time to reach excellence with TRIZ and Systematic Innovation. However, most of its techniques can be learned and applied independently, thus simplifying the implementation processes.

Common Patterns of Inventions

Let us have a look as how TRIZ works by comparing two problems.

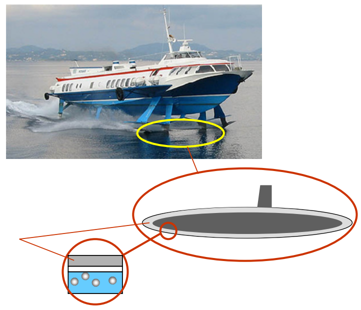
The first problem: how to protect a hydrofoil moving at a high speed from hydraulic cavitation, which results from collapsing air bubbles which destroy the metal surface of the foil? And the second problem: how to prevent orange plantations from being eaten by apes if installing fences around the plantations would be too expensive?

Are these problems similar? At a first glance, not at all.

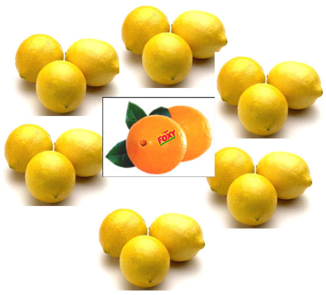
However from the TRIZ point of view, they are similar, because both the problems result in identical problem patterns. In both cases, there are two objects that interact with each other, and the interaction results in a negative effect.

In the first situation, the water destroys the foil, in the second – an ape eats an orange. And there is no visible and simple way to improve the situations. To solve this type of problems, TRIZ recommends introducing a new component between the existing ones. Well, but how? We tried it, and it did not work – fences are still expensive. What did the best inventors do in such cases? Analysis of the best inventions showed that yes, we should introduce a new object between the two, but this new object has to be a "modification" of one of the two existing objects!

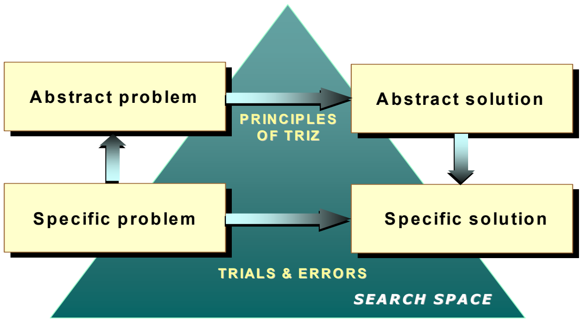
In TRIZ, the word "modification" is understood in broad terms. It can be a change of aggregate state of a substance, or a change of color, structure, etc. What can a modification of the water be? Ice. A refrigerator is installed inside the foil and freezes the water thus forming an ice layer over the foil surface. Now, the cavitations destroy the ice, which is constantly rebuilt.



What can be the "modification" of the orange? A lemon! The ape does not like the taste of the lemon so it was proposed to surround the orange plantations with lemon trees.



As seen, TRIZ suggests recommendations on solving new problems accordingly guidelines drawn from previous experience of tackling similar problems in different areas of technology. Well-known psychological methods for activation of thinking (brainstorm, for instance) or traditional design methods aim at finding a specific solution to a specific problem. It is difficult – too much information has to be browsed and there is no guarantee that we move in a right direction. TRIZ organizes translation of the specific problem into abstract problem and then proposes to use a generic principle or a pattern, which is relevant to the type of the problem. As clear, by operating at the level of conceptual models, the search space is significantly reduced that makes it much easier to find the needed solution concept among the patterns TRIZ offers.



Invention is a result of solving a contradiction

Another discovery of Altshuller was that every inventive solution is a result of elimination of a contradiction. The contradiction arises when two mutually exclusive requirements are put on the same object or a system. For example, the walls of a space shuttle have to be lightweight to decrease the mass of the shuttle when bringing it to the orbit. However, this cannot be done by simply decreasing the thickness of the walls due to the thermal impact when entering the Earth atmosphere. The problem is difficult due to the necessity to have two contrary values of the same parameter: according to the existing solutions, the walls have to be both heavyweight and lightweight at the same time.

