State of the Art for Evaluation of Inventive Design Solution Concepts

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Abstract. The concepts of solutions resulting from the inventive design process measures are generally described in a declarative manner, which does not allow having a shareable formal or visual representation between partners of the project. In addition, the absence of a model does not allow evaluation and compare competing concepts. In this paper, most relevant work regarding inventive design solution concept presented along with potential merits and demerits and highlighted the need of a systematic method to evaluate behavioral performance of solution concepts.

Keywords: Solution concept · Evaluation model of solution concepts · Inventive design · TRIZ

1 Introduction

In today's fast growing technological world companies, inventors and R&D facing with new challenges regarding its capacity to quickly and accurately respond to society's development demands or problems. To cope with the acceleration of new artefacts' demand, innovative activities need to be more assured in terms of optimal solution with respect to many aspects (functionality, maintainability, reliability, security, cost, quality, etc.) [1].

Ideas are defined in two ways i.e. useful or not useful. New ideas which are useful, constructive and profitable or solve a problem are referred as creative ideas while only fancy, not realistic and not useful ideas called mistakes [2]. With reference to the inventive design techniques like TRIZ (theory of inventive problem solving) where ideas are defined more properly than conventional terms of creative activities. After going through properly defined process, creative idea is called "Solution concept" [3]. A solution concept should be taken as an idea which has its all necessary information or characteristics most probably documented in sufficient details for an artefact (concrete way with a description template) so that an objective estimation becomes possible. In inventive design when ideas are characterized in a concrete way with description template, the concepts called Solution Concepts.

Inventive design is the field which develops methodologies for problem solution regarding the development of innovative artefacts [4]. There are many methods created which are able to successfully carry out inventive design steps to produce solution concepts or ideas and solution concept ranking processes [5]. However has the drawback “inability to evaluate optimum solution concept”. Herstatt highlighted the inability of routine design methods for creating inventive ideas [6].

2 Aim and Scope

The aim of this research is to identify, interpret and summaries the literature currently available on evaluation of inventive design solution concepts. Within the scope of this research, the focus has been on relevant research articles, and other authentic literature specifically for evaluation of solution concepts.

3 Inventive Design Solution Concepts

3.1 Inventive Design Definition

Several attempts have been made to define inventive design by both scientific and artistic terms. Inventive design is a thought-provoking engineering activity associated to all areas of human life. It follows the laws of science, fulfill the requirements for realization of a solution concept and needs professional integrity and responsibility. It is an attempt to possible realization of concepts by meeting particular constraints [2]. Inventive design is acquisition of knowledge and capitalization [7]. Inventiveness here is in terms of invention which means “the action of creating or designing (something that has not existed before), typically a process or device” [8]. T. Chikatham one of the authors [2] compared inventive design and routine design as given in Table 1: In Inventive Design, the contradicted features of a situation or problem by TRIZ tools is highlighted and these contradictions are then considered as a key source to solve problem [9].

Table 1. Inventive design vs routine design [2]

Routine design	Inventive design
Manage what is known	Discover what is unknown
Optimization of existing data for best result	Moving further ahead from the optimized result of existing data
Accept compromise as a potential solution	Refuse compromise as a possible solution

3.2 Our Position in Inventive Design Process

The first article on TRIZ was by Genrich Altshuller in 1956 [10]. Its application has been observed in various fields like technic, management, sociology, education and marketing [11]. During 80s Altshuller work developed into a set of tools to carryout systematic creativity called TRIZ “Theory of inventive problem solving” and in 90s to OTSM “General theory of strong thinking” and ZhSTL “Lifetime strategy for creative person” [10]. The research progress in field of TRIZ as a result gave rise to organized data in order to understand TRIZ and its extension as IDM (Inventive Design Method).

The Inventive Design Method is the output of many years of research by INSA Strasbourg France [12]. With the intention to build an abstract model with initial problem formulation using the theoretical approach of TRIZ C. Zanni Merk [7] proposed an ontology for computer based innovation. In further progress of TRIZ, Francois Rousselot [13] proposed an important formal definition of contradiction and its possible applications in inventive design with respect to the TRIZ fundamentals. Following the previous work the extension of TRIZ called inventive design method IDM proposed and developed and framed into a computer software named STEPS by INSA Strasbourg [14]. Currently there are different TRIZ based computer-aided innovation (CAI) systems, which support design phase inventive design [15]. These CAI systems provide suitable tools for designer to generate solution concepts and their rankings on the basis of multi criteria decision methods but still lack in evaluation of generated solution concepts. Keeping all these in consideration our focus will be regarding need of a confident evaluation model along with specific criteria (quality, maintainability etc.) of solution concepts, which come from the previous steps of inventive design using different TRIZ tools and methods.

Inventive design can be subdivided into four main steps shown in Fig. 1: initial situation analysis, contradiction formulation, solution concept generation, and solution concept selection or evaluation of solution concepts [5].

Fig. 1. Inventive design solution concepts evaluation status

The primary steps of inventive design development known by the term ‘concept development’. Concept development contains a sequences of divergent steps and convergent steps, completed at different levels of solution concept [16]. In concept development, generation of solution concepts belongs to divergent steps while evaluation and selection of the best solution concepts are related to convergent steps.

3.3 Inventive Design Solution Concept Evaluation

A concept of any product is a predicted representation of the shape of product, its working standards and technology. It is a well explained definition of product characteristics that how the product will satisfy the voice of customer. Generally a concept is considered as a sketch or 3D model following a detail description. The success of any product depends on the selection of best concept. Success here means the commercialization of the quality product.

