Formula of Concepts Definition and Its Application to Basic Concepts of Contemporary TRIZ

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Abstract. This is an article dedicated to the analysis of the rules of defining concepts.
Concepts in science create an evidence picture of the world. The more accurately such picture reflects reality, the more predictable are the outcomes of changes. Today, in TRIZ there are alternative concepts that often contradict each other and sometimes simply make it impossible to build an adequate model of the object or conflict.
The general principle of definition is shown by the example of the main concepts in TRIZ. The simple formula allows you to define from abstract (e.g. a function) to specific (e.g., pencil) concepts.

Keywords: TRIZ, Definition, Concept, Term, System Approach, Functional Approach, Glossary, Terminology, Functional System, Contradiction.

1 Introduction

Terminology as a communication tool plays an important role for methodologists and direct users. And they have an interest in both standardizing the process of defining concepts, and in unambiguous fixing the appropriate names.

The goal of terminology science is to make the link between “sign”, “concept” and “object” clear. As a natural corollary, the aim of terminology work is to ensure that a “sign” designates a precise “concept”, and that the “concept” fits the “object” it describes [1].

A concept is an element of thought, a mental construct that represents a class of objects. Concepts consist of a series of characteristics that are shared by a class of individual objects. These characteristics, which are also concepts, allow us to structure thought and to communicate. In order to communicate concepts and their supporting propositions, speakers use written or oral linguistic signs made up of a term or groups of terms, or some other type of symbols [2].

These three elements can be represented in the form of semantic triangle. This triangular model basically explores the relationships between some kind of reality (individual object), means to communicate about and to create this reality (symbol), and the center of reasoning about and of understanding both the world and language (concept in the human mind) [3].

Basic definitions [4]:

- Concept – unit of knowledge created by a unique combination of characteristics.
- Term – verbal designation of a general concept in a specific subject field.
- Definition – representation of a concept by a descriptive statement which serves to differentiate it from related concepts.

The classic kinds of definitions are presented, for example, in The Cambridge Dictionary of Philosophy [5].

General principles governing the formation of designations and the formulation of definitions have been established by the ISO 704 standard [6]. The rules of the ISO standards are proposed mainly for different classifications and cataloging information.

2 Background

2.1 About Glossaries in TRIZ

In TRIZ, the terminology is more or less established, but the concepts denoted by the well-known terms often have different meanings in different authors.

For example, in [7] provides a fairly detailed glossary of TRIZ-terms with references to the many other versions of dictionaries.

Almost all available TRIZ-dictionaries have the following disadvantages:

- the excessiveness of glossaries – they define even those terms that do not need it,
- the flexibility of interpretations – there is no systematic approach to the definition of concepts and coordination between different authors,
- the impracticality of most definitions – they are too wide which makes them difficult to use.

TRIZ, like any science, also needs a terminological order. This requires:

- take the logical model for the formulation of definitions,
- use this model to create a specialized dictionary – thesaurus,
- agree on the procedure for making changes to this thesaurus, in the process of developing discipline: by introducing new terms and by improving existing ones.

In that context, TRIZ community attempts to create a uniform structure of definition. There are some versions.

2.2 Versions of Structures for Defining a Concept

Today, the following publications dedicated to definition structures have been found (see Table below).

Table. Versions of definition structures.

Definition structure	Authors

To understand any entity, you should answer 4 questions of the system approach: 1) Where is IT coming from? 2) How is IT arranged? 3) Why is IT needed? (Who and when needs IT?) 4) What does IT mean?	Galyetov [8]
Algorithm of definition: 1) Determine the nearest supersystem (on the discussed function of defined object). 2) Define the function (for artificial objects) or the mode of existence (for natural objects). 3) Describe the differences between the examined object and other objects with the same function in the same supersystem.	Sibiryakov, Semyonova [9]
The content of the concept is based on the following parts: 1) supersystem; 2) main function; 3) subsystem; 4) properties and attributes.	Gredinarova [10]
The object, considered as a system with a given function, can be defined in the following way: Supersystem-attribute + MUF + OP + list of the main Subsystems 1) Supersystem-attribute – class, category, to which the defined object belongs; 2) MUF (main useful function) – role (purpose) of the concept in the selected category; 3) OP – operating principle; 4) Subsystems, including the working unit – what helps to fulfill the role.	Kislov [11]
Using MQS[1] to analyze concepts: 1) The organizational aspect. How is the whole constructed?	Podyakonova [12], based on [13]

[1] Method of qualitative structures (MQS) is a way of thinking about the whole. In any living (developing) object which is viewed as a whole we can see: the organizational aspect – construction, the functional aspect – production, the communicational aspect – the link between the object and other objects, with the World; and the coordination point – something which connects all aspects into a whole [13].

