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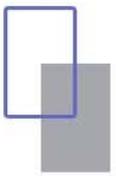
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# Comparison of problem model change mechanisms issued from CSP and TRIZ

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## Abstract

Different kinds of problem solving methods exist for different kinds of problems. One can recognize two kinds of problems: optimization ones, for which a solution can be found by adjustment of the value of problem parameters; and inventive problems, for which no solution is known. This problem insolvability can be due to the lack of a “good” solving algorithm or to a non adequate problem representation. If so, the problem, as it is modeled has to be reformulated, the model has to be changed, in order to build a representation enabling the resolution of the problem. The article will be focused on the question of problem model change and will compare the mechanisms to change this model for inventive problems from two problem solving theories: dialectical methods and models, on the one hand; and constraint satisfaction problem (CSP), on the other hand.

*Keywords:* over-constrained problems, dialectical methods, problem model

## 1. Introduction

TRIZ (Altshuller, 1988) is a theory for inventive problem resolution based on dialectical representation of problems. One among the main approaches of TRIZ for problem resolution is to use contradictions as a way to formulate problems and analyze this contradiction in order to solve the problem. A Generalized model of Contradiction has been proposed (Dubois, et al., 2009) to state inventive problems, whatever the domain of problem could be. A problem, in accordance with the generalized contradiction model, will be characterized by:

- a set of evaluation parameters, which represent the objective of the problem resolution;
- a set of action parameters, which are the resources to resolve the problem, i.e. to satisfy the evaluation parameters;
- a set of relations between the evaluation parameters and the action parameters.

One of the main interests of TRIZ is to propose principles to separate the contradictory properties of a situation, and thus to solve problems.

Constraint satisfaction problem is defined as (Freuder & Wallace, 1992):

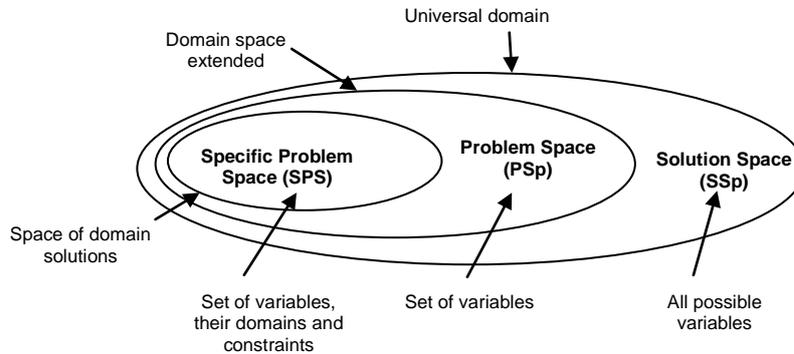
- a set of variables;
- for each variable, a finite set of possible values (its domain);
- and a set of constraints restricting the values that the variables can simultaneously take.

The solution of a constraint satisfaction problem is an assignment of a value from its domain to every variable, in such a way that all constraints are satisfied. Such systems, where it is not possible to find valuation satisfying all the constraints, are called over-constrained. There exist different algorithms to look for a solution for CSP and over-constrained CSP.

The objective of this article is to define the kind of model change that is operated by CSP resolution mechanism and also that the TRIZ principles lead to the building of a model that cannot be obtained with CSP algorithms. When a contradiction occurs in a problem, it means that two properties that cannot be satisfied simultaneously in the initial model of problem are identified. To be able to solve such a problem a new model of the problem has to be built in which the two properties can be both satisfied. What kinds of model changes are operated by the TRIZ principles to build such a model? In the article (Rasovska, et al., 2009) the different space browsed by the mechanisms of model change have been defined. In the present article the mechanisms to define and to browse these spaces will be illustrated. In (Rasovska, et al., 2009) different spaces have been defined, as illustrated on figure 1:

- Specific problem space is defined by variables (parameters) of the problem which are limited by their domains  $D_i$ . The dimension of this space is equal to the number of variables defined by the inventive problem.
- Problem space is also defined by variables (parameters) of the problem but these are not limited by their domains. The dimension of this space is equal to the number of variables too.

