RESEARCH ON AN EXPERT SYSTEM FOR TRIZ METHOD APPLYING

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ABSTRACT

TRIZ method is a powerful creative technique, used in the most diverse and competitive fields of engineering, and, among others, in value analysis / engineering. Psychological creativity tools, including brainstorming and related methods, have the disadvantage that they have unpredictable and unrepeatable results. Unlike these TRIZ provides repeatability, predictability, reliability and algorithmic approach. One of the fundamental concepts of TRIZ is that contradiction which must be removed from a technical system. It was found that there are 39 standard technical features that could lead to contradictions in the technical system analysis and 40 inventive principles that can resolve generated conflicts creatively. For this a method was developed to correlate the conflicts with inventive principles known as the "contradictions matrix". On the other hand, a problem in a particular area, it is a good candidate for expert system technology if it meets several criteria. One of the most important activities that precede construction of an expert system is knowledge representation, among the most popular models of knowledge representation being decision tables. The contradictions matrix can be transformed in decision tables with standard structure. An expert system for TRIZ method should, based on the 39 parameters that may in conflict, choose the inventive principles from contradictions matrix and then for each inventive principle chosen provide examples and afferent details and other related items resulting from experience.

Keywords: TRIZ method, inventive principles, contradictions matrix, expert system, decision table.

1. TRIZ method use

1.1. TRIZ method description

TRIZ is the Russian acronym for the phrase "Teoriya Resheniya Izobretatelnikh Zadatch" (in english is used acronym TIPS from "Theory of Inventive Problem Solving"), representing a powerful creative technique, based on empirical data that can provide solutions for a wide range technical and non technical issues.

Russian engineer and scientist Genrikh Altshuller (1926 Tashkent, USSR - 1998 Petrozavodsk, Russia) and his colleagues have developed the method of the former Soviet Union between 1946 and 1985. To 1969 Altshuller had analyzed summaries of approximately 40 000 patents (currently the number of patents considered reached more than three million) and discovering certain patterns, concluded that the development of a technical system is not a random process but is governed by objective laws.

In paper [1] TRIZ method is presented as a method that "opens up the pragmatic orientation of engineering creativity, represented more modest by value analysis (engineering) and by numerous analitico-matricial methods (e.g. arrays of discovery). The ambition that feeds this trend is to manufacture a machine (almost) axiomatic to diagnose and solve any problems, but mainly technical issues / technology... It is to be stated unequivocally that the ambition to make TRIZ ultimate and complete machine to diagnose and solve problems is an illusion ... at least until the inductive inference, which is part of any inference heuristic will be demonstrated that other than logic and subjective probable uncertain".

Apart from the ambition to be a tool to diagnose and solve any problems, TRIZ method results are considerable. So after exceptional achievements in soviet cosmonautics and aviation, with the end of the Cold War the circuit falls into the international TRIZ by emigrants from the former Soviet Union and makes, especially in the U.S., subject to successful applications in the most diverse and competitive fields of engineering. Publications as "Fortune 100 Companies" notes systematically a phenomenal increase in productivity and quality of solutions that have been designed by the TRIZ method. In 1989 the International TRIZ Association was first established that had as president Altshuller himself, the inventor of the method. Meanwhile the number of TRIZ institutes, associations and publications increases steadily just as the number of users and beneficiaries, and the applications are diversifying and expanding in fields other than technical / technological[1].

TRIZ use is increasingly common in Six Sigma processes, systems project management, risk management and organizational innovation initiatives[5]. Also, TRIZ is used in the methodology of value analysis, in the creative phase, when, to answer the fundamental question "How else can be made functions?". The team must develop a wide range of ideas that provide a variety of alternative ways to achieve a particular function to improve the project value.

Top Fortune 500 companies such as Ford, General Motors, Chrysler, Eastman Kodak, Exxon, Rockwell International, Procter & Gamble, Digital Equipment, Xerox, Hewlett Packard, Motorola, BAE Systems, Boeing, Philips Semiconductor, LG Electronics, Boston Scientific Intel, Samsung, etc., are successfully using TRIZ methodology[6].

Until the spread of TRIZ, common tools were limited to brainstorming and creativity related methods, which depend on intuition and knowledge of team members. These methods are usually described as psychological methods and have the disadvantage the unpredictable and unrepeatable results because it relies on spontaneous and intuitive creativity of individuals or groups. TRIZ is a method of resolving problems that are not based on logic but on intuition and empirical data, this accelerating the project team's ability to solve problems creatively. TRIZ also provides repeatability, predictability, reliability and algorithmic approach. TRIZ research began with the assumption that there are universal principles of creativity, principles which form the basis for innovation. If these principles could be identified and taught the creative process would become more predictable and productive[7].

