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THE FIRST LEVEL ALGORITHM FOR FINDING INVENTIVE SOLUTIONS BASED ON FUNCTION-ORIENTED MODELING OF CONFLICTS AND ANALYSIS

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Abstract: *Contemporary TRIZ is not just a theory but a very effective technology for both identification and formulation of non-standard problems, and for their solution.*
While the analytical tools do not use the functional approach to the full extent, the analysis and synthesis tools, designed to eliminate conflicts and find ideas for solving inventive problems, hardly use this approach at all. ARIZ-85C algorithm available in classical TRIZ has been used almost unchanged for more than 30 years. Although this algorithm makes it possible to solve the most complex non-standard (inventive) problems, it has a number of disadvantages that hinder its use and improvement.
Apart from the fact that ARIZ-85C does not use the functional approach, it is also too complicated to study without preliminary preparation of thinking through the use of simpler algorithms designed to achieve the same goals.
The basic algorithm of the new generation is presented here. It focuses on developing the skill of building a functional model of conflict. This algorithm logic is based on the principles of function-oriented modeling of conflicts and analysis.
This approach makes it possible to correctly build the learning process with gradual transition from the simple methodological tools to more complex ones.
The paper also discusses the issues of increasing the instrumentality of conflict modeling techniques. Recommendations on development of the educational process didactics are made.
Key words: *. Functional Approach, Element-Functional Model of Conflict, EFM.C, FOMCA, Analysis-Synthesis Algorithm, ARIZ, AFIS, Contemporary TRIZ.*

1. INTRODUCTION

Its contents should be structured in the following way: problem description, application field, research stages, methods used, results, further research, conclusions, and references. The number of problems to be solved is growing every year. Already, the total number of patent applications worldwide has exceeded 3 million. New solutions, in turn, become prototypes for new products through solving pending problems. Many companies are involved in this process, and new products are often developed and improved without using the instrumentation support.

Nevertheless, algorithms as a sequence of actions aimed at achieving the specified goals, play an important role at all stages of innovative projects implementation. The most powerful algorithms designed to solve non-standard problems are a part of the inventive problem-solving technology toolbox (TRIZ). It is non-standard solutions provide the basis for the most significant patents. However, to ensure their development it is necessary to organize education focused on obtaining skills for work with special techniques and methods.

Highly competitive environment and rapid development of technologies in the leading fields: computer technology; digital communication; electrical machinery, apparatus, energy; measurement, – where increase in patent activity is particularly obvious, forces companies to not only master the advanced innovative tools which enhance individual and team productivity, but also to do it quickly. Therefore, there is a tendency towards intensification of professional education, when it takes a limited time to acquire additional skills – usually within a few days. On the other hand, the low methodological level of analysis-synthesis tools limits the range of their users. Because of this, even long-term training may fail to produce the proper result.

According to some estimates, it takes at least 80 academic hours of face-to-face lectures to study the maximum algorithm (ARIZ-85C), not counting homework for solving learning assignments and preliminary methodological preparation. Even this does not guarantee the successful use of the tool in practice.

This means that there is a need for simplified algorithms, studying which would take only few days of a short-term educational course. After that, such program participants can apply these algorithms in practice to solve their non-standard problems.

The paper presents the methodological background and results of development of the new generation analysis-synthesis algorithm, which is designed to eliminate single functional conflicts. It is convenient to use it for solving relatively simple inventive problems and for first-level contemporary TRIZ training in a short-term educational course.

The subsequent courses will represent the next steps in learning this algorithm with add-in of additional guidelines on processing other types of problems, for example, containing contradictions of conditions. However, further study of more complex algorithms shall continue selectively depending on the need to solve such problems in the project team.

Thus, an option of step-by-step mastering contemporary TRIZ tools is pro-posed, where each stage contains a full-fledged algorithm for solving problems that can be applied immediately after a short-term educational course. This maneuver under long learning way will allow to divide studying process into separate, short but methodically completed courses.

2. GENERAL OVERVIEW

All algorithms created in recent years, available in TRIZ and aimed at synthesis of new inventive solutions, are based on ARIZ-85C [1], though to a varying de-gree. The best-known modifications are: ARIZ-91 [2], ARIP-2009 [3], ARIZ-2010 [4]. They are of about the same complexity as the prototype algorithm, namely, they contain many complex concepts, such as ideal final result, resources and contradictions, but at the same time they keep methodological inaccuracies and even errors inherited from the prototype. These shortcomings do not allow using these algorithms in full force.

For instance, at the first step, the technical system includes both the subject of the conflict function and the object of this function, and sometimes – even elements from the environment. This is unacceptable from the position of the system-functional representation of objects, but it is so.

