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Towards a formal definition of contradiction in inventive design

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ABSTRACT

For nearly two decades, TRIZ has appeared as a set of methodological tools useful for supporting inventive aims in industry. The central aspect of a process based on TRIZ invariably involves the formulation of a contradiction, although there has been very little research conducted about the formalization of this notion. Our paper proposes a formal definition of the contradiction and of its potential manipulations useful in inventive design in accordance to the fundamentals of TRIZ. This formalization is particularly important when software tools are needed to implement TRIZ in industry. This work is also necessary at a moment where perceptions associated with the TRIZ point of view about contradictions diverge away from what made TRIZ original and relevant in the innovation area.

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1. Introduction

In this paper, we are interested in the formalization of a core concept of TRIZ [1,2] (the Russian acronym for Theory of Inventive Problem Solving): the concept of contradiction. TRIZ takes its roots in dialectical thinking, which is briefly described later. The core goal of TRIZ is to structure inventive thinking. It is based on studies of several hundreds of thousands patents and has outlined typical general problems and their general solutions. TRIZ is a methodology mainly transmitted through generations by examples. As a result, it lacks formalization and many notions suffer from an absence of precise and shared definitions.

TRIZ is primarily anchored on technical and physical design problems, but is now being used on almost any problematic situation. The key to success in TRIZ is the fact that (technical) systems evolve in similar ways. So, by reducing any situation and its associated problems to an abstract level independent from the domain of the technical system, it is possible to apply standard solutions and problem solving techniques, even from very different domains: physics, chemistry, biology and so.

The theory provides several models and knowledge bases to lead analogical reasoning at different levels. The complete list of TRIZ components is very long indeed, and includes "evolution laws", "separation methods", and various lists of "inventive principles" (Fig. 1).

This figure shows that there are different ways to solve design problems with TRIZ depending on different models. Notice that the solution being at an abstract level is not a solution in the real world; it is "a concept of solution" needs to be validated in the context of a given real application.

The focus of this paper is on "contradictions" and on the model based on contradictions. But, why focus on contradictions? Because one of the essential TRIZ axioms establishes that every inventive problem may be reduced to a contradiction [1,2].

Even if TRIZ has undergone various attempts of computerization (such as the following commercial products, Tech Optimizer [3], Ideation Workbench [4], CreaTRIZ [5], IWIN [6]) the notion of contradiction remains unclear. Most of its use or synthesis is intuitive and there are no means to disclose easily and in a robust way the set of contradictions behind a problem. As a result and since the notion of contradiction is one of the two core concepts of TRIZ, each software tool appears, in practice, more like an art than like a clearly defined methodology. Therefore, our aim of disambiguation of the notion of contradiction through the proposal of a formal model is also meant to future computer projects aiming at a computer aided use of TRIZ.

TRIZ is focused on problems dealing with a limited amount of contradictions (from 1 to a maximum of 3), but in general, when dealing with a large quantity of contradictions, there are no clear indications on how to choose the key contradiction assuming that one cannot process all of them one by one. Nowadays problems grow in complexity involving, generally, several hundreds of contradictions.

The authors have been working for the last six years in the formalisation of the central notions used in TRIZ and have conceived an extension of the method in order to cope with complex problems (involving many contradictions related to several different domains). This new method, called Inventive