2) The communicational aspect. How does the whole communicate with other systems and the environment?
3) The functional aspect. How is the whole reflected in the outside world?
4) The aspect of coordination (operating principle). Is the content whole?

These versions certainly clarify the process of defining. They are very similar to each other. However, there are no coordination, completeness and precision in defining each element of these structures.

In general, there is a tendency to use the classical version of definitions – from formal logic and semantics: to define concepts through genus and species. However, the main disadvantage, perhaps, is that the proposed structures of definition are not used in practice, and are not being finalized.

3 Methods

In any science, we are dealing with concepts – representations of objects, interactions and conflicts. In order to understand the situation, and what to do with it, it is necessary to define concepts – to construct adequate models of reality.

The exact definition of these concepts allows: 1) to distinguish between the defined object and all other objects, through the description of distinctive features of the first object; and 2) to reveal the essence of the defined object.

The process of science formation leads to a deepening of knowledge and ideas about the objects under study. So, it is required to update the definitions, which must correspond to a new knowledge. The availability of suitable definition also allows us to formulate a precise goal and find the best ways to achieve it. For example, in order to successfully achieve the ideal desired result, you need to know exactly what it is.

Consider, for example, a pencil. Is it a technical system? Or just a system?

These concepts are perhaps the most important in TRIZ, therefore let us examine them more closely.

Originally there is an (real) object. It is represented in the images produced by our consciousness. We regulate these images by using concepts. “System” is one of such concepts. “System” is a linguistic term that designates an appropriate concept.

This object can also be represented as a system, if it fits the definition of this concept, and can be identified as belonging to the class of systems.

The technical system is one of the main concepts in TRIZ. It is a special class of systems, which fulfill functions and belong to engineering. Such system must have some features to fulfill successfully the given function, e.g. must be composed of certain elements.

Furthermore, the new term should be introduced to expand this concept: “functional system” or FS. That allows to avoid the limitations of its “technical” usage.

Now, if the FS is a system that fulfills a function, the object should consist of all required elements to be identified as a FS. If the function of the object is to hold a sheet of paper on the table by pressing it with its mass, some source should be included (and considered by designing) in the content of the FS: an energy source that helps to fulfill the function. In this case such source will be the mass of the pencil and, more precisely, its weight (gravitational energy). The given function can't be fulfilled without an adequate energy source.

If the main purpose of a pencil is to write notes on paper, it is a part, though important, but just a part of the FS, which is intended to dirty paper (or to leave marks on paper) by carrying a part of the lead to a paper surface (operating principle). And the content of this FS also will consist of other parts: elements – converters of energy which is needed by the working element to fulfill successfully the function. In this case the converter of energy is a person or a device that can replace it.

It is necessary to keep in mind "complete" FS, which can fulfill the function, for what it was intended.

Thus, each artificial object – product – modeled as a functional system has a composition (subsystems and structure) and environment (supersystem and operating conditions).

"Functionality" should be explained for all levels of the system hierarchy: functional supersystem | FS | functional subsystems. That allows us to construct it more precisely, in particular to define a supersystem. Without pointing to the function, the supersystem is often confused with a class (genus) to which the object belongs. Therefore, these categories should be distinguished in the formula of concepts definition.

The system hierarchy allows us to build a correct system operator (SO) at the next step of the analyses. Today, we often see system operators built without specifying the function of the system. This leads to the fact that instead of evolutionary cycle (EC), the life-cycle (LC) of the certain object is reviewed.

For full certainty – using of two types of system operators: SO of LC and SO of EC is proposed. All entities in their development go through these cycles.

For what purpose do objects go through all stages of these cycles? To satisfy the needs of users. It all starts and finishes with needs. The needs can be satisfied through fulfilling the functions. In this way, there is a circulation: from need as motivation, through invention, production and usage of the product to meet this need (Fig. 1).

