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Different ways to identify generalized system of contradictions, a strategic meaning

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Abstract

To overcome limitations of the classical TRIZ model of contradiction, a generalization of the model has been defined. This Generalized System of Contradictions (GSC) has now to demonstrate its usefulness and the way it can be operated. To go forward an elicitation of a method to use this GSC, different ways to recognise and to identify it will be proposed in this article. These different ways are based on different strategies that will have to be tested by the analysing of the robustness of the resolution for each of the strategies.

Keywords: Generalized system of contradictions; Automatic extraction;

1. Introduction

Designing new technical systems means making technical systems evolve [1]. Evolution can be made by two main ways [2, 3]: (1) increase the efficiency of systems by optimisation of its parameters or (2) re-design the system when, for example, the use of a new resource or the application of a new working principle is required. A hypothesis is that these two evolution types could be fitted with two kinds of problem resolution: when optimisation techniques enable resolution or when a change in the problem model is required. In this article the first case will be defined as optimisation problems, the second as inventive problems.

The usefulness of dialectical approaches for the resolution of inventive problems has been demonstrated and established. One of the main positive outputs and well-known development of dialectical based methods for designing of technical systems is TRIZ. In TRIZ it is specified that any problem have to be recognised as existing due to a set of contradictions coming from the confrontations of a set of evaluation parameters that represent the desired state; and a set of action parameters that define a specific state, working principle, of the considered system. More over in TRIZ based methods models are proposed to formulate these contradictions. The contradictions can be formulated at several levels of generalization, either representing the wish to make a situation evolve (administrative

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contradiction), either representing the difficulties to satisfy all the specs simultaneously (the technical contradiction), or analysing the limitations of the current system that disable from reaching the goal (the physical contradiction). In OTSM-TRIZ [4] these models have been enriched by the specification of the way technical and physical contradictions are linked, through a system of contradictions.

In [5] the limitations of this system of contradictions have been established and a generalization of the system of contradictions has been proposed in order to fit these limitations. A problematic situation is described by a set of features, either evaluation parameters, which require having specific values to fit the specs, either action parameter to act on the situation. With classical system of contradictions, it is possible to have a description of a problematic situation, defining a solution space in which no solution can be found, and in which no classical TRIZ system of contradictions could be identified. The Generalized System of Contradictions satisfies the equivalence relationship: if no solution can be found, at least one system of contradictions exists.

The model has been defined in order to satisfy the desired equivalence, its usefulness has now to be established. A working program has been established to prove it:

- Definition of the way to extract GSC.
- Interpretation with experts of the meaning of the extracted GSC.
- Resolution of the GSC.

In this article the first step of this program will be presented. After presenting the concept of GSC, the different strategies to extract and formulate them will be defined.

2. The generalized system of contradictions

2.1. Classical TRIZ models

TRIZ [6] is a Russian acronym for Theory for Inventive Problem Solving, it is a theory built on the elicitation of the modes of the technical systems' evolution. Its aim is to give the axioms to develop methods and techniques for problems resolution in the field of technical system design and in particular for problems that cannot be solved by optimisation techniques. TRIZ has been initiated and developed under the control of Genrich Altshuller. Classical TRIZ refers to the development of the theory approved by Altshuller. In border of this theory contradiction is the main problem-stating model. "A problem exists" is equivalent to "a contradiction can be elicited".

TRIZ defines three kinds of contradiction:

- The administrative contradiction identifies some dissatisfaction in a situation, without any mean to act on the situation. "I know what I want, but I don't know how to reach it".
- The technical contradiction is the expression of two opposite requirements. "The satisfaction of the first requirement disables the satisfaction of the second requirement and vice versa."
- The physical contradiction is the expression of two contradictory yet required states of the same parameter. "A parameter is required to be both in state one and in its opposite state".

2.2. OTSM-TRIZ system of contradictions

The idea of contradiction has been reinforced in border of OTSM-TRIZ [4], but for a generalized application, including non technical problems.

The administrative contradiction has not been kept in the border of OTSM-TRIZ. This level of contradiction definition put the emphasis on the objective of the study, on the existence of the problem, but no corresponding solving tool exists. The two kinds of contradictions that are proposed in OTSM-TRIZ are the Contradiction of a System and the Contradiction of the Parameter, which respectively generalize the TRIZ technical contradiction and physical one.