The core of all inventive algorithms is to analyze the identified (localized) conflict, which can be represented (modeled) as a single conflict function or as a contradiction of conditions (two related functions) and to subsequently trans-form this model into a series of inventive solutions models and further – into inventive challenges.

The paper, of course, focuses on the already existing algorithms that are avail-able in the instrumental TRIZ (as a technology). In particular, the simplest first versions of algorithms, starting with ARIZ-59 [5], are most interesting. This algorithm is a complete copy (calque) of Pappus algorithm described by George Polya [6], and they both have the following structure:

1. Presentation of the desired outcome and possible obstacles to its achievement.

2. Analysis of the situation (and environment) to find suitable resources that shall help to come to the outcome stated in item 1 by eliminating the obstacles.

3. Operational stage – assessment of the resources found for their suitability for achieving the goal.

4. Synthesis of solutions using the most complete resource chains, taking into ac-count capabilities and desires of the person (i.e., solver resources).

In practice, when solving the complex problems, it is more convenient to first analyze the situation with localization and modeling of the conflict. After that, the desired outcome, the way of idealization and achieving it will become obvious.

Despite numerous additions, this procedure remained in the subsequent classical TRIZ algorithms, up to the latest version – ARIZ-85C. These complications make it possible to handle conflicts of various types, but, due to the said disadvantages, they do not allow doing this with maximum efficiency.

Significant contribution to understanding of thinking processes, puzzled by finding solutions to inventive problems, was made by J. Dewey [7], K. Duncker [8], and M. Wertheimer [9] who worked on the theory of productive thinking based on data obtained during experimental research. In fact, the results of their work were detailed algorithms for accessing insight states in the process of solving non-standard problems. The logic of the results was also used to create first algorithms in TRIZ.

For transition from the initial problem situation (in which there is neither understanding of the goal nor means of achieving it) to the specific conflicts (disadvantages), various analytical tools are used, where the situation with functional modeling is more or less good. Therefore, these initial stages are not considered now.

However, when it comes to subsequent processing the identified conflicts, functional approach is losing steam. This applies to both ARIZ and the so-called Substance-Field analysis. In other words, the first steps in conflict modeling and analyzing these models have not yet been sufficiently developed. This is why all subsequent formulations in the currently used algorithms are quite weak. As the result, the emphasis is placed not on the methodology but on skills of the inventor himself, which reduces the efficiency of innovation processes in companies.

To correct this situation, it is necessary to enhance the methodological equipment of TRIZ tools, which shall reduce the human factor influence at all stages of work with conflicts. It is building the accurate conflict models and rules for working with them that will be discussed below prior to moving to describing the new version of the first level algorithm – the algorithm for finding inventive solutions (AFIS-1) with the use of the element-functional model of conflict (EFM.C) [10]. Since the key stage here is the conflict modeling stage, modification of the first level algorithm has gotten an additional name for the corresponding transformations: function-oriented modeling of conflicts and analysis (FOMCA).

Next, it shall be demonstrated how such concepts as function and functional system (FS) had been integrated into the algorithmic approach, adding practicality and efficiency to it. This study shall be useful for those who need a simple but effective tool for solving non-standard problems and for those who are engaged in teaching the innovative methods of designing new systems and conflict resolution processes.

3. FUNCTION-ORIENTED MODELING OF CONFLICTS AND ANALYSIS

Methodological background in the form of a brief description of the structure and rules for building and analyzing EFM.C, which underlies the proposed algorithm, is presented in this section.

3.1 About functional approach

Problems always arise when the objects of reality interact with each other. To analyze problem situations for their understanding, it is necessary to work not with the real objects but with their models. The main entities to be modeled are the relationships, which in contemporary TRIZ are represented as functions.

Function is a model of changing or preserving the state of one element under the action of another element [11].

In order that the function carrier element is able to successfully fulfill it, at least two conditions should be met:

1. Availability of energy that can be supplied to this element from the outside.
2. Ability of the element to convert this energy and transfer it to the receiver element to change its state.

In fact, these are the very basic criteria, which shall identify the functional system.

Functional System (FS) is a system with a purpose, which is implemented through the external function [11].

In practice, one more condition is necessary: availability of a minimum control device for turning on/off the energy supply to the working element. To simplify generation and analysis of the conflict model, there is no need to use control elements in the scheme. Moreover, subsequent rules of the model transformation will play this role.

In turn, the influenced element (object of function) should be able to resist the influence to some extent. To do this, it should also be able to convert energy, which is sufficient to compensate part of the influence of the function carrier element (subject). Otherwise, the object of function can be destroyed. This means that it should also be expanded to a functional system.

