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Integration of Extenics and Axiomatic Design theory

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Abstract

Efforts are made to improve the design process of Axiomatic Design (AD) in this paper. Rooted in logic and rational thought, AD provides systemic tools that helps facilitate design process. However, the mapping process and operability of AD remain to be clearly defined. The research on AD theory shows that AD lacked the description of elements in domains and the specific method during mapping process, which could lead to confusions of the designers. To remedy the issue, the Extenics theory is integrated with AD to provide improved guidance for design activity. The integration of the two theories are established in the form of mathematical expression and flow chart. Examples are presented to illustrate the integration of the two theories. The resulted mapping of the decomposition process is shown to be properly guided.

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Keywords: Extenics; Axiomatic Design; Integrated theories; Case study

1. Introduction

AD theory, proposed by Pro. Suh [1] in 1990, is a basic theory for design, which has been widely analyzed. As a principle of design, AD theory provides a theoretical basis according to logic and rational thought. It offers systemic tools and design process to complete the design. AD theory has been developing all the time. On the one side, people has been exploring new areas for application of AD [2-4]. For example, Donnarumma et al. [5] applied AD to the soft design. Huang et al. [6] extended AD into a systematic theory of axiomatic design review to establish the web-based framework support for product design review. Ngai and Jiao [7] adopted AD theory and developed a domain-based reference model to solve the conceptualization of a factory loading allocation problem. On the other side, AD theory also has been improving in respects of logic and rationality [9]. Suh [8] established the definition of large system, during the research, theorems were stated that the quality of design depends on the selection of FRs and the mapping from domains to domains. However, after all the efforts made

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by now, it still lacks the specific methods to guide the mapping process. Moreover, the AD theory provide four domains, namely, Customer Domain, Functional Domain, Physical Domain, and Process Domain, but it lacks the detailed descriptions for the elements in domains, which may cause confusion to the designer. For that one cannot decide what is supposed to be in each domain.

According to the analysis of the development of AD theory, it can be seen that AD is focused on developing the theoretical frame, while the methods for solving problems and implementing the program are deficient. In other words, AD theory is used to help select better scheme, but not to generate the scheme [10]. Many efforts have been made to remedy the disadvantages including the improvement of AD itself and the integration with other methodologies.

This paper is aimed at solving the above problems and improving AD theory for design by integrating AD with Extenics. Extenics theory is a new discipline established by Chinese scholars led by Professor Cai Wen in 1983. It has been widely used in various areas [11, 12]. Wang et al. [13] proposed an extension configuration model of the mechanism scheme design based on Axiomatic Design and the extension theory. It proved the possibility of integration of AD and Extenics. But during that research, AD theory was used to develop the hierarchical structure, then Extenics helped to describe and reuse the design knowledge. In that process of design, AD and Extenics were applied separately, and they did not integrate on the theoretical level. In this paper, effort was made to perfect AD theory by introducing Extenics during the mapping process. In the next section, a brief introduction to AD and Extenics theory is provided.

Nomenclature

FR	functional requirement
DP	design parameter
R	matter element
I	affair element

2. Research on AD and Extenics theory

2.1. The introduction of AD theory

AD explores the concepts of four domains, two axioms, and a mapping process for the scientific framework of design. According to AD method, designers can obtain a successful new design using their existing design tools and software, or diagnose and correct an existing design. The wide application introduced in last section illustrated the validity and efficiency of AD theory.

AD theory is trying to build a general principle for design process while the design problems can be complicated and changeable. Then there may exist some drawbacks during the specific design process:

(1) AD theory proposed the concept of domains, but it didn't define the elements in domains clearly which leads to the difficulty in determining the content in each domain.

(2) AD theory put forward the zigzag mapping process, but it didn't provide the specific methods for the implementation.

(3) AD theory encouraged the innovative design, but it didn't have the innovation method to generate the innovative thought.