1.2. Resolving of technical systems contradictions using inventive principles

One of the fundamental concepts of TRIZ is that contradiction which must be removed from a technical system. Objective laws governing the evolution of all technical systems show that the improvement of any system parameter that causes the deterioration of another parameter of the system, which leads to a conflict. This conflict will lead to an eventual improvement in the less developed part of the system, such a process would be launched to approximate the ideal condition system[8]. This is exactly what TRIZ method aims, namely to "transfer" the system towards the ideal state, which could be a state where there are no mechanisms, but only functions[2]. Example: A meat processing plant from South America send its products to the United States. During transport, to keep meat frozen refrigeration was needed, which required the installation of refrigeration systems on cargo planes. When competition increased the factory owner has sought solutions to reduce the cost of delivery. A review showed that a solution could remove the refrigeration system to increase the amount of meat carried. Consequently from that moment on the planes were able to fly at an altitude of 4500-7500 m where the air temperature below 0^{o}C obviates the refrigeration system[8].

TRIZ recognizes two categories of contradictions:

1. Technical contradictions, named so because they appear within the technical systems to compromise the cause of classical engineering[7]. In this case the desired state of the system cannot be achieved because a certain part of the system allows. In other words, improving one parameter is accompanied by worsening another, as can be seen in the following examples:
    a) increase in the mechanical strength is accompanied by increased consumption of material
    b) increase of bandwidth in a communications system is accompanied by increased energy consumption
    c) personalizing a service for each client complicates the Service system.
    d) increasing dimensions of an organization is beneficial in terms of access to resources but this affects its agility and ability of change.
    e) the existence of a department is justified by the functions they perform for the company but on the other hand, it costs by charging their own operating costs
2. Physical contradictions, also called "inherent" contradictions occur when two opposite contradictory properties, are requested from the same component of a technical system or from the technical system itself. There are various methods to solve the physical contradictions (separation of conflicting requirements in time and space, physical change of a substance, etc.). Example: the landing gear must be present in an airplane during landing and takeoff, but it should not be present during the flight due to increased resistance to air. The Physical Contradiction - landing gear must be present and absent both - is solved by separating the time requirements, which require that the landing gear is retractable[8].

Altshuller concluded that, in practice, there are 39 standard technical features that could lead to conflict within the system analysis technique, characteristics which he called "engineering

parameters”.
Traditionally, the technical contradictions are resolved through compromise, leading to what is called optimization. TRIZ seeks to eliminate contradictions without using compromise[2].
Altshuller identified 40 principles, which he called "inventive principles, through which most technical contradictions may be resolved. Also to solve physical / inherent contradictions TRIZ research has identified four principles of separation. The inventive principles have broad applicability, with a little imagination being able to be used in almost every industry. Therefore, when solving a problem of conflict of innovative services, products or intangible processes, intellectual effort is needed to interpret the inventive principles not necessarily in a restrictive, mechanistic, physical way, but creatively, broadly metaphorical[2]. In [9] 40 inventive principles are accompanied by examples from technique, in [10] by examples from business and in [11] by social examples.

1.3. TRIZ method running

”The engineering creative machine” called TRIZ should have five subsystems, namely[1]

- a set of rules to interpret any particular problem in a standardized problem
- a set of standardized questions
- a standardized set of standardized problem solving
- a set of rules, all standardized of allocating procedures for solving problems to be solved
- a set of rules to retranslate solution standardized terms in the context of the particular problem.

In other presentations of the method, the term “standard problems” is replaced with “general problems”. Whatever term used, the method operates on the sequence of steps in Figure 1.

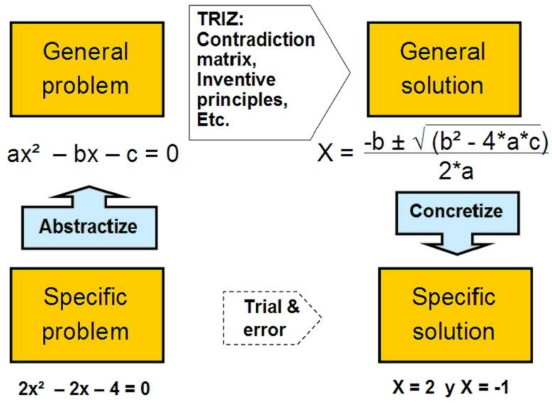

Figure 1. TRIZ method running[14]

1.4. Contradictions matrix use

To resolve contradictions in a creative way that can result from combining the 39 technical parameters, using the 40 inventive principles, Altshuller developed a method of correlating the inventive principles of conflicts known as the "contradictions matrix"(or contradictions table) presented in table no. 1.