Moreover a System of Contradictions is proposed in the frame of OTSM-TRIZ to build the coherence between the levels of Contradiction of the System and Contradiction of the Parameter, as illustrated on figure 1.

This system of contradictions is based on the existence of a parameter contradiction and of two contradictions of the system that justify the need of the two different states of the parameter. The two system contradictions are complementary as they correspond to the increasing of the first parameter that implies the decreasing of the second; and of the increasing of the second parameter that implies the decreasing of the first. The two parameters of the contradictions of the system are defined in [7] as taking part in the description of the objective, they are called Evaluation Parameters, whereas the parameter of the parameter contradiction is a mean to make the situation change, defined as Action Parameter.

2.3. Generalized system of contradictions model

In [7, 8] a postulate has been proposed to build a generic model for inventive problem statement: this model has to satisfy the following equivalence: “a contradiction exists” is equivalent to “no solution can be found by optimisation of a known model”. The models proposed in classical TRIZ and in OTSM-TRIZ do not fit this requirement. Thus in order to get this equivalence we propose a generalization of OTSM-TRIZ system of contradictions. As a result we get the Generalized System of Contradictions (GSC), as illustrated in figure 2. The generalization is based on the use of concepts, which are defined as logical assertions about values of the parameters.

Thus as generalization of the physical contradiction, a set of action parameters and concepts involving exclusively those action parameters respectively replace the action parameter and their values. The generalisation of the technical contradiction is then built on two concepts involving two sets of evaluation parameters. Thus the Generalized System of Contradictions is the generalisation of the OTSM-TRIZ system of contradictions where two concepts based on a set of action parameters satisfy two sets of evaluation parameters. The desired result is then the simultaneous satisfaction of the two sets of evaluation parameters. The Generalized System of Contradictions is represented on figure 2.

3. Different strategies to identify GSC

3.1. Extraction of the generalized system of contradictions

The Generalized System of Contradictions can be represented in a Design of Experiments (DoE) model quite easily [9]. Independently from the values of the action parameters, a Generalized System of Contradictions can be recognized on the arrangement of a set of evaluation parameters.

Let us define a DoE characterized by a set of controlled parameters, action parameters, $X=(x_1,\ldots, x_l)$, a set of evaluation parameters $Y=(y_1,\ldots, y_r)$ and a set of experiments $E=(e_1,\ldots,e_9)$ as presented on table 1. An experiment e_i is characterized by a set of values $(v_{i1},\ldots, v_{il})$ attributed to the set of controlled parameters and by a set of values $(z_{i1},\ldots, z_{ri})$ taken by the evaluation parameters. In the rest of the article the values z_{ij} will be considered logical values, equal to 1 if the evaluation parameter y_i is satisfied by the experiment e_j, equal to 0 otherwise.

	x_1	…	x_l	y_1	...	y_i	...	y_r
e_1	v_{11}		v_{1l}	z_{11}		z_{1i}		z_{1r}
e_2	v_{21}		v_{2l}	z_{21}		z_{2i}		z_{2r}
…								
e_8	v_{81}		V_{8l}	z_{81}		z_{8i}		z_{8r}
e_9	v_{91}		v_{9l}	z_{91}		z_{9i}		z_{9r}

Table 1: A Design of Experiments table.

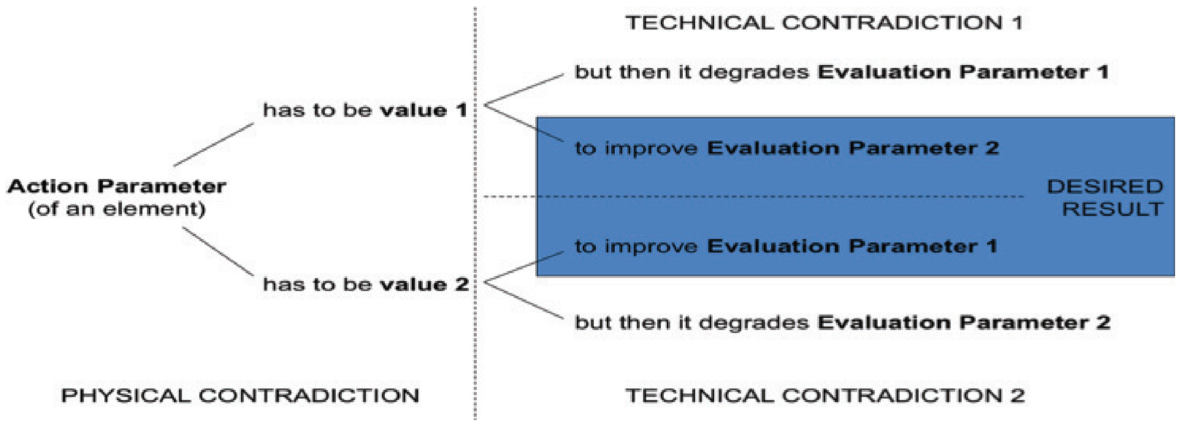

Figure 1: OTSM-TRIZ system of contradiction.