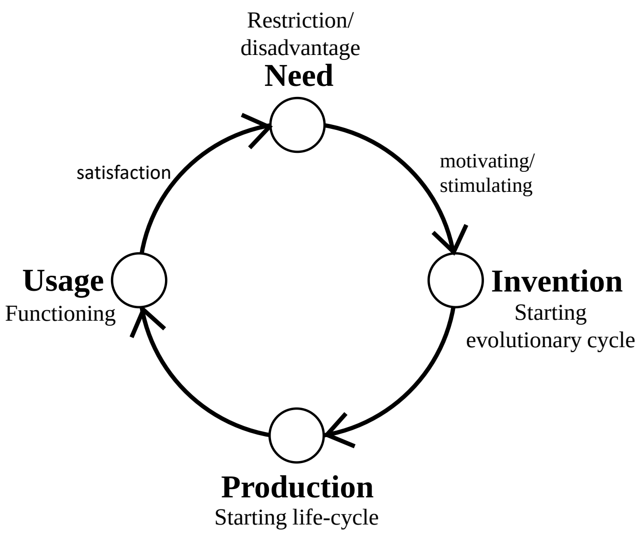

Fig. 1. Circulation of satisfaction of needs (NIPU-cycle).

The results of these analysis allow us to build a generalized formula of definition of concepts.

4 Results

4.1 Formula of Concepts Definition

Based on the NIPU-cycle, the formula of concepts definition will include the following components:

1. Invention – genesis.
   1.1. Prerequisites and the beginning of evolutionary cycle. For what the object is conceived? What need it will satisfy?
   1.2. Classification – to which genus/class of entities the newly created entity belongs.
2. Production of a specific object: the transition to a life cycle.
   2.1. Content – Functional Subsystems (FSubS), Elements.
   2.2. Structure – how subsystem elements connect and interact each other.
   2.3. Process – is determined by method and conditions of manufacture/assembly.
3. Usage.
   3.1. Function – functional definition – change in a destination (under processed) object. External functions – including main useful function (MUF).
   3.2. Operating principle (OP). Object characteristics that enable it to realize the MUF.
   3.3. Functional Supersystem (FSuperS) – the designated object as integral to the process or to the device is considered.

3.4. Operating conditions – taking into account interactions with environmental elements.
3.5. Operational definition – process of changes in the designated object.

It is important that any definitions could be applied in practice. Therefore, from the general formula it is enough to choose only those parts that, at least, satisfy this criterion. Common sense will suggest the required degree of completeness of the definition.

The presented formula is not an axiom, but a guide that helps you not to miss important, significant, distinctive qualities of the modeled object. It is similar to the questionnaire used at the beginning of any project. Similarly, the glossary is the beginning of any science.

4.2 Example of Definition

For example, Spoon.

[Invention] This is an element of cutlery;

[Production] consists of a handle and a working element – scoop – usually a small shallow container;

It is necessary to take into account all sources and converters of energy and to determine what role a person will play in the process of functioning [Usage].

In addition to the composition, it is also useful to describe the process of manufacturing, preparing, or assembling a defined object.

[Usage] It intended for manual use (a process as interacting with a person or a control device); for separating, capturing and moving food (functions – the process of realizing the destination); by mechanical action on objects (operating principle).

It is most often a part of the process of cooking and eating food, making tea, etc., performing the corresponding functional operations (additional classification by the FSuperS – where does this object belong, which process or device).

If necessary, it is also possible to describe the external conditions for using the object: in the kitchen, in transport, on a trip and so on (higher level supersystems) as well as the various environmental conditions.

5 Example of Glossary – Basic Concepts of Contemporary TRIZ

We should describe all abstract entities that science of invention deals with: element; its activity that results in changes of other elements; the possibility of linking elements together, based on their activities that leads to formation of complex structures – systems that, having in turn new properties and thus possibilities, also may interact with each other.

The definitions should begin with elementary entities and then should be expanded designating more complex entities.

Since this paper deals with a specific discipline, we should refer to appropriate models, based on the object of study that will increase the effectiveness in achieving goals of the discipline.

Each science has its own understanding of reality. It depends on the object of study and on what is actually being studied in this object.

The science of invention is based on the core presuppositions of classic TRIZ; the objects of its study are creative thinking of people and, in general, systems, with the objectives defined by people.

Within the science of invention, where TRIZ is the heuristic part, there are the following models:

Basic Entities.

Element – a unit of the whole that is also regarded as an indivisible whole – within the model. It can be either matter (substance, energy) or information, or a complex object consisting of a number of elements when there is no reason to look deeper at its inner structure.