If the working element is not able to convert energy available from the source, it is necessary to introduce a mediator as an additional energy converter between the energy source and the working element. This converter can be one of the two types: 1st kind – for converting energy from one form to another, and 2nd kind – for quantitative energy conversion and transmitting it over a distance.

In the proposed algorithm it is sufficient to take into account only conditions for the minimum system functionality and represent the conflict model with the use of trimmed (minimal) architectures of functional systems (Fig. 1).

If necessary, FS trimmed architecture can be expanded to the full version.

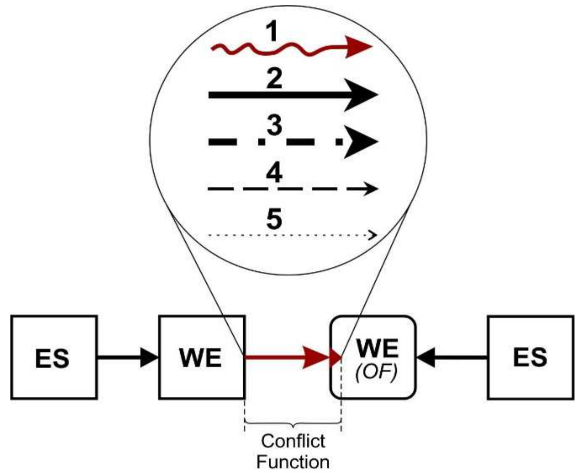

Fig. 1. Element-functional model of conflict (EFM.C) using a trimmed architecture of functional systems (executive levels), *where ES – Energy Source, WE – Working Element; OF – Object of Function; Types of conflict activities: 1. Infliction of harm, 2. Excessive or over activity, 3. Unstable (nonpersistent) action, 4. Weak or insufficient activity, 5. No activity or malfunction.*

3.2 About the basic rules for conflict model analysis

Since the conflict is based on undesirable functions, it shall be a natural tendency to transform them into desirable functions or to eliminate them. Presentation of the desired outcome when implementing the conflict functions (CF) was described in [12]. This outcome depends on type of the conflict function.

In this case it shall be determined by a new future state of the conflict function: 1) for harmful function – elimination or neutralization; 2) for inadequate function – normalization; 3) for missing function – availability (Fig. 2).

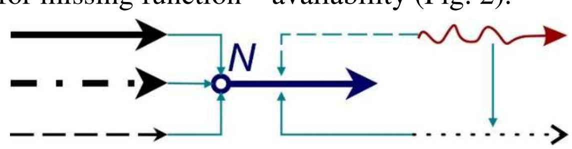

Fig. 2. Transferring conflict functions to a new desired (normalized) state.

To achieve the desired outcome, certain actions are required. It is possible to determine the application points for these actions with the purpose of the model transformation by selecting abstract entities that affect the system functioning. These entities are elements, functions, and energy flows between elements in the (trimmed) system architecture (see Fig. 1).

The paper describes only the general rules for working with models. For specific conflicts, 76 well-known standards can serve as such rules for solving inventive problems [1], which include techniques, trends, and physical effects. This is especially relevant at this stage of the toolbox development.

The main recommendation is necessity of influence on the model entities in the direction of energy flows in order to achieve the desired outcome: (1 and 5) ES, (2 and 6) energy flow from ES to WE (internal function), (3 and 7) WE, (4 and 8) energy flow from WE to the object of function (external function) (Fig. 3).
How to do that? Through actions related to the specified entities: elements, energy flows and functions:

- to eliminate;
- to add;
- to change (modify, replace).

This shows that a *function* can also be defined as a model of changing or preserving the state of an element through acting on it with an energy flow.

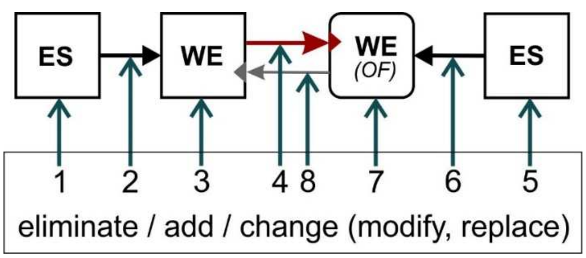

Fig. 3. Basic rules for EFM.C transformation.

In order to manage with such transformations, it is necessary to use element-functional resources (EFR), retrieval of which is made at the initial stage or immediately after formulating the desired outcome.

It is proposed to use the found resources: through their direct implementation in the conflict model or through applying their capabilities (properties, functions) to change the entities in the model.