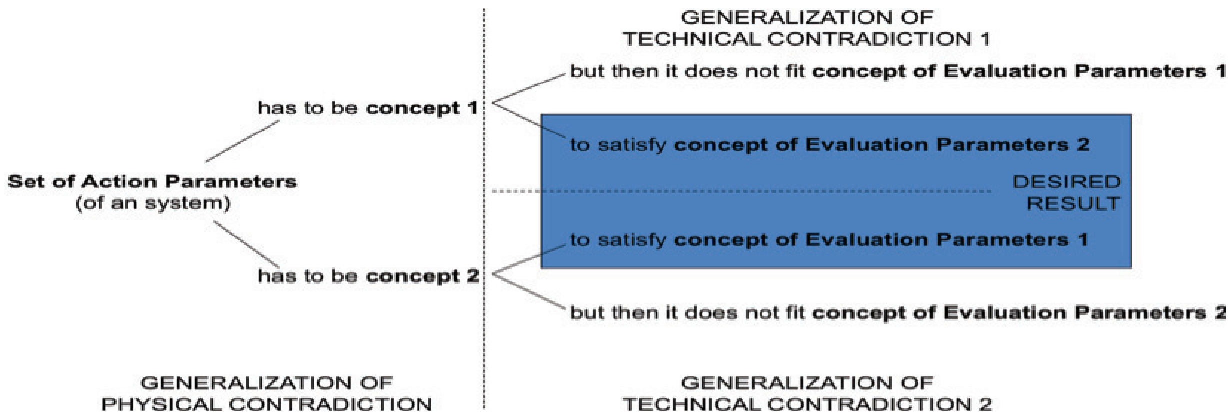

Figure 2: Generalized System of Contradictions.

If no solution exists in such a table, i.e. if no experiment satisfies all the evaluation parameters, a Generalized System of Contradictions could be formulated [8]. Identifying a Generalized System of Contradictions in such a table is looking for:

- Three sets of evaluation parameters Y0, Y1 and Y2, such as $Y0 \cap Y1 = \emptyset$, $Y1 \cap Y2 = \emptyset$, $Y0 \cap Y2 = \emptyset$, $Y0 \cup Y1 \cup Y2 = Y$, $Y1 \neq \emptyset$ and $Y2 \neq \emptyset$.
- Three sets of experiments E0, E1 and E2: $E0 \cap E1 = \emptyset$, $E1 \cap E2 = \emptyset$, $E0 \cap E2 = \emptyset$, $E0 \cup E1 \cup E2 = E$, $E1 \neq \emptyset$ and $E2 \neq \emptyset$. Moreover.
- E1 is a set of experiments for which all the evaluation parameters of Y1 are satisfied.
- E2 is a set of experiments for which all the evaluation parameters of Y2 are satisfied.

The table 2, which is obtained by permuting rows and columns of table 1 in order to group the identified Ei and Yi, represents the properties of the Generalized System of Contradictions from the values of the evaluation parameters.

In table 2, the values of the evaluation parameters are normalized as being 1 if the parameter is satisfied, according to the objective of the resolution, and as being 0 if the parameter does not fit the requirement.

X	Y_1	Y_2	Y_0
E_1	$E_1 \times Y_1$: $z_{ij}=1$	$\forall e_i \in E_1$ $e_i \times Y_2$: $\exists j / z_{ij}=0$	$E_1 \times Y_0$
E_2	$\forall e_i \in E_2$ $e_i \times Y_1$: $\exists j / z_{ij}=0$	$E_2 \times Y_2$: $z_{ij}=1$	$E_2 \times Y_0$
E_0	$E_0 \times Y_1$	$E_0 \times Y_2$	$E_0 \times Y_0$

Table 2: Representation of a GSC in a DoE.