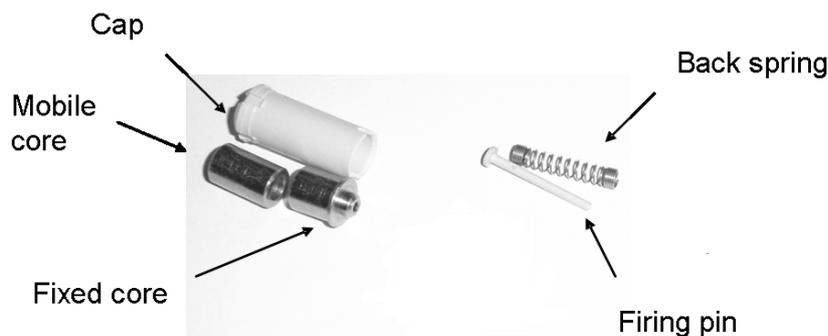
- Solution space is defined by all possible variables concerning the system the inventive problem concerns. The dimension of this solution space is so infinite.



**Figure 1. Definition of knowledge spaces**

## 2. Problem statement

Let us consider an electrical circuit breaker. When an overload occurs, the overload creates a force (due to magnets and electrical field) which operates a piece called firing pin. The firing pin opens the circuit by pressing the switch, located in the circuit breaker. In case of high overload, the firing pin, this is a plastic stem, breaks without opening the switch. Components are presented on figure 2.



**Figure 2. Components of electrical circuit breaker.**

The problem has been studied and the main system parameters and their domains have been defined as:  $x_1$ : firing pin material (plastic – 1, metal – 0) ;  $x_2$ : core internal diameter (high – 1, low – 0) ;  $x_3$ : core external diameter (high – 1, low – 0) ;  $x_4$ : firing pin diameter (high – 1, low – 0) ;  $x_5$ : spring straightness (high – 2, medium – 1, low – 0) ;  $y_1$ : circuit breaker disrepair (satisfied – 1, unsatisfied – 0) ;  $y_2$ : circuit breaker reusability (satisfied – 1, unsatisfied – 0) ;  $y_3$ : spring core mounting (satisfied – 1, unsatisfied – 0) ;  $y_4$ :

firing pin bobbin mounting (satisfied – 1, unsatisfied – 0) ;  $y_5$ : normal mode release (satisfied – 1, unsatisfied – 0) ;  $y_6$ : firing pin initial position return (satisfied – 1, unsatisfied – 0). In this definition of the problem the  $x_i$  are the action parameters whereas the  $y_i$  are the evaluation ones. The system behavior was modeled by Design of Experiments and it is shown in table 1. The objectives that have been established to build the DoE are:

- the satisfaction of at least one evaluation parameter in each experiment;
- each of the action parameters has at least one time each of its possible values;
- to minimize the number of experiments.

Even if the assumption is not totally consistent, the action parameters have been considered independent in the limits of their defined domains.

**Table 1. DoE for the circuit breaker**

	x1	x2	x3	x4	x5	y1	y2	y3	y4	y5	y6
e1	1	1	0	0	1	1	0	1	1	1	1
e2	0	1	1	1	1	0	1	0	0	1	1
e3	1	0	1	0	0	1	0	1	0	0	0
e4	1	1	0	0	0	1	1	1	1	0	0
e5	1	0	1	0	1	1	0	1	0	1	1
e6	0	1	0	1	2	0	1	0	1	1	1
e7	1	0	1	1	0	1	0	1	0	0	0
e8	1	0	0	0	1	1	0	0	1	1	1
e9	0	1	0	0	2	0	1	0	1	1	1

First evidence is that no solution can be found in the defined DoE, as no experiment enables the satisfaction of all the evaluation parameters. This problem can be recognised as an inventive one, or an over-constrained one.

### 3. Resolution by means of over-constrained CSP

#### 3.1 Application of the resolution mechanisms

One can consider each experiment of the previously defined DoE as a constraint, for example:

$$C_i: [1, 1, 0, 0, 1] \Rightarrow [1, 0, 1, 1, 1, 1] \quad (1)$$

This leads the definition of nine constraints. Then the search for a solution is defined by an optimisation function (Barták, 1999), defined in Equation (2).

$$\text{Maximize } \sum y_i \Rightarrow \text{Optimal Solution} = [1, 1, 1, 1, 1, 1] \quad (2)$$

The solution to Equation (2) cannot be found in the initial Specific Problem Space, it is thus necessary to refer to methods for over-constrained problems. One of the well known methods is the hierarchy of constraints (Borning, et al., 1992). It means that the satisfaction of the evaluation parameters will be relaxed according to a defined hierarchy of importance. For example, one can define that the satisfaction of the parameters  $y_1$ ,  $y_5$  and  $y_6$  are required, the satisfaction of the parameters  $y_3$  and  $y_4$  are strong constraints and that the satisfaction of  $y_2$  is a weak constraint. Then the solution will be searched by satisfying first the required constraints, then the strong ones and at least, if possible the weak ones.