When a designer faces a contradiction that cannot be solved by redesigning a product in a known way, this means that he faces an inventive problem, and its solution resides outside a domain the product belongs to. One known method to solve problems with contradicting demands is to find a compromise between two conflicting parameters or values. But what to do if no optimum can be reached that solves the problem? TRIZ suggests solving problems by removing the contradictions.

A comprehensive study of patent collections undertaken by TRIZ researchers and thorough tests of TRIZ within industries have proven the fact that if a new problem is represented in terms of a contradiction, a relevant TRIZ principle has to be used to find a way to eliminate the contradiction. The principle indicates how to eliminate the same type of the contradiction encountered in some area of technology before

A collection of TRIZ inventive principles is the most known and widely used TRIZ problem solving technique. Each principle in the collection is a guideline, which recommends a certain method for solving a particular type of an inventive problem. There are 40 inventive principles in the collection, which are available in a systematic way according to a type of a contradiction that arises during attempts to solve the problem. Examples of the inventive principles are:

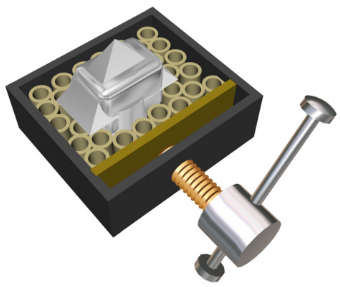
- *Variability Principle*: Characteristics of the object (or external environment) should change such as to be optimal at each stage of operation; the object is to be divided into parts capable of movement relative to each other; if the object as a whole is immobile, to make it mobile or movable.
- *Segmentation Principle*: Divide the object into independent parts; make the object such that it could be easily taken apart; increase the degree of the object's fragmentation (segmentation). Instead of non-fragmented objects, more fragmented objects can be used, as well as granules, powders, liquids, gases.

Access to the principles is provided through a matrix, which consists of 39 rows and columns. Positive effects that have to be achieved (so-called "generalized requirements") are listed along the vertical axis while negative effects, which arise when attempting to achieve the positive effects, are listed along the horizontal axis. A selection of a pair of positive and negative effects indicates which principles should be used to solve the problem.

	what gets worse as a result of improvement				
	Speed	Force	Stress	.....	Stability
what to improve					
Speed		13,28,15,19	6,18,38,40	.....	28,33,1
Force	13,28,15		18, 21,11	.....	35,10,21
Stress	6, 35,36	36,35,21		.....	35, 2,40
.....	.....	....	....		.....
Stability	33,28	10,35,21	2,35,40	.....	

A matrix of principles for engineering contradiction elimination. Numbers indicate what principles have to be used: 1 - Segmentation; 2 - Removing; 10 - Preliminary action; 13 - Other way round; etc.

For instance, a problem is that we need a device to hold an easily breakable part, which has a complex shape. If we use a traditional vise with clamping teeth, the contradiction is the following: to hold the part reliably (positive effect), we have to apply sufficient forces. However, the forces are distributed non-uniformly and the part can be damaged (negative effect).



To solve this type of contradictions TRIZ recommends using "Segmentation Principle" mentioned above. So we must to segment the clamping teeth. It can be done by replacing the teeth with a chamber filled with small-sized elastic cylinders and to compress the cylinders by moving the chamber wall. As a result, the contradiction is eliminated: a part of almost any shape can be hold by such the device and the forces will be distributed uniformly.

Physics for inventors

Sometimes, just to be capable of seeing things different is not enough. New breakthrough products often result from a synergy of non-ordinary view of a problem and knowledge of the latest scientific advances. TRIZ suggest to search for new principles by defining what function is needed and then finding which physical principle can deliver the function.

Studies of the patent collections indicated, that inventive solutions are often obtained by utilizing physical effects not used previously in a specific area of technology. Knowledge of natural phenomena often makes it possible to avoid the development of complex and unreliable designs. For instance, instead of a mechanical design including many parts for precise displacement of an object for a short distance, it is possible to apply the effect of thermal expansion to control the displacement.

