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ORIGINAL ARTICLE

A heuristic algorithm to approximate dynamic program of a novel new product development process

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Abstract We are concerned with a new product development (NPD) network in digital environment in which the aim is to find integrated attributes for value added purposes. Different views exist for new product development. Here, the effective factors are categorized into customers, competitors and the company's own past experience. Also, various attributes are considered for the development of a product. Thus, using digital data of attributes, the optimal set of attributes is chosen for user in the new product development. Regarding the multi stage decision making process of the customer, competitor and company's own past experience, we develop a multi-dimensional dynamic program as a useful tool for multi stage decision making. To counteract the dynamism of the digital data in different time periods, two concepts of state and policy direction are introduced to determine the cost of moving through the stages of the proposed NPD digital network. Since the space requirements and value function computations become impractical for even moderate size, we approximate the optimal value function developing a heuristic algorithm.

1. Introduction

Product design has been long recognized as an opportunity for differential advantage in the market place. A number of companies successfully focus on product design as a competitive tool (Creusen and Schoormans, 2005). Nowadays, new requirements for enterprises are envisaged, such as more product variety, shorter time-to-market, lower product cost and higher quality. Globalization of competition in manufacturing industry and diversification of customers' demands as well as rapid technological developments continue to spur technology-based innovations at an intensive pace. Product design innovation has thus developed quickly and has gradually become one of mainstream production modes of manufacturing industries.

Therefore, improving product development performance is becoming increasingly more important and challenging. New product development (NPD) is undeniably vital in determining the economic success of manufacturing companies. Firms need to create and sustain competitive advantages in order to

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survive in today's highly competitive business environment. One major determinant of sustaining competitive advantage is the ability of firms to develop and launch successful new products. Differentiation through NPD is therefore one of the most effective strategies for achieving success. As competition in global markets is becoming intense, firms have begun to understand the importance of NPD and innovation issues. Through innovation and introduction of new products, new markets and growth possibilities can be created. Increasing international competition accentuates the importance of the NPD process which is secure and accurate (Ozer, 2005; Sherman et al., 2005). Gemser and Leenders (2001) conclude that being innovative with respect to design and design strategy can enhance competitiveness regardless of the industry's evolution. Timely, correct and responsive NPD has become even more critical in the highly competitive global environment. The need to respond quickly to these dynamic global market forces requires the firm to establish a specialized evaluation mechanism and platform for the NPD performance.

However, the decision-making in NPD is highly complex and uncertain due to a demanding environment characterized by increased globalization and segmentation of markets, increased levels of product complexity, changing customer needs, and shorter product life cycles (Belecheanu et al., 2003). New product introduction in today's technology-driven markets carries significant risks. New product failure rates can be as low as one of every three products or as high as 90% of new grocery products which are withdrawn within a year of their introductions. New technology, improved communications, increased profit demands and shorter product life cycles have added to the inherent risk. Yet, without the introduction of new products, deterioration of the firm's market position is inevitable. Without new products, firms will inevitably stagnate (Yelkur and Herbig, 1996). In order to evaluate the performance of NPD more appropriately, the firms should consider not only quantitative indices but also qualitative factors which are evaluated by multiple decision-makers or experts. Thus, the evaluation of NPD performance should be regarded as a group multiple criteria decision-making process as well.

Here, the effective factors on new product development are categorized into customers, competitors and the company's own past experience. Also, various attributes are considered to develop a product. Thus, using digital data of attributes, the optimal set of attributes is chosen to be included in the new product development. The remainder of our work is organized as follows. In Section 2, we review the related literature. In Section 3, the proposed problem is stated. The mathematical model of the proposed multi-dimensional problem is given in Section 4. A computational study is given in Section 5. We conclude in Section 6.

2. Literature review

In the literature, a related subject to our work lays in NPD project selection studies. Because NPD project selection plays a critical role in future market competitiveness, a company requires a well-rounded consideration when top managers assess and rank NPD projects. To address such complicated decision-making challenges, many studies apply a multi-criteria decision-making model (MCDM) to help high-level managers scientifically select an alternative with a quantitative analysis. For example, Brenner (1994) used the AHP method to gain criteria weights of NPD and exhibited advantages and disadvantages of each project with diagrams. Al-Harbi (2001) used AHP to estimate the degree of importance of each assessment indicator for the projects and to calculate an objective weight for each indicator in decision-making. Ahn and Choi (2008) combined AHP and simulation methods to create a simulation-based AHP (SiAHP) and verified the elasticity of the model with an ERP project selection case. Lee and Kim (2000), for aggregation of group opinions and understanding of the relation among the selection criteria, used the analytic network process (ANP) and the zero-one goal programming (ZOGP) to select an information system project. To assist companies in making the most correct decisions and the most effective resource allocation, Meade and Preslley (2002) used the ANP technique to quantify the importance of qualitative criteria and to conduct a performance analysis for selection of R&D projects.

Data envelopment analysis (DEA) has been applied to the assessment of alternatives in recent years. The DEA uses the inputs and the outputs of decision making unit (DMU) to measure the alternatives' performance. Linton et al. (2002) applied a basic DEA model to R&D project selection and used diagrams to analyze product portfolios. Sowlati et al. (2005) employed AHP to obtain weights for each selection criterion and used DEA to select an NPD project with potential. Eilat et al. (2006) used the balanced scoreboard (BSC) method to gain performance assessment values of qualitative criteria and then applied a DEA model for project screening.

The foregoing methods cannot deal with uncertainty and fuzziness under subjective judgment. To improve the models, fuzzy theory has been gradually applied to project selection (Buyukozkan and Feyzioglu, 2004; Chen et al., 2007; Huang et al., 2008; Machacha and Bhattacharya, 2000). To consider uncertainty as a result of incomplete information in project selection, Feyzioglu and Buyukozkan (2006) combined artificial neural network (ANN), fuzzy theory and the Choquet integral model to develop an integrated decision-making method and used past experience to rapidly assess NPD projects. Mahmoodzadeh et al. (2007) added conventional AHP with the fuzzy concept to build a fuzzy judgment matrix to indicate the fuzziness of subjective judgment of decision makers and applied the technique for order preference by similarity to ideal solution (TOPSIS) for project ranking. To alleviate the impact of uncertainty in the environment, Wang and Hwang (2007) applied the plausibility theory to develop a fuzzy integer planning model to gain an optimal investment portfolio. Chiu et al. (2006) and Wang et al. (2008) applied a fuzzy concept to the project selection process with the fuzzy multi-criteria decision-making model (FMCDM) to select the optimal alternatives.

Sun et al. (2008) used the fuzzy AHP to establish decision support systems (DSSs) for selection of R&D projects. Trappey et al. (2009) employed the fuzzy theory to screen NPD projects, and then used an evaluation model of resource requirements of product portfolios to create the plausible product portfolios. Finally, according to the revenues and the risks of feasible product portfolios, the optimal product portfolio was created.

To sum up the background of the research the following dimensions are noted: