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Review

Enhancing functional decomposition and morphology with TRIZ: Literature review

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ABSTRACT

One of most acknowledged approaches for conceptual design is the so-called "Functional Decomposition and Morphology" (FDM), which provides a systematic framework for transforming a set of technical requirements in a product concept. However, as observed by some scholars, this particular procedure acknowledges some flaws, also concerning a non-comprehensive support in generating creative ideas. Accordingly, literature suggests to combine creativity-enhancer tools or methods with the FDM process. The TRIZ base of knowledge appears to be one of the viable options, as shown in the fragmental indications reported in well-acknowledged design textbooks. Accordingly, other contributions can be found in literature, which are focused on more structured ways for enhancing FDM approaches with TRIZ. In such a context, the objectives of this paper is to collect the literature contributions focused on the TRIZ-FDM integration, with the aim of providing a first comprehensive classification and discussing about observable differences and lacks.

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1. Introduction

The design process is a complex activity aimed at conceiving and developing product ideas, and providing the information needed for their physical realization. Several scholars deeply investigated such a fascinating process, leading to methods, models and theoretical discussions about designing. Among the design models acknowledged by literature [1–3], the so called "German systematic design" is one of the most taught and robust, grounding its historical roots on two centuries of engineering experiences [4]. In particular, concerning conceptual design activities, the recalled model adopts the well-known Functional Decomposition and Morphology (FDM) approach.

Unfortunately, despite their academic success, systematic approaches suffer a poor industrial diffusion, as well as other contributions coming from academia. Literature infers several possible reasons behind this lack and, among the others, a non-comprehensive support to (or even the hindering of) creativity (i.e. the ability to generate novel and useful ideas [5]) has been often pointed out as one of the most impacting ones. In order to overcome the recalled limitation, some scholars suggested the application of specific methods and/or tools to support idea generation activities (e.g. Pahl et al. [6]). One of these "aids" can be provided by TRIZ [7], which is considered in some textbooks (e.g. [8,9]) as a suitable support for designers in generating creative solutions. However, the cited contributions only report very short introductions to the TRIZ body of knowledge, neglecting a comprehensive description about the use of the related tools within the FDM framework. Unfortunately, FDM and TRIZ are very different approaches with different purposes. Indeed, while FDM is an engineering design method based on functions, TRIZ is a problem solving approach strongly based on the concept of "contradiction", using specific techniques for solving them. Therefore, any attempt of integration between the two approaches should comprehensively face the recalled differences. Nevertheless, among the literature references concerning TRIZ, some of them propose different combinations with FDM aimed at exploiting the positive characteristics of both the approaches. In such a context, this paper argues about the current scientific proposals that explicitly try to enhance FDM with TRIZ. More precisely, the relevant contributions available in literature are collected and analyzed to understand how TRIZ tools are exploited in the fuzzy front-end phases of systematic design processes. Indeed, literature reviews focused on TRIZ are certainly present, but none of them contemplates the combined use with FDM. For instance, Ilevbare et al. [10] performed an analysis of successful and unsuccessful cases in order to collect information about people who tried to apply and understand TRIZ methodology. Such a survey was aimed at indicating to beginners the tools of TRIZ toolkit useful to learn first, based on thei observed degree of usage by the survey respondents. More recently, Chechurin at al. [11] presented a literature review of 100 most cited contributions about TRIZ to verify its diffusion and application fields. Furthermore, the literature presents publications that review the proposals aimed at integrating TRIZ with other methods like Axiomatic Design (AD) [12], or with other ideation tools and processes diffused in industry [13]. Hence, due to the absence of literature reviews focused on the FDM/TRIZ combination, this paper provides a first comprehensive state of the art on the recalled topic, with the aim of:

- Highlighting the main similarities and differences between the reviewed contributions.
- Discussing about their observable lacks.
- Providing suggestions for future research activities on the argument.

The following section reports a brief overview of TRIZ, introducing the fundamentals, the historical roots and information about its dissemination. In Section 3, the systematic conceptual design approach is introduced, together with a discussion about the possible causes that hinder its industrial uptake. In Section 4, the current literature contributions concerning possible links between FDM and TRIZ are reviewed and discussed. Section 5 reports a discussion on the outcomes of this work and the relevant research issues concerning the integration of FDM with TRIZ. Eventually, in the last section conclusions are presented, while the Appendix A shortly introduces the TRIZ tools considered in the reviewed contributions.

2. Short introduction to TRIZ

TRIZ is the Russian acronym for "Teoriya Resheniya Izobretatelskikh Zadach", i.e. the "theory of the resolution of inventive problems" that was formerly developed by Genrich Altshuller, a Soviet engineer, inventor and science fiction writer [14]. The first publication ("On the psychology of inventive creation" [15]) dates back 1956 and argues about how to solve thousands of different technical contradictions by means of a limited number of "Inventive Principles" (see Appendix A for a short introduction to the tool). In 1969, Altshuller published "The Innovation Algorithm" [16], a milestone where the well-known 40 Inventive Principles and the first version of the so-called "ARIZ" (Russian acronym for the "algorithm for the solution of inventive problems") were presented. The three main observations made by Altshuller as a consequence of his noticeable research effort, can be summarized as it follows [17]:

- Technical systems evolve according to objective laws, toward an increasing degree of ideality (i.e. the ratio between benefits and the sum of costs and harmful effects).
- Any specific technical problem can be converted into a more general one through an abstraction process. Thanks to the abstraction, Altshuller observed that similar problems arise in very different fields, allowing to group the related solving processes in a finite number of "solving principles".
- Given a finite number of standardized problems and solving principles, solutions based on similar concepts can be used for solving apparently different technical problems. Consequently, it has been possible to build the invention theory, aimed at

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