In practice, for building element-functional model (EFM), it is convenient to use the following addition [14]. Element is a model of energy converter[2]:

Energy converter of the first kind – converts energy by form;

Energy converter of the second kind – converts the characteristics of energy within a single species.

(See also definition of "Functional system").

System [by structure] as an object model – is a set of interacting or interdependent elements forming a complex and unified whole, that has a new feature that is not limited to a simple sum of the features of these elements.

Function [by result] is a model of changing or preserving the state of an element, through actions on it by another element.

The change is an outcome of action: to detect changes means to determine action. This proves the presence of the function: action plus changing as a reaction to this action.

All changes require energy. Energy converters are needed to coordinate the type, intensity and location of the application of energy with the required change (Fig. 2).

The function definition should reflect the essence of the change that occur to the element. For example, the function of the ax is "to divide the log" into two parts, by applying the required force in a given space location. Thus, the state of integrity of the log is changed.

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[2] In general, an element, like the entire functional system, can also play the role of a converter of other elements.

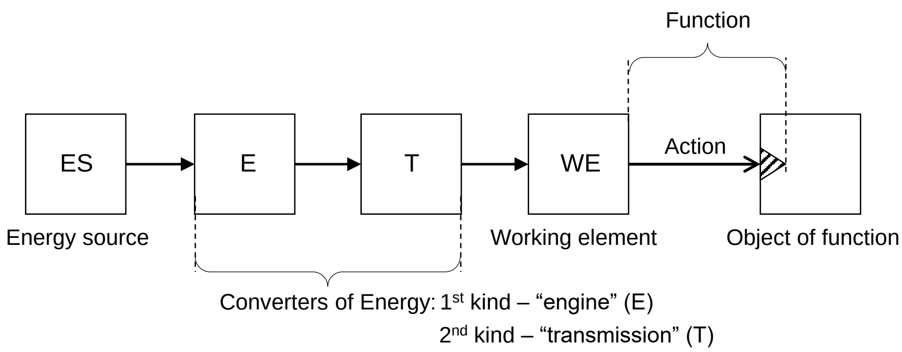

Fig. 2. Elements and Function.

The definition of “function” in TRIZ is quite similar to the definition of the concept “action” was given by Cornel Popa [15]: it is intentional, conscious changing of objects of the natural or social environment according to the predetermined goal.

Achievement of Purpose and System Hierarchy. The system approach certainly means more than a simple modelling of separate objects (devices, organizations, operations, services, etc.) in the form of systems. The presupposition is that these objects have some purpose as soon as we think of them. Since the purpose is being modelled through the function, these two concepts should be combined.

Therefore, the system acts as an intermediary connection that helps to form the new concept of working definition – functional system.

Functional System (FS) is a system with a purpose, which is realized through the external function.

If we want to give the whole definition of FS, to understand what FS means, we should determine its features, the ones that allow it to fulfill successfully the function.

Functional system is a system, consisting of at least two elements: source of energy and working element and meant to fulfill the actions towards external objects.

More broadly, the system is functional when it meets the following criteria (Fig. 3):

- It consists of the elements – energy converters.
- The elements are linked with each other and can exchange energy (and information) – which means the presence of internal functions.
- The energy is transferred to the element performing an action (working element) for changing characteristics of external element – “object of function” (it is a part of another FS).
- The control system exchanges energy (as an information carrier) with elements of FS. The function of the control system aims at changing characteristics of elements of the examined FS.