The rules for adding a new element to the model: introduction to an existing entity (integration), attachment to an entity (addition, mediator), for instance, through introduction to the environment.

It is also necessary to provide ways for extracting the introduced elements af-ter their successful operation: integrate into the system, make indistinguishable from system elements or neutral, exit the system (independently, using system elements or another resource) including disappearance.

NB! The proposed approach focuses on modeling conflict without idealizing the desired outcome. An option of the algorithm with idealization is recommend-ed for use on the second level course, can be found in [12].

Where to get resources (places for search): conflicting elements, elements from the available conflict environment, elements from functional subsystems / system / supersystem. The sequence of using resources at the stage of finding (synthesis) the problem inventive solutions is shown in Fig. 4.

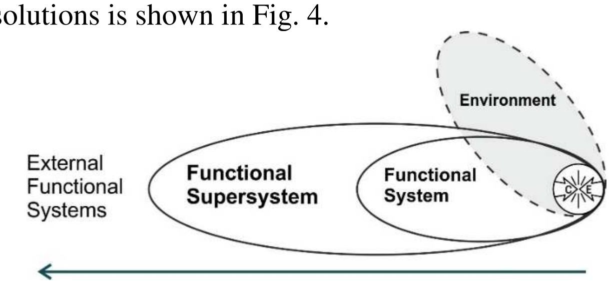

Fig. 4. Priority order of EFR application, *where CE – Conflicting Elements.*

Based on the general logic of finding inventive solutions, as well as guided by the formula of concepts definition [11], it is possible to give the following brief definition of the inventive activity, which can also be extended to creativity, at least for Pro and Big levels in accordance with 4C's model [13].

Invention is a process / activity to create absolutely new and useful entities (in the language of models – functional systems) through mobilization (search and application) of element-functional resources using capabilities and limitations in space and time.

This definition makes it clear that resources play a key role in finding inventive solutions. They help the successful application of the rules, which should lead to achievement of the desired outcome.

Thus, all key concepts have been presented, and it is possible to proceed to the claimed algorithm.

4. THE FIRST LEVEL ALGORITHM FOR FINDING INVENTIVE SOLUTIONS

The algorithm comes into effect based on formulation of a problem situation if at least one functional conflict in it is obvious. If the conflicts are not obvious, as well as their cause-effect relations (for the best choice), then it is necessary to first make a triple analysis (component – structural – functional) of the initial problem situation.

In the presented algorithm template (Fig. 5) the field numbers correspond to the steps described in detail below. This template is also convenient to use in educational seminars and for solving practical problems.

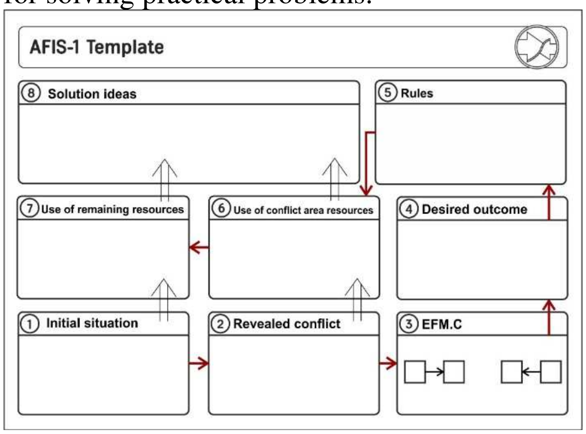

Fig. 5. The first level algorithm for finding inventive solutions (AFIS-1) template.

4.1 Step 1. Identification of elements within the area of consideration

After choosing a localized conflict, it is necessary to determine all available elements from this area and close to it (in time and space) with description of their features and active and possible functions.

It is also necessary to collect information about all elements of the environment available in and around the operational area: composition and parameters of the atmosphere, background fields (magnetic, light, gravity, etc.), energy sources, reserves of substances (stock materials) and operations already performed (related and close processes), etc.

4.2 Step 2. Determination of conflicting elements

Modeling implies transition from objects and interactions from reality to elements and functions from abstraction.

It is necessary to determine place of the conflict, starting time and duration of the conflict and to identify the conflict function between the conflicting elements.

If there are related (conjugate) functions appearing under one condition (two functions as consequences of one condition), then it is necessary to proceed to Algorithm for Removing Contradiction of Conditions (ARCC).

4.3 Step 3. Designing EFM.C

To start conflict modeling it is necessary to determine properties (states) of conflicting elements and to identify their energy sources ensuring: (1) implementation of the conflict function – for the working element of "FS-tool" and (2) resistance to the conflict function – for the working element of "FS-workpiece".