Finding a physical principle that would be capable of meeting a new design requirement is one of the most important tasks in the early phases of design. However, it is nearly impossible to use handbooks on physics or chemistry to search for principles for new products. The descriptions of natural phenomena available there present information on specific properties of the effects from a scientific point of view, and it is unclear how these properties can be used to deliver particular technical functions.

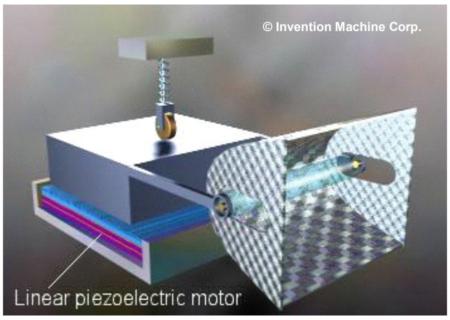
TRIZ Catalogues of the effects bridge a gap between technology and science. In TRIZ Catalogues, each natural phenomenon is identified with a number of technical functions that might be achieved on the basis of the phenomenon.

The search for effect is possible through formulation of a problem in terms of a technical function. Each technical function indicates an operation that can be performed with respect to a physical object or field. Examples of the technical functions are "move a loose body" or "change density ", "generate heat field", and "accumulate energy".

Function	**Effects**
To separate mixtures	Electrical and magnetic separation. Centrifugal forces. Adsorption. Diffusion. Osmosis. Electroosmosis. Electrophoresis, …
To stabilize object	Electrical and magnetic fields. Fixation in fluids which change their density or viscosity when subjected to magnetic or electric fields (magnetic and electro-rheological liquids). Jet motion. Gyroscopic effect,

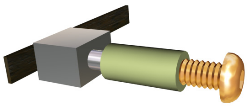
Fragment of the pointer to physical effects

One of the first patents obtained with the use of TRIZ outside of the former ex-USSR was issued to Eastman Kodak. Engineers used the TRIZ Catalogue of effects to develop a new solution for camera's flash. The flash has to move precisely to change the angle of lightning. A traditional design includes a motor and mechanical transmission. It complicates the whole design and makes it difficult to precisely control the displacement. A newly patented solution uses piezoelectric effect and involves a piezoelectric linear motor, which is more reliable and easier to control.

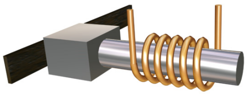


Another example illustrates the use the TRIZ Catalogues of physical effects. How to accurately control the distance between a magnetic head and a surface of a tape in a special high-performance digital tape recorder, where the gap should be different during different recording modes and a change must be produced very quickly?

In the TRIZ Catalogue to physical effects, the function "to move a solid object" refers to several effects. One of the effects is the physical effect of magnetostriction: a change in the dimensions and shape of a solid body (made of a specific metal alloy) under changing the intensity of applied magnetic field. This effect is similar to the effect of thermal expansion, but it is caused by magnetic field rather than thermal field. The magnetic head is fixed to a magnetostrictive rod. A coil generating magnetic field is placed around the rod. A change of the magnetic field's intensity is used to compress and extend the rod exactly to the required distance between the head and the recording surface.



Picture A



Picture B

Solving a problem with TRIZ pointer to physical effects. Picture A: Old design with a screw, Picture B: new design with a magnetostrictive rod and a electromagnetic induction coil

Trends of the Technology Evolution

Altshuller also discovered that the technology evolution is not a random process. Many years of studies revealed that there are a number of general trends governing the technology evolution no matter what area the products belong to.

The practical use of trends is possible through specific patterns. Every pattern indicates a line of evolution containing particular transitions between old and new structures of a design product. In total, TRIZ presents nine trends of the technology evolution. One of the trends – Evolution of systems by transitions to more dynamic structures is shown at the figure below.

The significance of knowing the trend of the technology evolution is that they can be used to estimate what phases of the evolution a system has passed. As a consequence, it is possible to foresee what changes the system will experience. And, what is more important, produce the forecast in specific technological terms.

