Int. J. Production Economics 169 (2015) 299–309

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Optimization of a platform configuration with generational changes

Suryakant [a], Satish Tyagi [b,*]

[a] Department of Mechanical Engineering, Indian Institute of Technology, Chennai 600036, India
[b] Department of Industrial and Systems Engineering, Wayne State University, MI 48202, United States

ARTICLE INFO

Article history:
Received 19 April 2015
Accepted 17 August 2015
Available online 24 August 2015

Keywords:
Platform
Generation variety index
Simulated DNA computation
Genetic algorithm

ABSTRACT

Platform is an established strategy for producing customized products while managing the economy of scale. Innovation in various areas makes different components in a platform outdated or redundant within a short span of time. This poses severe challenge to the robustness of the platform configuration that efficiently satisfies the volatile needs of the customers from various segments. Therefore, deciding the platform configuration that can adequately accommodate generational changes in the product design is emerging as a new challenge. This paper deals with optimization of a platform configuration through a couple of product generations. For this, specifications from different customers and their probable attribute changes are mapped to product's utility, which signifies importance of each component through a period of time. Utility by cost ratio for different products forms the basic variable for optimizing the configuration of a platform. An illustrative example is detailed to demonstrate the methodology adopted in exploring the optimal platform configuration. This paper incorporates an intelligent DNA-based technique to reach the optimal configuration. The results of simulated DNA computation are compared with that of genetic algorithm (GA). The results show significant improvement in the number of objective function evaluations before reaching the optimal result, against that of GA thus establishing its superiority in numerical optimization.

1. Introduction

An organization categorizes the existing consumer base into different segments, broadly recognized by their volume and buying capacities. Each of these segments has their own specific demands and meeting them essentially requires customized products suiting the buyer's needs (Muffatto, 1999; Tyagi et al., 2012). Based on the specifications gathered from different segments, a manufacturer designs a product family to please each of these customer's demands separately. Offering product variety (customized products) helps an organization in reaching to a larger consumer base, and enables to price their products higher, but associates them with the risk of increasing cost of design, development and manufacturing. Customized products create an explosion of product variety and make very difficult for the firms to maintain the economy of scale. Hence, a different strategy is required for negotiation between product customization and economy of scale. Numerous strategies such as platform have been deployed to compensate the adverse effects of product customization. Platform offers product advancement team to develop a wide range of products, reducing complexities of varied products and better leverage investments in product design and development (Krishnan and Gupta, 2001; Kwong et al., 2011).

Platform is defined as an intellectual and material asset shared across a product family (Robertson and Ulrich, 1998). A robust and flexible platform configuration offers several benefits to the manufacturer. A long lived platform reduces the cost of developing individual products, cuts down development risk by using proven elements in a firm's offerings. It also enhances flexibility and responsiveness of the manufacturing processes allowing freedom to invest more in design and development (Sawhney, 1998; Wei et al., 2014). Beside these benefits, its drawbacks have also been cited in the literature (Brun and Zorzini, 2009; Wu, 2012; Agrawal et al., 2013; Chen et al., 2014; Moon et al., 2014). The cost associated with platform development may make it inappropriate for some products. It can even lead to over design of features for low end products or high end products may yield as per design. It can also distort the real or perceived value of the product to consumer when component sharing is visible or is known to the consumers. Nevertheless, there have been examples where companies found it difficult to maintain its product distinctiveness and have been blamed to sell common features at different prices to different segments (Desai et al., 2001). A proper bargain of commonality and distinctiveness helped firms like Sony and Kodak to gain wide market share with its product variety.

* Corresponding author.
E-mail address: Satish.Tyagi@Wayne.edu (S. Tyagi).

http://dx.doi.org/10.1016/j.ijpe.2015.08.013
0925-5273/

Sanderson and Uzumeri (1997) studied SONY's strategy to produce "walkman" products based on carefully designed platform. Clark and Wheelwright (1995) explored KODAK's platform based strategy against FUJI Quicksnap.

Exploring the platform configuration is a prominent topic of research in manufacturing strategy. Consumer electronic product like mobile, computers etc. are among best examples of mass customized products experiencing rapid generational changes. Technologies involved in different modules are upgraded so rapidly that it takes no time for a product to get outdated in the present market. This puts a serious threat on the robustness of platform-based production. A careful configuration of the platform requires consideration of these generational factors. In addition, the changes in cost and volume of production also have great effect on platform configuration. These factors are still untouched in research of platform configuration. This paper deals with optimization of a platform configuration through a couple of product generations by estimating the probable changes in module attributes. For this, specifications from different customers and their probable attribute changes are mapped to product's utility, which signifies importance of each component through a period of time. Utility by cost ratio for different products forms the basic variable for optimizing the platform configuration. Change in the production volume to identify the optimal platform configuration is a topic for future research.