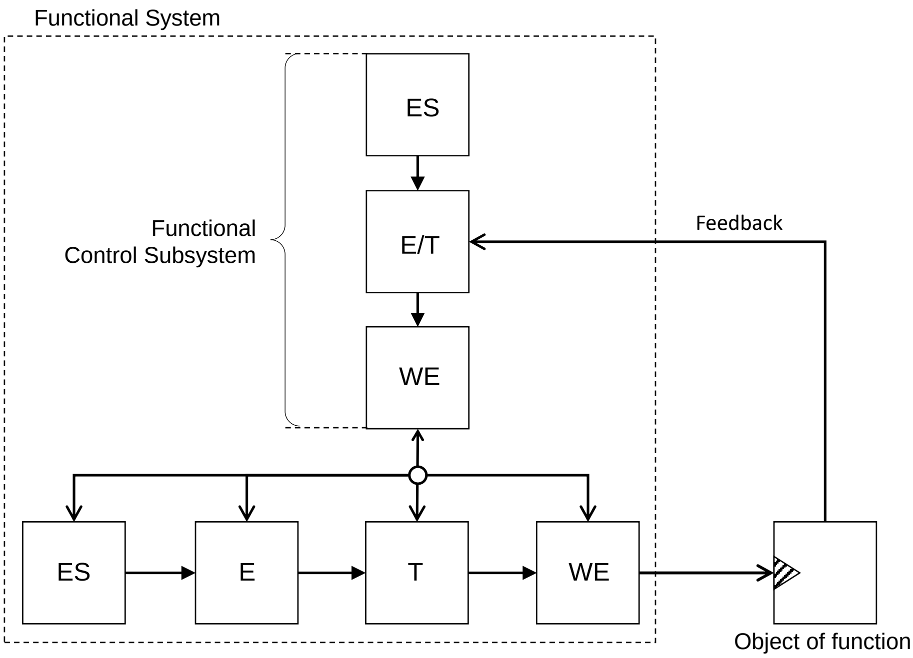

Fig. 3. Simplified structure of the "complete" Functional System.

Functional Subsystem (FSubS) is a functional system that is an integral part of the examined FS.

Every system consists of at least several elements, which are needed to support the system and fulfill its functions. This level of the studying the composition of the system is called usually subsystem.

We have examined the direction to "zoom in" – from the whole system to its components, with separating of subsystems.

The opposite direction is "zoom out", when the system is considered as a part of the more general construction.

Functional Supersystem (FSuperS) is a FS that includes the examined FS as a functional subsystem (FSubS).

This means, that the belonging of the FS to the functional supersystem is defined, in the first place, through the context of situation (problem).

The Processes of Development, Production and Usage of the System should be also performed as models.

Evolutionary Cycle (EC) is a model of the sequence of the development stages of the class of systems from invention (or even from the moment when the need in such a system appears) to leaving markets or going to a narrow market niche. There is a visual representation as the S-curve.

The Life-Cycle (LC) is a model of the sequence of the process stages, which covers the different states of the system: from manufacture to utilization/recycling.

System Operator (SO) is a model of development (time axis) of the structure of functional system (hierarchical axis).

System operator enables actions (operations) on FS at different stages of EC/LC, including forecasting with trends of functional system evolution (foredesign). In fact, every science tends to calculate and predict the examined events by building adequate models of reality.

System operator is also used to direct the thinking process of the inventor, who is working on improving current FS and/or developing the new one.

SO of EC (SO.EC) – is a SO indicating the possibilities in the development of FS, FSuperS and FSubS at the different stages of EC.

SO of LC (SO.LC) – is a SO that indicates possible changes of FS, FSuperS and FSubS at different stages of LC.

Conflict and Contradictions. There are also other important concepts that are connected with more complex logical-semiotic entities, such as contradiction.

The contradictions in general may be divided into two types: formal logical and dialectic [16].

Remark 1. Generally speaking, both contradictions are being examined in TRIZ: technical contradiction as dialectic, and physical – as formal.

Furthermore, there are statements which are called contradictions in TRIZ, in fact, often they are not – especially when the conflicts don’t intersect in space and/or in time. In this case it’s more appropriate to use other terms, e.g. such as “conflict”, “opposing tendency” or “opposing interest” [17].

It’s easier to begin with the describing of the conflict.

Conflict is an unwanted function (e.g. harmful function) or an absence of the desired function within at least two elements.

As a rule, some principles can be used to eliminate the initial conflict. But this may lead to an unwanted change in the normal functioning of the elements – the unwanted function appears, connected with the normalized one (conjugate functions). In this case we should talk about an appearance of the contradiction of conditions – here the conditions are connected with the using/not using of principle.

Contradiction of Conditions (CC) is a conflict, where the consequence (or result) of performing the condition – for using or changing of the entity – are connected (conjugate) functions, one of which is corrected [positive consequence 1], the other – unwanted [negative consequence 2], and which change to their opposites by changing of the condition.

And here, as an additional term, it is appropriate to represent the scheme of this contradiction – for greater clarity.

The structure of the contradiction of conditions (see also Fig. 4):

If [condition 1] then [positive consequence 1], but also [negative consequence 2].