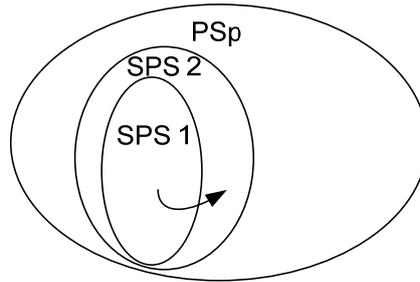
The experiments  $C_1$ ,  $C_5$  and  $C_8$  satisfy the required constraints, the experiment  $C_1$  satisfy also the strong constraints, but no solution can be found to satisfy all the constraints. Then, according to this algorithm, and to this hierarchy, the solution is the experiment  $C_1$ .

### 3.2 Analysis of the resolution impact on the solution space

The comparison of initial domain and domain of solution lead to the following conclusions:

- The set of parameters remains the same
- The considered constraints are different, as the constraint  $y_2=1$  is not considered anymore.

The intensification of this mechanism lead to a space defined by the initial set of parameters without any constraints. This means that solving principles of constraint hierarchies and PCSP start from initial problem defined by the specific problem space 1 (SPS1) and extend this space by relaxing certain constraints and variables in order to define a new specific problem space SPS2. This space is larger than SPS1 but always covered by respective Problem Space characterized by the set of variables describing the initial problem (see figure 3).



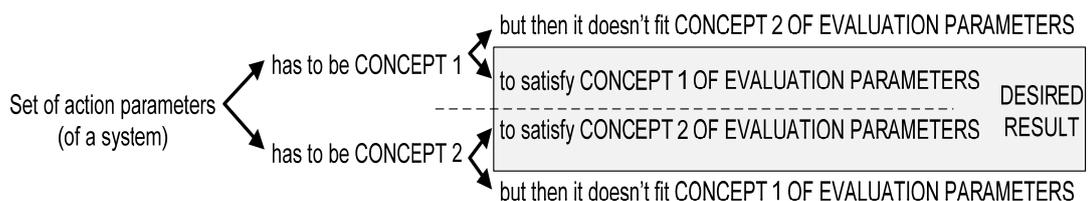
**Figure 3. Model change mechanism of optimization methods**

#### 4. Resolution by means of dialectical approach

To solve an inventive problem with TRIZ-based methods, it is first necessary to formulate the problem in an adequate form, i.e. to identify the contradictions. Then, the application of resolution mechanisms could be applied

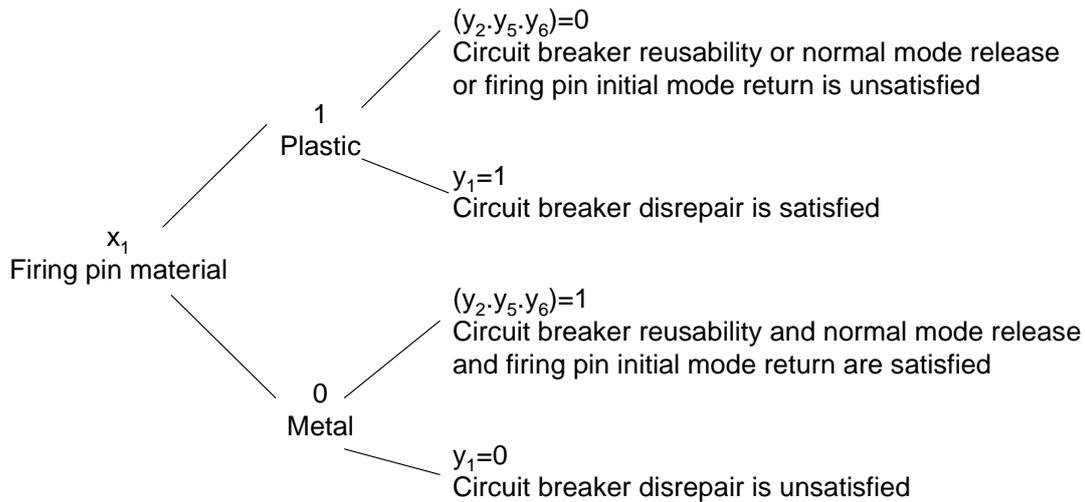
##### 4.1 Identification of contradictions

In classical TRIZ approach (Altshuller, 1988), there exist different kinds of contradictions (administrative, technical and physical ones). Only the technical and physical contradictions are helpful as they propose of formulation of the problem enabling the application of resolution mechanisms. In (Khomenko, et al., 2007) a system of contradiction has been proposed to clarify the role of each element of the contradiction and also to clarify the link between technical and physical contradictions. In (Dubois, et al., 2009) a generalization of this concept of system of contradiction is defined as Generalized System of Contradiction and is presented on figure 4.