Table 1. The contradictions matrix[2]

			Parameters (eP_c) or (eP_{c1}, ..., eP_n), which worsen as a result of improvements in other parameters							
			1	2	3	4		37	38	39
			Weight of moving object	Static weight of the object	The length of the moving object	Static object length	………	Complexity control	Level of automation	Capacity / Productivity
Parameters (eP_i) which should improve	1	Weight of moving object			15,8 29,34		…	28,29 26,32	26,35 18,19	35,3 24,37
	2	Static weight of the object				10,1, 29,35	…	25,28 17,15	2,26 35	1,28 15,35
	3	The length of the moving object	8,15 29,34				…	35,1 26,24	17,24 26,16	14,4 28,29
	4	Static object length		35,28 40,29			…	26		30,14 7,26
		………	…	…	…	…	…	…	…	…
	37	Complexity control	27,26 28,13	6,13 28,1	16,17 26,24	26	…		34,21	35,18
	38	Level of automation	28,26 18,35	28,26 35,10	14,13 17,28	23	…	34,27 25		5,12 35,26
	39	Capacity / Productivity	35,26 24,37	28,27 15,3	18,4 28,38	30,7 14,26	…	35,18 27,2	5,12 35,26	

This array consists of 39 rows and 39 columns, each row or column being allocated to one of the 39 technical parameters that could lead to conflict within the technical system analysis. In cell (i, j) located at intersection of the line *i* with column *j*, are given numbers of inventive principles to resolve the contradiction between the parameter should be improved and the parameter or parameters that are worsening as a result of improvements in the parameter i. In other words, X axis is the axis parameters which worsen because of improving the parameters of the axis Y. As a technical parameter it cannot be in conflict with itself, in the cells for which $i = j$, located on the main diagonal of the matrix does not have contradictions, and therefore no inventive principles to resolve them. Also other cells are empty and located at the intersection of rows and columns corresponding to the parameters that are not in conflict, such as for example for $i = 4$ (Static object length) and $j = 38$ (Level of automation).

When considering the conflicts within a technical system the characteristics that generate conflicts should be sought in the set of 39 parameters.

How to work with TRIZ method is as follows[figure 1]:

1. To start, we have identified the parameter to be improved (P_i) and parameter (P_c) or parameters (P_{c1},...,P_{cn}) which is in conflict with the parameter to be improved, thus stating the specific problem. The difficulty lies in the fact that conflicts are not always immediately apparent.
2. In table 1, it has to be found a pair of parameters (eP_i, eP_c) which are in conflict; (eP_i) is equivalent to (P_i) and (eP_c) or (eP_{c1},..., eP_{cn}) that equivalent counterparts of (P_c). In this way the general technical problem is formulated, that has to be approached innovatively. Here the difficult problem consists in finding which of the 39 parameters are generalized parameters identified in paragraph no 1.
3. In Table 3, the cell line located at the intersection parameter (eP_i) with his column (eP_c) or (eP_{c1}, ..., eP_{cn}) contains principles that will help finding the general solution(solutions). The inventive principles extracted do not represent the solution or the solutions of the problem. They just give some directions which should be sought innovative solutions to resolve conflict without compromise. As shown in the contradictions matrix, for a given conflict there may be several ways to search for innovative solutions. Consequently we reach the conclusion that more innovative solutions could result in a problem of conflict. You can choose one of the innovative solutions (the one that best meets a set of performance criteria), or it may propose a hybrid variant[2].
4. Getting specific solution. It is possible that some of the inventive principles suggested by the contradictions matrix be less suitable for the case study. Those principles are not necessarily taken into account. On the other hand, a mismatch may indicate that the pair of parameters that are in conflict was not properly chosen. Also, some inventive principle proposed by the contradictions matrix should not be dismissed immediately, just because it seems appropriate for the subject under consideration. A rather less obvious principle can be a source of inspiration for finding a higher level of innovative solutions. For example, when, where applications such as software, are seen as principles “32. Color change”, “35.Properties change” "may be found interesting solutions if they resort to creative thinking is beyond the psychological barrier, it moves “beyond the line”. The final result depends on the creative potential and experience of those involved and their ability to not look things rigid and narrow. This is, in fact, major barrier the way of TRIZ method superior capitalization[2].