If [condition 2] then [missing negative consequence 2], but also [missing positive consequence 1].

As a rule: condition 2 = − (condition 1), except the cases, when in the conditions different tools (or different degrees of action of the same tool), methods of the implementation of the process or inventive principles to eliminate the conflict are present.

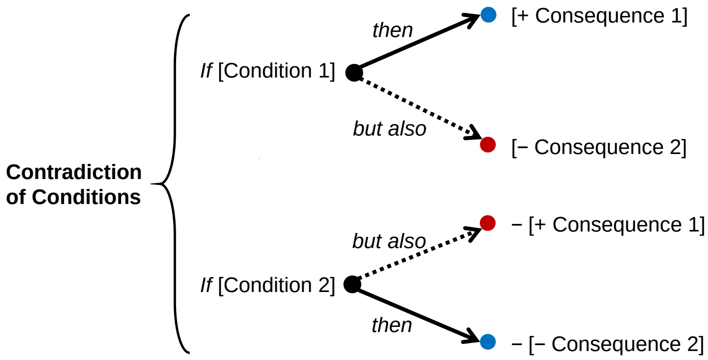

Fig. 4. Contradiction of Conditions (CC).

If the principle hasn't worked as it should, and the conflict hasn't been eliminated without negative consequence, that means the problem is not solved at the system level. It is necessary to go to either a supersystem, or subsystems. The subsystem conflict area will be required to have no negative consequences by using of the chosen condition. In this case CC is reformulated to the contradiction of requirements which can be resolved both with inventive principles and by using resources.

Contradiction of Requirements (CR) is a kind of the conflict, when the same entity should satisfy contradictory or contrary requirements in order to fulfill the positive consequences from the contradiction of conditions [positive consequence 1 & missing negative consequence 2].

The structure of the contradiction of requirements (see also Fig. 5):

e.g., under the Condition 1: the entity (operational zone or resource) must be [requirement 1] in order to fulfill [positive consequence 1], AND the same entity must be [requirement 2] in order to fulfill [missing negative consequence 2].

if requirement 2 = − (requirement 1) then CR is formal contradiction (hard & not hard); else: CR is contrary (hard & soft). These statements can transform from one into the other. It depends on the conditions of the problem.

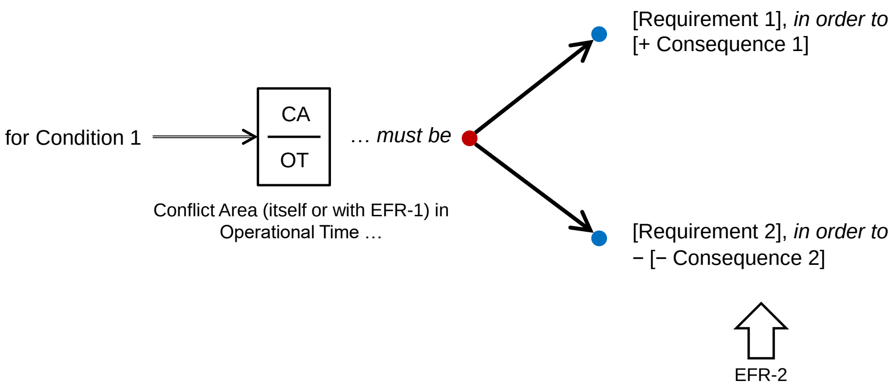

Fig. 5. Contradiction of Requirements (CR), *where EFR – element-functional resources.*

Therefore, the contradiction of requirements is connected with the contradiction of conditions within one problem.

From the practical point of view, the contradictions should be constructed for different system levels: CC – for localized system conflicts; CR – for revised subsystem area of the conflict. Such transition from CC to CR gives a significant heuristic effect by solving inventive problems.

Remark 2. CC and CR are used as more general terms for contradictions instead of technical and physical contradictions used in the classic TRIZ. Such designations are more universal and therefore applicable in the various fields of activity (not only in engineering); and reflect the essence of the contradictions which include conflicts between conditions and requirements accordingly.

6 Conclusions

To understand means to define the concept.

The definition of concepts is an important part of the foundation of any science. The science of invention is not an exception. The suggested approach enables us to better understand the subject of the study and to improve effectiveness of the applied models and rules of their construction and transformation: techniques, methods, algorithms. The effective tools of invention, in turn, ensure more predictable results which can be more easily applied in the real world.

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