A platform design is often modeled as type of configuration, which aims at selecting and arranging a set of predefined components/modules subject to customer requirements and engineering/physical constraints (Jiao et al., 2006; Chandrasegaran et al., 2013). This requires searching for commonality among different product varieties to be produced on a universal platform and then addition of specific components which makes the product suitable and distinct for specific segment. As the number of components/modules increases, number of possible alternatives becomes huge and the computational complexity increases exponentially. This makes the task of finding optimal platform configuration quite cumbersome. Regular techniques such as deterministic optimization lack the competitive edge in solving problems of such complexity. Simulated DNA computation (or molecular computing) has emerged as a powerful tool for such a complex problem. With Adleman's revolutionary experiment to solve Hamiltonian Path Problem, a new direction has emerged for solving such complex problems. Simulated DNA computation has emerged as a new frontier for the computational technology for achieving greater computational challenges. It edges ahead over these existing facilities in solving such problems (see Section 5.3 for more details). It can perform greater number of calculation in considerably less time and occupies much less volume compared to transistor based computers. This paper explores the implementation of simulated DNA to another NP hard problem of platform configuration optimization.

The rest of the paper is organized as follows: the next section explores the relevant literature pertaining to the platform configuration. The problem description and mathematical formulation are discussed in Section 3. An illustrative example of designing a computer family is detailed in Section 4. Further, background and implementation procedure of simulated DNA computation are elaborated in Section 5. Results obtained from computational experiment and their discussions are reported in Section 6 whereas whole paper is concluded in Section 7.

2. Related work

Product family is defined as a set of individual products that share components, modules or technology and addresses related set of market applications (Meyer and Lehnerd, 1997). The key to successful product family lies in platform-based development where product variants are derived either by adding, removing or substituting one or more component/modules to a platform. By employing the platform strategy, an organization develops a products variety efficiently. This increases the flexibility and responsiveness and can take market share away from competitors that develop only one product at a time (Robertson and Ulrich, 1998). Plethora of researches has been carried out for accessing the performance of product family design. Meyer et al. (1997) measured effectiveness by estimating cost of developing product varieties. Schellhammer and Karandikar (2001) later used project ranking index based on planning concepts given by Wheelwright and Clark (1992). Alizon et al. (2007) and Nanda et al., (2007) discussed knowledge reuse at various steps of product family design. Moon et al. (2007) used an agent based recommender system to support product customization.

Intermediate steps in platform configuration such as market segmentation, modularization and various other features are also being explored. Wedel and Kamakura (1997) identified several variables responsible for market segmentation. Jiao and Zhang (2005) constructed product offering based on discrete product attribute values. Modularization is among the most studied aspects of product design and platform design. Dedicated studies have been carried on for different stages and facets of modularization. Stone et al. (2000) presented a heuristic approach to identify modules in a given product. Blackenfelt and Sellgren (2000) designed a method for developing robust interface among constituent modules. Modularization in specific fields like mechatronic (Huang and Kusiak, 1999), automotive, motors (Simpson et al. 2001) are found in the literature. Their approach is one of several that use quality function deployment to help identify modules within a product family (Cohen, 1995; Ericsson and Erixon, 1999; Sand et al., 2002).

Improving an existing platform poses a sever cost challenge to the manufacturer. This is a serious problem with products of comparatively shorter life span such as mobile phones, computers etc. Various optimization approaches (Kusiak and Wei, 2013) have been tried to find the best design variables and their varieties suited to determine optimal platform configuration for a single generation. Designers have aimed to use various techniques to identify common features and uniqueness in the product varieties (Moon et al., 2014). In the part, researchers applauded statistical technique, heuristic approaches and various evolutionary optimization techniques like genetic algorithm (GA), simulated annealing etc. to solve the combinatorial complexity of platform configuration. D'Souza and Simpson (2003) used multi-objective GA to optimize a family of general aviation aircrafts. Jiao et al. (2006) proposed a generic GA to solve a product family design problem for motors. Considering the complexity of problem, many researchers like Gonzalez-Zugasti and Otto (2000), Fujita and Yoshida (2001), Li and Azarm (2002) and D'Souza and Simpson (2003) have advocated use of GAs for platform configuration. Tyagi et al. (2012) proposed a mathematical formulation for optimization of multiple platform design of mobile phones and compared the results obtained by application of various optimization techniques.

The contribution of this paper is two folds. First, an analytical methodology for searching optimum commonality in various features of a product family is developed. This helps in achieving a better utility to cost ratio by bringing them on a common platform. Utility by cost ratio for different products forms the basic variable for optimizing the configuration of a platform. Second, the paper proposes a simulated DNA computation to solve the combinatorial optimization problem (platform configuration). An example of designing a platform for assembled computers to meet the demands for three different segments with their specific utilities has been discussed to illustrate and justify the use of proposed framework. As computer components are upgraded