Evolution Phase	Example	Illustrations
Solid object	Traditional mobile phone.	
Solid object divided into two segments with non-flexible link	Mobile phone with a sliding part which contains a microphone.	
Two segments with a flexible link	Flip-flop phone of two parts.	
Many segments with flexible links	Phone which is made as a wrist watch: its bracelet is made of segments, which contain different parts of the phone.	
Flexible object	A flexible liquid-crystal film, which can be rolled in and out and stored inside a plastic cylinder (serves also as a mobile videophone).	

Patterns of increasing the degree of system dynamics

Practical value of TRIZ

Today, TRIZ and TRIZ software are used in about than 5000 companies and government organizations across the globe. In general, the use of TRIZ provides the following benefits:

1. Considerable increase of productivity in searching for new ideas and concepts to create new products or solve existing problems. As estimated by the European TRIZ Association experts on the basis of industrial case studies, these processes are usually accelerated 5-10 times. Sometimes, new solutions became only possible from using TRIZ.
2. Increasing the ratio "Useful ideas / useless ideas" during problem solving by providing immediate access to hundreds of unique innovative principles and thousands of scientific and technological principles stored in TRIZ knowledge bases.

3. Reducing risk of missing an important solution to a specific problem due to a broad range of generic patterns of inventive solutions offered by TRIZ.
4. Using the scientifically-based trends of technology evolution to examine all possible alternatives of future evolution of a specific technology or a design product and select the right direction of the evolution.
5. Leveraging intellectual capital of organizations via increasing a number of patented solutions of high quality.
6. Raising the degree of personal creativity index by training personnel to approach and solve inventive and innovative problems in a systematic way.

TRIZ is the most powerful and effective practical methodology of creating new ideas available today. However, TRIZ does not replace human creativity – instead, amplifies it and helps to move to the right direction. As proven during long-term studies, everyone can invent and solve non-trivial problems with TRIZ.

TRIZ in the world

Today, TRIZ is widely recognized as a leading method for innovation worldwide. Leading Japanese research organization, Mitsubishi Research Institute, which unites research efforts of 50 major Japanese corporations, invested US$ 14 mln to bring TRIZ and TRIZ-relates software to Japan.

In 1998, the TRIZ Association was formed in France, which involves such participants as Renault, Peugeot, EDF, Legrand. In South Korea, LG Electronics uses TRIZ to solve major inventive problems and develop new products. Motorola purchased 2000 packages of TRIZ software, while Unilever has recently released information about investing US$ 1.2 mln into purchasing TRIZ software and using it as a major tool for achieving competitive leadership.

In 2000, the European TRIZ Association was established, with a global coordination group of 26 countries including representatives from Japan, South Korea, USA.

In 2004, Samsung Corporation recognized TRIZ as a best practice for innovation after a number of successful TRIZ projects, which resulted in total economic benefits of 1.5 billion Euros during three years.

Small and medium-sized companies benefit from using TRIZ as well. TRIZ helps to define and solve problems within short time and with relatively small efforts thus avoiding large R&D investments for approaching solutions and finding new design concepts.

Further information

More information about TRIZ-related issues, products and services can be obtained from info@xtriz.com, phone +31-53-4342884, fax +31-53-4342870; email info@xtriz.com

A good starting point, the Online TRIZ Journal is available on the Internet: http://www.triz-journal.com.

Selected Literature

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About the author

Valeri Souchkov, has over 18 years of experience with training, facilitating and implementing Systematic Innovation worldwide. He was one of the first who started promotion of TRIZ outside the former Soviet Union. His major research and practical background resides in the area of knowledge-based innovation. He was a co-founder of Invention Machine Labs in 1988 (currently Invention Machine Corporation, a global leader in Knowledge-Based Innovation software), as well a co-founder and Research Coordinator of European TRIZ association. Among his clients are ASML, BASF, Philips, Siemens, Unilever. He can be reached at valeri@xtriz.com.