2. Research on an expert system for TRIZ method applying

2.1. The opportunity of an expert system for TRIZ method applying

Among the typical applications of expert systems in management predicting and evaluating consequences of alternative decision-making and planning (prioritization, programming) are to be found.

From the viewpoint of knowledge management expert systems can perform the following activities[3]:

1. It multiplies the number of persons who make knowledge available
2. It combines knowledge of several experts
3. It provides expertise when experts are not available
4. It maintains expert knowledge after they leave the organization
5. It contributes to training new employees
6. It performs routine tasks such as human workers can concentrate on creative activities, a more challenging
7. It helps reduce human error

A problem in a particular area is a good candidate for expert systems technology if it meets a number of criteria. The full list of criteria to be observed that the introduction of expert systems technology to succeed, it was proposed by Frank Puppe at the University of Karlsruhe. Each criterion has a weight attached to it(a number from 0 to 10) depending on its complete application (10 points) or failure (0 points). For a potential application, the final assessment takes place by adding these weights and dividing the result by the total number of criteria taken into scoring methodology means. If the value obtained is greater than five, the application is feasible with expert systems[4].

In table 2 we suggest such a score for that list to assess the opportunity of an expert system TRIZ method. The pessimistic variant value obtained is 6.50> 5, and 7.64 in the optimistic scenario, so it can be concluded that such an expert system is appropriate.

Table 2. Opportunity estimation of an expert system for TRIZ method applying

	I. The main criteria	Scoring criteria	Pessimistic scoring	Optimistic scoring
1	the users expect great benefits in routine operations	10	-	10
2	the users expect that the size and limits of expert system to be realistic	10	10	10
3	the system project is well supported by management	10	-	10
4	the problem does not require natural language processing	10	10	10
5	the problem does not involve too much knowledge intensive	10	10	10
6	the problem is heuristic in nature	8	8	8
7	the test cases for all degrees of difficulty are available	10	-	-
8	the system can be developed through incremental methods, and the problem is divisible	7	-	-
9	the optimal solutions are not required to issue	8	8	8
10	the common solutions are not necessary (good sense) of the problem	10	10	10
11	the problem is relevant in the foreseeable future	10	-	10
12	is not essential to completion of the system shortly	7	7	7
13	the problem is easy, but not as easy for the system	8	-	8
14	there are experts available	10	-	10
15	the available expert is a recognized	10	-	10
16	the expert is available for a long time	10	-	10
17	the available expert is cooperating	8	-	8
18	the expert is easy to understand and express clearly	8	-	8
19	the expert is a reliable person with experience in expert systems projects	8	-	-
20	the wizard uses symbolic reasoning	8	-	-
21	it is difficult but not impossible, to transfer expertise	7	7	7
22	the expert problem solvers with a high cognitive competence	10	-	-
23	different experts agree that the proposed solution is better	10	-	10
24	the expert should not be creative when problem solving	10	-	-

II. Desirable criteria			-	-
1	the management supports the project and after completion	8	-	8
2	the introduction of expert system does not require much reorganization	4	4	4
3	the user can interact with expert system	4	4	4
4	the system can explain its reasoning	4	4	4
5	the questions of the system are necessary and not too many	4	4	4
6	the problem is known in advance as a problematic situation	4	4	4
7	the problem solutions are explained	4	4	4
8	the problem does not require a response time too short	5	5	5
9	the successful expert systems already exist which resemble the proposed project	8	-	8
10	the system can be used in several places at once	5	5	5
11	the problem is dangerous or at least unattractive for man	3	-	-
12	the problem involves subjective knowledge	4	-	-
13	the expert in the future is no longer available	3	-	-
14	the expert is willing to identify intellectually with the expert system	3	-	-
15	The expert does not feel insulted or treated badly	4	-	-
16	the expert knowledge used to solve the problem is structured	2	-	-
		Average	6,50	7,64

Other arguments that militate in favor of an expert system for TRIZ method applying would be:

- TRIZ methodology includes, among other things, a knowledge base[12], or an essential component of expert system is just the knowledge base
- using TRIZ method to its true potential requires at least 6 months of training and experience[2], so in these circumstances a system to perform useful work seven in terms of knowledge management is justified
- major benefits of competitive product development result in the application of TRIZ methodology of integrated planning methods for example - planning is one of the typical applications of expert systems
- TRIZ methodology relies on a table 1(contradictions matrix), table showing the inventive principles by which we can resolve the contradictions. As we shall see table 1 can be transformed into a decision table. Compared to a decision table, an expert system can provide some extra features, such as explanations by which to substantiate recommendations.