With reference to inventive design solution concepts, the arrival of TRIZ and its extension to IDM has been considered as a systematic methodology to produce set of solution concepts as compared to earlier unstructured methods [17]. As mentioned in the introduction that a solution concept should be describe in a concrete way with a description template. The description template for solution concept characterizes into five categories [13]. These five categories are: 1) an abstract of idea describing the general properties, all the relevant performing functions, extra note, merits/demerits. 2) A complete explanation of problem model (in which contradiction contain action parameter and evaluation parameter or SU-field model) and solution model (using tools like inventive principle, inventive standard, physical effect database). 3) Possible outcomes, trends and developments from the outcomes of related projects in term of hypothesizes and laws of technical systems evolution, 4) keeping the objective of the project point out all the unacceptable conditions. 5) A sketch of the solution concept, which is synthesized by model of solution and hypothesis of solution concept. After the set of solution concepts are identified and ranked using Pugh matrix by the inventive design methodology for the next step to select the solution concept to develop or solution concept evaluation.

The evaluation phase of solution concept is the key challenge for the designers, as well as the customers. Particularly in solution concept selection phase qualitative methods are used to evaluate the generated solution concepts. Although, to facilitate the inventive design solution concepts evaluation steps, there are many methodologies used by designers and customers [14, 19]. However, these methodologies are generally described in a qualitative, declarative manner, which does not allow to choose the best solution concept neither to have a shareable formal or visual representation between partners of the project. In inventive design the process stops after ranking of solution concepts and final selection of solution concept to develop depends on R&D or the top management of company. That is why, the absence of a confident model does not allow evaluation and compare competing concepts thereby making a challenge for researchers and designers to develop a confident model for evaluation of inventive design solution concepts.

3.4 Research Gaps in Inventive Design Solution Concept Evaluation

In this section, an overview of the most prominent research work regarding inventive design solution concept is given in the Table 2. The purpose of this research is to highlight the need for inventive design solution concepts evaluation model.

Table 2. Literature review on inventive design solution concepts

Title of paper	Focus area	Research gap	Ref.	Year
Improving Inventive Design Methodology's Agility	Focus on elimination of non-value added activities to reduce long time taking in inventive design solution concepts process	After solution concepts making the final selection depends on the R&D or decision makers of company, no semantic model available for evaluation of solution concepts	[20]	2019
Contribution to Formalizing Links Between Invention and Optimization in the Inventive Design Method	Prevention of rejection of good solution concepts at early phases of inventive design and ranking of solution concepts for decision makers to select	Need for quantitative evaluation method to give adequate confident to decision makers regarding selection of solution concept to develop	[2]	2017
An Approach to Identify the Readiness Level of a Solution Concept in the Inventive Design Method	Solution Concept Feasibility	Selection of Solution concept depends of expertise of decision maker	[3]	2016
On Solution Concept Evaluation/Selection in Inventive Design	Improve early decision processes for feasibility of solution concepts	Lack of evaluation or selection method for solution concepts	[14]	2015
A Software Framework to Support Engineering Analysis for Inventive Solution Concepts	Pre dimensioning and feasibility criteria of solution concept	No proper facility for solution concept selection	[21]	2015
Towards a formal definition of contradiction in inventive design	Formalization of contradictions to reach relevant solution concept synthesis stage	After Ranking of Solution concepts using Pugh Matrix, final selection depends on R&D or top management of company and no confident model for evaluation of solution concepts	[13]	2012
A research agenda for computing developments associated with innovation pipelines	Computer added innovation and future agenda proposal	Need innovative methods for concept selection and solution concept evaluation	[22]	2011

(continued)

Table 2. (continued)

Title of paper	Focus area	Research gap	Ref.	Year
Monitoring the Impact of Solution Concepts within a Given Problematic	Using Pugh's approach for qualitative evaluation of concepts of for producing solution concepts	After given list of solution concepts the method stops further input in selection of solution concepts	[23]	2009

Not every method is used in every inventive design process. Only those that seem appropriate for the problem situation and that contribute to a successful outcome are used. Based on the most relevant and latest research articles considered in this state of the art, we clearly identify the research gap regarding evaluation of inventive design solution concepts. More clearly stating that there is not any certain tool, model etc., for evaluation of solution concepts in inventive design to suggest a specific solution in the solution concept building phase or solution evaluation phase as showing our position in Fig. 1.

4 Conclusion and Future Research

Instead of all the features included in the IDM there is still a gap in providing a model to the best selection of solution concept. The evaluation of solution concepts is no doubt the most important step of inventive design process because of its effect on all following steps in terms of performance, quality, maintainability, cost, safety, etc., of the selected solution concept for development. As it is obvious that failure of a selected solution concept for development can barely be compensated at next phases of advance design and development by resulting long time of redesign and rework expense. According to S.R Daly [24] almost 80% of the cost is committed at solution concept selection phase and figured out that 80% of a manufactured product's cost occur during the process of product design.

To date most of research in inventive design has been made in from the very beginning steps to solution concept ranking. One of the toughest, critical and complex problems in inventive design process is the evaluation of best solution concept to go for manufacture or implement [24]. Following the research gaps through this research, we are considering to propose a semantic modeling approach and method to evaluate behavioral performance of solution concepts in inventive design along with the proper definition of solution concept.

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