**Figure 4. Generalized System of Contradictions**

The analysis of table 1 enables the identification of several Generalized Systems of Contradictions; one of these GSC is presented on figure 5.

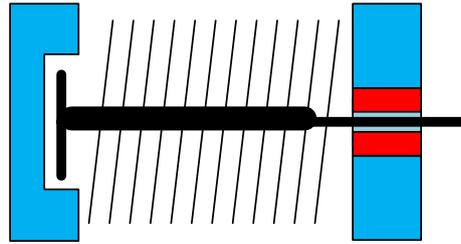


**Figure 5. Generalized System of Contradictions for the example**

The elicited contradiction can be reformulated this way: the firing pin material has to be plastic in order to disable the disrepair of the circuit breaker; but the firing pin diameter has to be metallic in order to satisfy simultaneously the reusability of the circuit breaker, the normal mode release and the return in initial position of the firing pin.

#### 4.2 Application of the resolution mechanisms

The GSC identified on figure 5 tackles the problem linked with the firing pin diameter which has to be high and small in the same time. One of the well known TRIZ mechanisms to solve problems is the separation of contradictory properties in space. Could the contradictory properties be separated in space? Actually the firing pin has to be metallic only from the front of the fixed core, where it begins to deform. And this fixed core is a metallic part. Then a new system of contradictions could be formulated: the fixed core has to become the firing pin as it is a metallic part, but the fixed core cannot be the firing pin as it is fixed. This contradiction can be solved easily through the application of another TRIZ resolution mechanism, the segmentation. One part of the fixed core has to become mobile. The inherent concept of solution is presented on figure 6.



**Figure 6. Concept of solution for the formulated problem**

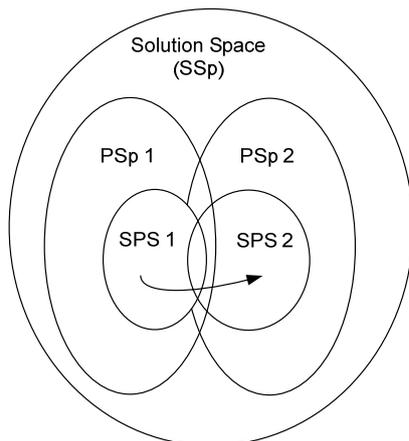
### 4.3 Analysis of the resolution impact on the solution space

If comparing the final concept of solution with initial model of problem, one can recognized that one parameter has been changed and a new one has been introduced. The parameter  $x_4$ , firing pin diameter has been splitted into two: the diameter of the upper part of the firing pin and the diameter of the low part of the firing pin. The parameter  $x_6$ , fixed core segmentation has been introduced. Thus the new solution corresponds to a new set of constraints which enables a new line in the initial DoE, as presented in table 2.

**Table 2. Representation of the concept of solution**

$x_1$	$x_2$	$x_3$	$x_{4a}$	$x_{4b}$	$x_5$	$x_6$	$y_1$	$y_2$	$y_3$	$y_4$	$y_5$	$y_6$
1	1	0	1	0	2	1	1	1	1	1	1	1

If analyzing the kind of transformation achieved by these resolution mechanisms and the impact on the browsed solution space, one can consider that a new specific problem space is built, with new parameters and new constraints. And for this new SPS, a new Problems Space is defined, as illustrated on figure 7.



**Figure 7. Model change mechanism of inventive methods**

## 5. Conclusion

In this article the way different kind of spaces are defined by the resolution mechanisms from optimization methods (CSP ones) and inventive methods (TRIZ based ones) are illustrated. It is both showed the nature of the browsed spaces and also the way the model changes are realized.

The consideration of the complementary aspects of both families of solving principles is of great interest and it put the emphasis on the necessity to define a unified model that permits to shift easily from an optimisation approach to an inventive one.

Each inventive method involves one or more operators of model changes. At the first time, every operator of model change and its using should be described in more details. The mutual enrichment of optimization and inventive methods will support a precise description of the inventive principles involving proposition of algorithms. At the second time, the efficiency of operators should be measured in order to prove a progress in the problem resolution. Later the whole process of inventive problem solving could be described as a succession of single model changes.

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