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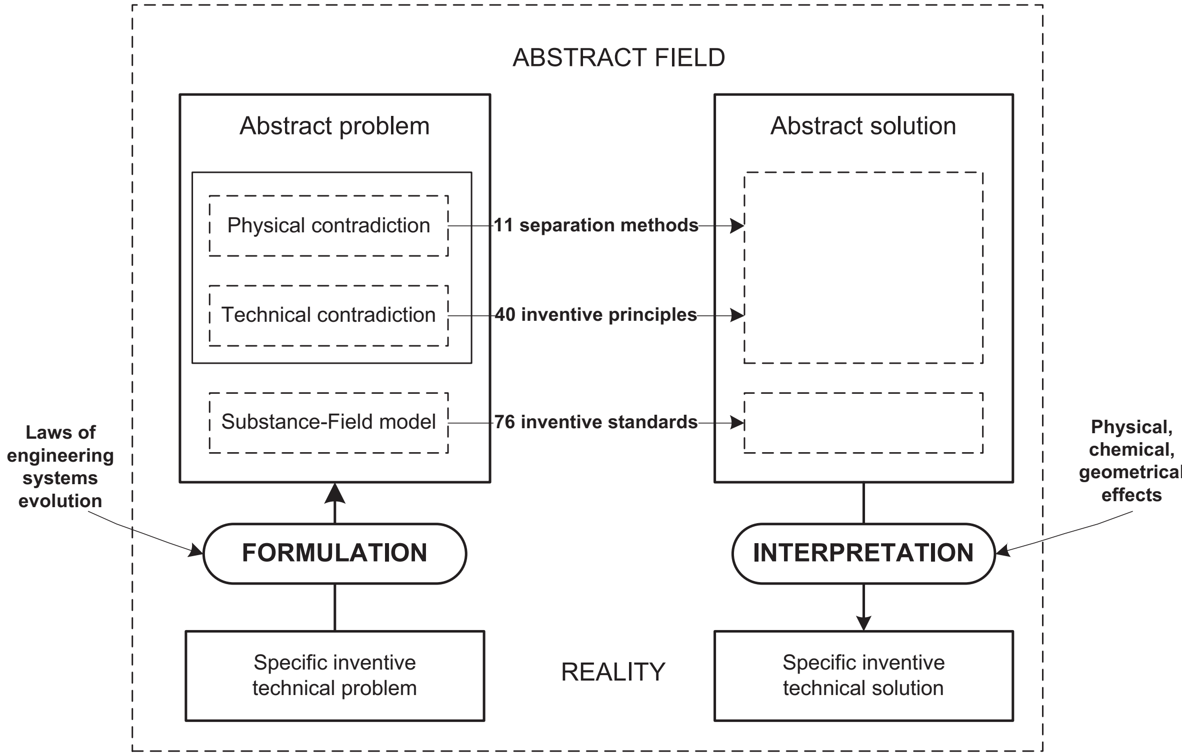

Fig. 1. The TRIZ problem solving process.

Design Method (IDM) has already been presented in other publications [7].

Fig. 2 recalls the main steps of IDM.

For IDM, an ontology describing the main notions borrowed from classical TRIZ and the new own concepts of our methodology has been developed, along with the specification of this new method for conducting inventive design studies.

From the point of view of computer sciences, and more particularly, from the knowledge engineering field, the most used definition of ontology is the one from [8]: "An ontology is a formal and explicit specification of a shared conceptualization". The term conceptualization is related to an abstract model of a certain phenomenon in the world by the identification of the appropriated concepts of the phenomenon. Explicit means that the type of the used concepts and the restrictions about their use are explicitly defined. Formal is related to the fact that the ontology should be comprehensible by a computer. Shared reflects the notion that the ontology captures consensual knowledge, that is not private, but commonly admitted by a group.

In a general way, an ontology contains a formalized vocabulary grouping, for a given field, the set of concepts and their relationships. The definitions associated to each concept come from a consensus among the different actors and future users of the ontology. In this way, the main result of the developed ontology is the normalisation of the vocabulary used by the experts and the explicit exhibition of the links among the generally used concepts.

While many other researchers stay attached to functional approaches to describe systems, the focus here is on knowledge extraction resulting in parameters and the influences that modifications on them may have on each other.

The use of functional approaches implies that the links among parameters are named. This seems to be contradictory, somehow, with the philosophy of TRIZ, that stipulates the study of problems in a very high abstraction level. For instance, in the case of a problem about grass cutting, TRIZ experts would formulate the problem as "to improve the way to maintain the grass short", instead of saying "to improve the grass cutter". In this case, the means (the grass cutter to improve) is fixed in advance, excluding, therefore, other means to solve the problem (by using GMOs for example).

It is to be remarked that the notion of contradiction in IDM has very few in common with the contradiction of formal logics. In formal logics, a contradiction has a static meaning, and may be expressed as $A \wedge \bar{A}$; where A is a proposition that cannot be simultaneously true and false. In IDM, the context is dynamic, where things evolve and may influence among each other.

In the following, the notions of dialectics (Section 2) and contradiction (Section 3) will be briefly introduced. As the contradiction model relies on a list of parameters, in the following sections, a method to ensure that the possible set of parameters will be as complete as possible will be presented. The notion of poly-contradiction will be also introduced (section 4).

Section 5 describes the formal contradiction model and the usefulness of the model is discussed (Section 6). Later, a method to weight parameters to reflect reality is described. These weights will facilitate the choice of the most appropriate contradiction to be solved (Section 7). Also, the formalized IDM model is compared to the numerical models coming from optimization approaches as CSP (constraint satisfaction problems) in Section 8. Finally, a real industrial case is presented as an example of the formalization (Section 9). In the end, Section 10 presents our conclusions and perspectives of future work.

2. Dialectics

Dialectics is a philosophical school having roots in the old Greek philosophy, represented by Heraclitus and Aristotle. In particular, Aristotle, in his "Metaphysics", speaks about an "ontological non contradiction principle" which establishes that an object cannot simultaneously have and not have a given property P.

The philosophy grows out of the Hegelian discussion about the relation (or contradiction) between ideas and reality. Thus, the key

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