The matrix of table 2 has specific features:

- $E_1 \times Y_1$: $\forall$ (i,j) / ($e_i \in E_1$) AND ($y_j \in Y_1$), $z_{ij}=1$.
- $E_1 \times Y_2$: $\forall$ i / ($e_i \in E_1$), $\exists$ j / ($y_j \in Y_2$) AND ($z_{ij}=1$).
- $E_2 \times Y_2$: $\forall$ (i,j) / ($e_i \in E_2$) AND ($y_j \in Y_2$), $z_{ij}=1$.
- $E_2 \times Y_1$: $\forall$ i / ($e_i \in E_2$), $\exists$ j / ($y_j \in Y_1$) AND ($z_{ij}=1$).

The analysis and automatic extraction of the three sets out of the DoE result has to defined based on the chosen strategy, but several algorithms exists to facilitate this extraction [10].

3.2. Different strategies, different GSC

According to the previous set of constraints defining the GSC, some freedom to build a GSC remains. Indeed several ways can be identified in order to extract a GSC, but each of these ways is based on a different strategy. One can recognize at least four strategies:

- First strategy: choosing the nearest configuration to the solution. One configuration, in a DoE is one line, or a set of lines, of the table, a particular arrangement of the action parameters. The configuration that is the nearest to the solution is recognised as satisfying the maximum number of evaluation parameters. The usefulness of such a choice is the consideration that the gap to fulfil from this configuration to the solution is maybe the minimal gap. To identify this configuration, in terms of extraction it means to maximize one of the subset Y_1 or Y_2. Such a strategy aims at increasing the efficiency of the resolution by minimizing the resources required to solve the GSC.
- Second strategy: choosing the GSC which resolution will lead to the satisfaction of the maximum number of evaluation parameters, ideally, if it exist, a GSC which resolution will satisfy all the evaluation parameters. This usefulness of this strategy it to minimize the number of iterations required to solve the problem, i.e. to satisfy all the evaluation parameters. The constraint to identify such a GSC is that the sum of the numbers of evaluation parameters included in Y_1 and Y_2 is maximized, i.e. $Y_1+Y_2 \rightarrow Y$ or $Y0 \rightarrow 0$.
- Third strategy: choosing the GSC that includes the more important amount of information about the problem. This strategy also aims at minimizing the number of iterations, as most of the information will be taken into account since the first contradiction. The information about the problematic situation, in a DoE, is represented by the lines of the table. Thus, considering the GSC in which the most information about the problematic situation is included is considering the GSC in which $E_0 \rightarrow 0$.
- The fourth strategy is ore a philosophical strategy. Its objective is to reinforce the contradictory nature of the contradiction by limiting the number of satisfied parameters in the set of non-satisfied parameters. For example, the constraint for $E_1 \times Y_2$ is that there exists at least one evaluation parameter of Y_2 that is not satisfied in each experiment of E_1. The new constraints will be that all the evaluation parameters of Y_2 will not be satisfied: $E_1 \times Y_2$: $z_{ij}=0$.

3.3. How to choose the good strategy?

Four strategies have been defined, based on different assumptions:

- To limit the difficulty to resolve the problem, first strategy.
- To limit the number of iterations from the problem to the solution, in order to evolve towards a "one-shot resolution", second and third strategy.
- To reinforce the contradictory nature of the GSC, fourth strategy.

It is now necessary to choose between these four strategies the one that is the more suitable and the more useful for the resolution of the problems. Two criteria have been identified to evaluate the relevancy of the chosen GSC:

- The meaningfulness of the GSC for the experts of the domain: the complexity of the concept inherent to the GSC could lead to expression that does not have any interest for the analysis. Of course, it is always possible to simplify the expression of the concepts, but then it is necessary to propose simplified concepts which still are exhaustive and discriminative.
- The robustness of the obtained solution, this robustness could only be evaluated afterwards. It will be based on the easiness for the solver to apply the solution, on the lifetime of the solution, on its relevancy in accordance to the market.

To be able to evaluate and to choose the more relevant strategy, tests will now be performed by formulating the different GSC for problems, considering the meaningfulness of the concepts with experts, and then analyse the robustness of the solutions coming from the different GSC.

4. Conclusion

The GSC has been defined in order to satisfy the non-equivalence of the existence of a contradiction for any inventive problem for the classical TRIZ model of contradiction. After having demonstrated how the GSC could be automatically extracted in [9], in this article different strategies to recognize and formulate GSC are proposed. The next step will now be to understand which of these strategies is the most useful for resolution.

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