Available online at www.sciencedirect.com
SCIENCE DIRECT®
Mechanism and Machine Theory 41 (2006) 567–583
Mechanism and Machine Theory
www.elsevier.com/locate/mechmt

An integrated computational intelligence approach to product concept generation and evaluation

Hong-Zhong Huang [a,b,*], Ruifeng Bo [b], Wei Chen [c]

[a] School of Mechatronics Engineering, University of Electronic Science and Technology of China, Chengdu, Sichuan 610054, China
[b] School of Mechanical Engineering, Dalian University of Technology, Dalian 116023, China
[c] Department of Mechanical Engineering, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208-3111, USA

Received 18 October 2004; received in revised form 7 July 2005; accepted 28 July 2005
Available online 23 September 2005

Abstract

Product concept generation and evaluation are two major activities for obtaining an optimal concept in conceptual design. In this paper, an integrated computational intelligence approach is proposed for dealing with these two aspects. A group of satisfactory concepts are generated first by using genetic algorithm and incorporating the information from knowledge base. Then concept evaluation and decision making are implemented using fuzzy neural network to obtain an optimal concept. Our procedure of using computational intelligence in conceptual design is described. The key issues in implementing the proposed approach are discussed, and finally the applicability of the proposed method is illustrated with an engineering example.

Keywords: Conceptual design; Computational intelligence; Optimal concept; Genetic algorithm; Fuzzy neural network

* Corresponding author. Address: School of Mechatronics Engineering, University of Electronic Science and Technology of China, Chengdu, Sichuan 610054, China. Tel./fax: +86 28 8320 6916.
E-mail address: hzhuang@uestc.edu.cn (H.-Z. Huang).

0094-114X/$ - see front matter
doi:10.1016/j.mechmachtheory.2005.07.006

1. Introduction

The goal of conceptual design in product design is to obtain an optimal design concept as a starting point for further engineering development. In the current literature, the approaches of morphology matrix, bond graph, and design catalogues combined with expert system [1,2] are used for concept generation, in which concepts are usually combined and enumerated through function analysis. However, owing to the combinatorial nature, it is difficult to evaluate the large number of concepts one by one to obtain the best concept. With the expert system, great difficulties exist in knowledge acquisition, knowledge representation and reasoning. In fact, besides logical reasoning, intuition, experience, association, and even inspiration are synthetically used in the process of designer's thinking in conceptual design. However, they cannot be fully captured by knowledge-based reasoning. Compared with the detailed design stage, more emphases are laid on creativity in the conceptual design stage. Since conceptual design is in the preliminary stage of design, design requirements are usually approximate, imprecise and even uncertain. As a result, the best design concept cannot be easily obtained using existing methods in artificial intelligence [3,4]. The intellectualization of the conceptual design process becomes critical.

Computational intelligence, which consists of neural network, fuzzy logic and evolutionary computing, and so on, is a novel technology to bring intelligence into computation. Compared with the traditional artificial intelligence, a significant characteristic of computational intelligence is that the precise model need not to be established when dealing with imprecise, uncertain, and incomplete information. Therefore it is especially useful for solving those problems in which valid and formalized models cannot be established with ease. It is also effective to deal with the combinational problem in designing complicated systems. Conceptual design is a highly intellectual and creative process. Neural network, fuzzy logic and genetic algorithm can simulate the human activities naturally.

Attempts have been made in recent years to introduce computational intelligence into conceptual design. Wang and Zou [5] proposed a method of three-level fuzzy synthetical evaluation to deal with the fuzzy and multi-layer characteristics of concept evaluation metrics. They used fuzzy logic to evaluate the mechanical design concepts. Venugopal and Naredran [6] utilized a discrete Hopfield neural network to preserve the component concepts in manufacturing system and an appropriate design concept is retrieved during conceptual design using the associative memory. Xue and Dong [7] developed a fuzzy-based design function coding system to identify appropriate design concepts from stored design candidates classified based on design functions. Chang and Tsai [8] proposed a prototype of a feature-based design retrieval system using a modified ART1 neural network with destructive solid geometry for identifying similar design candidates for design improvement. Their proposed system has been demonstrated as an efficient and robust design retrieving tool. Ng and Leng [9] investigated the feasibility of automating the conceptual design of a micro-air vehicle on a personal computer system. Their proposed design methodology uses genetic algorithm as the search engine. Sun and Kalenchuk [10] proposed a method for design candidate evaluation and identification using neural network-based fuzzy reasoning, in which the relationship between design specifications and customer requirements is modeled using a multi-layer feed-forward neural network, and the satisfactory conceptual design candidate is retrieved by fuzzy reasoning based on requirements. Shu and Hao [11] proposed a CAD system model based on genetic algorithm to improve design efficiency and accuracy for mechanical products.