2.2. Transformation of TRIZ contradiction matrix in decision tables

The expert systems are the oldest and most well proven family of intelligent systems, especially one of their subcategories, namely, rule-based expert systems of production. Using production rules based on knowledge representation in the form of condition-action pairs such as:

IF <condition> *is satisfied*
THEN *running* <action1>
ELSE *running* <action2>

One of the most important activities that precede construction of an expert system is knowledge representation. The most popular models of knowledge representation are decision tables, decision trees and production rules. The three models of knowledge representation, are equivalent and there are algorithms for converting from one model to another. Also these models of knowledge representation are easily understood by users[13].

Standard structure for a decision table has four quadrants (figure 2).

Conditions	Conditions values
Actions	Input actions

Figure 2 Structure of a standard decision table

As can see, in a decision table there are associated the two components of a production rules, namely, the conditions to be fulfilled and actions to be executed. In most cases, decision tables are constructed by human experts.

Intuitively, we can see that the contradictions matrix(table1) is a decision table. To prove this I tried to turn the table into a table of standard structure decision. But I noticed that, in fact, contradictions matrix as shown in table 1, is equivalent to two decision tables, namely one which should include data above the main diagonal and the other under the diagonal data. Contradictions matrix being very voluminous (39 lines x 39 columns), for example, I chose to transform in the decision tables only part of its , namely the lower left corner because, having fewer empty cells, is more representative. For the data above the main diagonal resulted table 3 and for the data below the main diagonal results table 4. With Rm/n I noted rule obtained by combining the parameters m and n.

Table 3. Decision table for the above main diagonal of contradictions matrix data

			R35 /36	R35 /37	R35 /38	R35 /39	R36 /37	R36 /38	R36 /39	R37 /38	R37 /39	R38 /39
Condiţii (DACĂ)	Parametrii Inginereşti	35	x	x	x	x						
		36	x				x	x	x			
		37		x			x			x	x	
		38			x			x		x		x
		39				x			x		x	x
Acţiuni (ATUNCI)	Principiile Inventive	34			x					x		
		35			x	x					x	x
		36										
		37	x			x	x					
		38										
		39										
		40										

Table 4. Decision table for the below main diagonal of contradictions matrix data

			R39 /38	R39 /37	R39 /36	R39 /35	R38 /37	R38 /36	R38 /35	R37 /36	R37 /35	R36 /35
Condiţii (DACĂ)	Parametrii Inginereşti	39	x	x	x	x						
		38	x				x	x	x			
		37		x			x			x	x	
		36			x			x		x		x
		35				x			x		x	x
Acţiuni (ATUNCI)	Principiile Inventive	34					x					
		35	x	x					x			
		36										
		37				x				x		x
		38										
		39										
		40										

2.3. Characteristics of an expert system for TRIZ method applying

In essence, an expert system for applying the TRIZ method based on the 39 parameters that may conflict, should choose the contradictions matrix and inventive principles and then for each inventive principle chosen it should provide examples and details and other related items that could be added.

Whether we start directly from the contradictions matrix, or whether we start from the tables of decision rules for choosing its equivalent inventive principles we have the following form:

IF < *parameter_to_be_improved* **AND**
parameter which is worse>
THEN <*inventive principle_a* **AND**
inventive principle_b **AND**
inventive principle_c **AND**
inventive principle_d >

It is to be noticed that in part IF of the rule there are admitted both the AND logical operator and OR, while in part THEN only the AND operator is admitted.

For each cell of the contradictions matrix, in which the inventive principles are mentioned, it has to be formulated one rule namely one instruction IF -

THEN. The number of rules to be formulated to cover the contradictions matrix, namely the number of instruction IF - THEN, is equal to the number of cells in which inventive principles are mentioned, number that can be obtained by subtracting the number of 39x39= 1521 cells, 39 cells located on the diagonal main matrix and the other empty cells. The IF - THEN Instructions can be replaced by SWITCH statement. Although to build the expert system other rules should be added, however, we can appreciate that we are dealing with an expert system for medium size, if we take into account the classification scheme of expert systems based on the number of rules in table 5.

Table 5. Expert systems size depending on the number of rules

Size	Number of Rules
Small	< 500
Medium	500≤ N≤10.000
Large	> 10.000

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