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Early feasibility evaluation of Solution Concepts in an Inventive Design Method Framework: Approach and support tool

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ABSTRACT

The concept evaluation and selection process in the early stage of the Inventive Design Method (IDM) faces immediate reactions on the part of decision makers that usually exert a strong degree of influence and appear invariably to be negative when confronted with implementing an original solution that is subject to time restrictions in the design cycle. An obvious reaction to this is to abandon Solution Concepts that are considered unfeasible or overly risky. In parallel, computer support in this stage is still largely absent. In this paper we propose a method and tool to support evaluating and selecting a Solution Concept derived from the IDM framework. Our main objective is to determine how to prevent the rejection of good Solution Concepts and screen out unfeasible ones as early as possible. The proposed framework should be used as a decision-making aid and tool. Its purpose is to assist designers in increasing confidence in a Solution Concept by providing a rapid estimate or by exploring the feasibility of a tested Solution Concept. We submit a case study at the end of the paper to demonstrate the viability of the proposed framework.

1. Introduction

The Inventive Design Method (IDM) [1–3] was developed to solve classical TRIZ (Theory of Inventive Problem Solving) [4,5] limits and consequently to address wider and more complex problematic situations specifically in the concept generation stage. The four major steps of IDM depicted in Fig. 1 are:

1) Analysis of the initial situation
2) Contradiction formulation
3) Synthesis of Solution Concepts
4) Choice of Solution Concepts to develop

In the third step, the key components of the contradictions are used as input to generate Solution Concepts assisted by computer-based TRIZ techniques. This framework has already been published and has been developed into a software prototype called STEPS (Systematic Tool for Efficient Problem Solving) [6].

The context of concepts developed with the aid of IDM (in this paper called Solution Concepts) is incomplete, conflicting and produces uncertain information due to the resolution of contradictions and the differences in knowledge domain between the Model of Solution and the Model of Problem. In addition, the differences between each Solution Concept are diverse. As a result, it becomes more difficult to evaluate then select which Solution Concepts to refine for more in-depth development.

Early evaluation stages (Step 4 of IDM) usually comprise informal meetings held by expert personnel. This stage generally involves producing instinctive judgments based on experience and tends to lack accuracy [7]. When experts confront the novelty of Solution Concepts and time restrictions in the design cycle, an immediate reaction is to abandon Solution Concepts considered unfeasible or overly risky, since they are outside of the design project's primary focus. In such situations, more reasonable Solution Concepts are chosen. As a consequence, there is a high probability that in each R&D department many potentially better Solution Concepts are abandoned based solely on experts' intuition. Frequently, abandoned Solution Concepts show a higher potential of completing all design requirements if only they can be explored in detail. Unfortunately, studies of these Solution Concepts are undertaken only after several rejections of higher ranked Solution Concepts that have been selected.

Several authors [8–11] have suggested using rough calculations based on simplified assumptions to investigate the feasibility of design concepts. By relying on simple physical and empirical equations, an approximate evaluation of the behavior of the concepts being studied can be achieved. Unfortunately, depending

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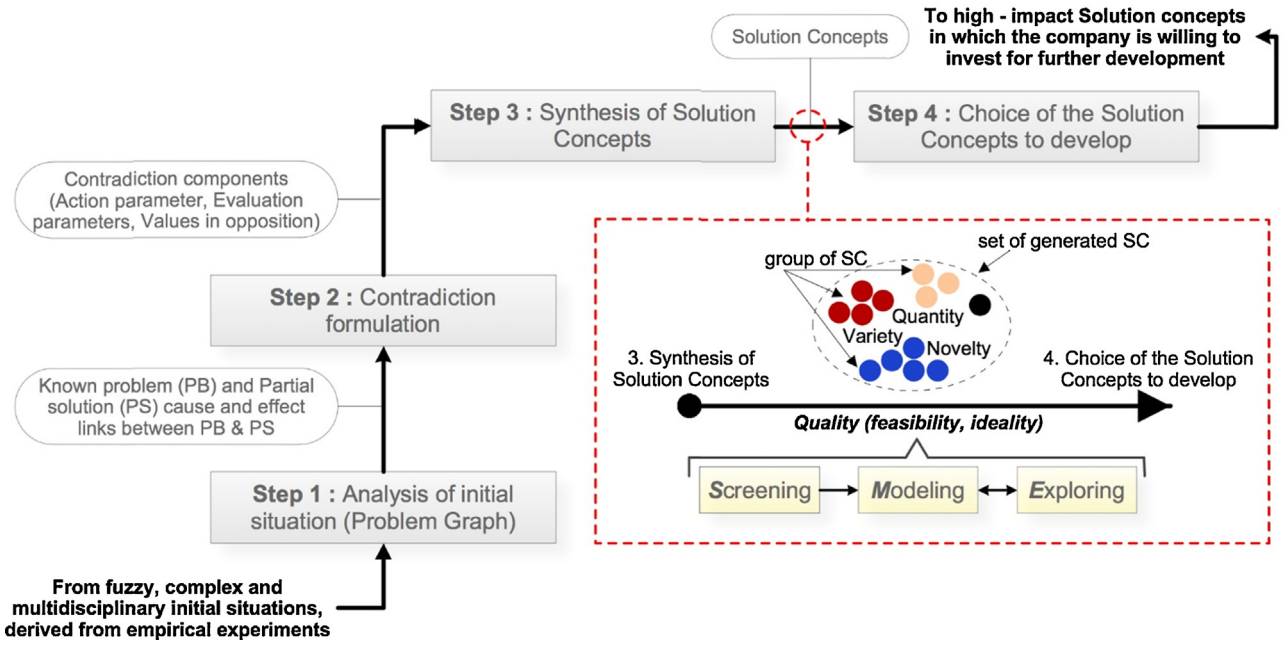