The proposed algorithm focuses on designing an element-functional model of conflict and further working with it. This allows not only finding strong solutions to non-standard problems but also getting proper skills to apply systematic and functional approaches.

It shall also allow confident moving to designing the accurate functional contradictions of conditions at subsequent levels of mastering the applied invention tools.

4.4 Step 4. Formulation of desired outcome

The desired outcome is based on type of the conflict function, that is, to achieve it, it is necessary to eliminate the harmful, normalize the inadequate or ensure availability of the missing function.

Formulation should be very specific: for instance, it is necessary to strengthen the function of holding the element by a predetermined amount.

4.5 Step 5. Ways to achieve desired outcome

The desired outcome can be obtained through consistent implementation of the transformation rules to all entities included in EFM.C (see Fig. 3). The rules are designed to change entities in concordance with energy flows for both conflicting functional systems.

4.6 Step 6 and 7. Use of Resources

Search for hidden resources and inventory of available resources are done in steps 1 and 2. Here it is possible to update and supplement the existing list.

To successfully implement the rules for model transformation, it is necessary to use the elements, their properties and functions, both obvious and hidden: first – from step 2, and then – from step 1.

If the available elements in the considered area fail to cope with the task, it is necessary to add resources from regions remote from the conflicting systems: elements of the functional supersystem, external resources and resources of alternative systems (see Fig. 4).

It is also necessary to use combinations and chains of resources, so that they can help each other in linking the current conflict state and the expected result. In addition, if any resource fails work, it is quite possible to activate it using another resource.

4.7 Step 8. Recording all ideas

Record not only ideas that arise in the process of resources use, but also secondary problems, some of which being typical (for example, how to find or activate the resource in the given conditions), and to solve them it is enough to use well-known techniques and methods.

Following that, the standard project stages shall be executed to assess possibility of transferring ideas into concepts, patenting and implementing them.

5. CONCLUSIONS

The methodology and tool were proven in practice by solving a number of problems and during teaching contemporary TRIZ within the International Public University of TRIZ.

Use of the function-oriented modeling of conflicts and analysis of these models makes it possible to increase the heuristic power of the algorithmic approach within the framework of contemporary TRIZ.

This way of modeling objects and conflicts is characterized by using both the systematic approach known in TRIZ and the functional approach is almost never used for solving problems. Such integration leads to the ability to represent these entities as adequate conceptual models on the basis of which applied tools are developed.

This also reduces time from the start of the contemporary TRIZ mastering to learning the first tool, aimed at elimination of conflicts, and finding inventive solutions. This is the important milestone in designing productive thinking, giving the individual real creative confidence, which plays the key role in desire to learn more complex inventive tools. Appropriate tools are provided for the most difficult conflicts with contradictions of conditions.

The ideas presented in this work are especially relevant for multi-stage education in companies engaged in innovative research and development, and striving to strengthen their market position in the shortest possible time.

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Primul nivel al algoritmului pentru găsirea soluțiilor inventive bazate pe modelarea orientată pe funcții a conflictelor și analizelor

Rezumat: TRIZ contemporan nu este doar o teorie, ci o tehnologie foarte eficientă atât pentru identificarea și formularea problemelor nestandardizate, cât și pentru soluționarea lor.

În timp ce instrumentele analitice nu utilizează abordarea funcțională a întregii categorii, instrumentele de analiză și sinteză, concepute pentru a elimina conflictele și a găsi idei pentru rezolvarea inventiva a problemelor, utilizează in orice caz cu greu această abordare. Algoritmul ARIZ-85C disponibil în TRIZ clasic a fost folosit aproape neschimbat de mai bine de 30 de ani. Deși acest algoritm face posibilă rezolvarea celor mai complexe probleme non-standard (inventive), are o serie de dezavantaje care împiedică utilizarea și îmbunătățirea acestuia.

În afară de faptul că ARIZ-85C nu utilizează abordarea funcțională, este, de asemenea, prea complicat de studiat fără pregătirea preliminară a gândirii prin utilizarea algoritmilor mai simpli, concepuți pentru atingerea acelorași obiective.

Algoritmul de bază al noii generații este prezentat aici. Se concentrează pe dezvoltarea abilității de a construi un model funcțional de conflict. Acest algoritm logică se bazează pe principiile modelării orientate spre funcții ale conflictelor și analizelor.

Această abordare face posibilă construirea corectă a procesului de învățare cu trecerea treptată de la instrumentele metodologice simple la instrumente mai complexe.

Lucrarea tratează, de asemenea, problemele creșterii instrumentalității tehnicilor de modelare a conflictelor. Sunt făcute recomandări privind dezvoltarea proceselor didactice educaționale.

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