Product Design Generation and Decision Making Through Strategic Integration of Evolutionary Grammars and Kano Model

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ABSTRACT

The ability for a product developer to successfully launch useful products is tied to the company’s product design strategies. Due to the complexity of perception and expectations on new product design from customers and the diverse perspectives of the product developer, any approaches without systematically analyzing these complex criteria to assess decision making on product design strategies are therefore deemed as inappropriate. A systematic approach to determine appropriate product design strategies based on the attributes of product design and customer expectations should thus be considered. This research focuses on the investigation of shape formulation process using evolutionary grammars (EG) and non-linear product design analysis with Kano model to refine product design strategies. Through the strategic integration of evolutionary grammars and Kano model, the complex effects on the evolutionary design process and product design strategies are revealed. In order to demonstrate the viability of the approach, experiments are described and a comparison analysis on three EG-Kano reference models is performed. Upon determining the appropriate EG-Kano reference model, the product developer can refine the product design strategies to suit the targeted market.

Keywords: Customer Satisfaction, Decision Making, Evolutionary Grammars (EG)-Kano Reference Model, Genetic Programming, Kano Model, Non-Linear Product Design Analysis, Product and Engineering Design, Product Design Strategies

1. INTRODUCTION

Creativity is the key successful factor and a global priority in engineering industries. Creating innovative designs involves research on new algorithms in addressing the design issues. Shape formulation is a critical issue in product and engineering design. Over thirty years of research on design computational algorithms like shape grammars has established a solid
theoretic foundation in shape formulation for various domains like architecture, structural and engineering design. A comprehensive survey which compared the development processes, application areas and interaction features of different shape grammar approaches are given by Chase (2002). Recently, research in exploring shape grammar approaches to product and engineering design has received more attention by many researchers. For instance, Cagan et al. developed the coffeemaker grammar, motorcycle grammar, hood panel grammar and vehicle grammar (Agarwal et al., 1998, McCormack et al., 2002, Pugliese et al., 2002; Orsborn et al., 2006). However, most of these approaches do not address the flexibility in modifying the grammar rules within the system. As a result, the generative capability of shape grammars is hindered to generate innovative product designs.

Another critical issue in creating innovative designs is affected by product design strategies. The ability for a product developer to successfully launch useful products to a market is tied to the company’s product design strategies, thus making profitability. Due to the complexity of the perception and expectations on new product design from the various customers and the diverse perspectives of the product developer, any approaches without systematically analyzing these complex criteria to assess decision making on product design strategies are therefore deemed as inappropriate. A systematic approach to determine appropriate product design strategies based on the attributes of product design and customer expectations should therefore be considered by the product developer. These two critical issues in product design: 1) Product design exploration and 2) Product design strategies are the focus to be addressed in this research.

The objectives of this research are to: 1) Design a new evolutionary algorithm to dynamically evolve the grammar rules to explore innovative product designs, and 2) Design a new approach to strategically integrate the proposed evolutionary grammar algorithm with Kano model to refine product design strategies.

To merge these two objectives into one paradigm, this research realizes the implications on the analysis results by comparing them against the attribute curves of Kano model. The Kano model is developed in the 80s by Professor Noriaki Kano to define product development strategies in relation to customer satisfaction which classifies customer preferences into five categories: Attractive, One-Dimensional, Must-Be, Indifferent and Reverse (Kano et al., 1984). The reasons for mapping Kano attribute curves to the product design analysis results are to: 1) Redevelop or modify the control strategies of the framework by the shape grammar developer, and 2) Refine or adjust the product design strategies by the product developer.

The contributions of this paper are: 1) Enhancing the generative capability of traditional shape grammar approaches to generate innovative designs, and 2) Analyzing the complex effects on product design attributes and customer satisfaction through strategic integration of evolutionary grammars with Kano model to refine product design strategies.

First, evolutionary grammar algorithm can dynamically evolve new grammar rules to generate innovative designs. However, the evaluation criteria could be so complex with many multi-dimensional variables. This may lead the product developer to have difficulties in making decisions by interpreting the analysis results. In this research, the Artificial Selection Fitness parameters of the performance graph is selected to be modified in the new algorithm and integrated with Kano model so as to understand the complex relationships among product design attributes and customer satisfaction.

Second, in order to consider how the most appropriate strategies might be chosen, and understand their effects on different design attributes, this research focuses on the investigation of shape formulation process using evolutionary grammars and non-linear product design analysis with Kano model to refine product design strategies. Through the strategic integration of evolutionary grammars and Kano model, the complex effects on the evolutionary
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