Fig. 1. Positioning of this paper in the Inventive Design Method Framework.

on time constraints and limitations of knowledge requirements during the early design stage, this calculation is often made only after viable concepts have been selected. The need for this calculation aid and tool has been discussed in previous work [12] and still poses a challenge to the inventive design-research link.

This paper reports on the ongoing development of the calculation aid/tool in support of this situation. The main objective behind this development is to prevent the rejection of good Solution Concepts and to screen out unfeasible ones at the earliest possible stage. We offer a **S**creening, **M**odeling and **E**xploring (SME) approach to rapidly estimate and explore the feasibility of a Solution Concept during the evaluation and selection process (Fig. 1). The overall SME steps are configured into a software support tool that is known as the **C**oncrete **S**olution **C**oncept Modeler, or CSC-Modeler. Several templates have been provided in the CSC-Modeler to assist designers in bridging the knowledge gap between doubts and uncertain conditions characterizing a Solution Concept, which can then be developed into an analyzable form. In this way, a simple analysis task is implemented in a short-cycle period and decision-making will occur accurately depending on analysis results obtained.

The remainder of this paper is organized as follows: Section 2 presents the technical background. In Section 3, we introduce our approach. Section 4 briefly describes ongoing development of a support tool. We illustrate our approach with a case study in Section 5. Finally, in Section 6, we conclude and discuss future work.

2. Technical background

In this section, we review the characteristics of a Solution Concept from the standpoint of the IDM framework. We then investigate certain work related to the proposed methodology.

2.1. Deriving a Solution Concept from the IDM framework

The main components of each Solution Concept are:

(1) A *description template*, which describes an abstract context, general properties, performance functions and a Model of Problem.

(2) A *sketch* of the Solution Concept, which is synthesized from a Model of Solution, hypotheses and a technical systems' laws of evolution.

The model for characterizing a Solution Concept is presented in Fig. 2.

Conflicts among evaluation parameters should be eliminated after a Solution Concept has been interpreted. Nonetheless, a Problem Model often remains relevant to the Solution Concept and is a source of risks and doubts. Consequently, the existence of new uncertain conditions is often the main cause for abandoning Solution Concepts during the evaluation and selection process.

2.2. Feasibility evaluation in the early stages of inventive design

Ullman [10] has classified the feasibility evaluation process in terms of the immediate reaction of designers and decision-makers into three types:

(1) Not feasible
(2) Conditional
(3) Worth consideration

The notion of immediate reaction describes the degree of confidence decision-makers have in a Solution Concept, taking into account doubts and uncertain conditions surrounding it.

In this paper, the feasibility of a Solution Concept is determined through physical properties of Solution Concepts, such as approximate possible configuration, dimensions of geometry and behavior. None of this information is available in this early stage of design and there is not sufficient information to initiate high granularity tools such as CAD or CAE. These tools require a detailed description of the characteristics of a design concept and their obvious limitations lie in the extreme level of expertise required to be able to use them [12].

As mentioned earlier, the feasibility of design concepts is explored through rough calculation, which relies on simple physical and empirical equations. This type of calculation requires