A Data Mining Methodology for Product Family Design

Seung Ki Moon
The Pennsylvania State University, USA

Timothy W. Simpson
The Pennsylvania State University, USA

Soundar R. T. Kumara
The Pennsylvania State University, USA

INTRODUCTION

Many companies strive to maximize resource utilization by sharing and reusing distributed design knowledge and information when developing new products. By sharing and reusing assets such as components, modules, processes, information, and knowledge across a family of products and services, companies can efficiently develop a set of differentiated products by improving the flexibility and responsiveness of product development (Simpson, 2004). Product family planning is a way to achieve cost-effective mass customization by allowing highly differentiated products to be developed from a shared platform while targeting products to distinct market segments (Shooter et al., 2005).

In product design, data mining can be used to help identify customer needs, to find relationships between customer needs and functional requirements, and to cluster products based on functional similarity to facilitate modular design (Braha, 2001). The objective in this chapter is to introduce a methodology for identifying a platform along with variant and unique modules in a product family using design knowledge extracted with data mining techniques. During conceptual design, data mining can facilitate decision-making when selecting design concepts by extracting design knowledge and rules, clustering design cases, and exploring conceptual designs in large product design databases interactively (Braha, 2001). Moreover, since design knowledge for a product depends on the experience and knowledge of designers, representation of design knowledge, such as linguistic representation, may fail to describe a crisp representation completely. When clustering design knowledge, the knowledge is needed to assign to clusters with varying degrees of membership. Fuzzy membership can be used to represent and model the fuzziness of design knowledge (Braha, 2001). Design knowledge can be defined as linguistic variables based on the fuzzy set theory to support decision-making in product development (Ma et al., 2007).

BACKGROUND

A product family is a group of related products based on a product platform, facilitating mass customization by providing a variety of products for different market segments cost-effectively (Simpson et al., 2005). A successful product family depends on how well the trade-offs between the economic benefits and performance losses incurred from having a platform are managed. Various data mining approaches have been applied to product family design and product development. Clustering can be used to group customers or functions of similar behavior (Agard & Kusiak, 2004; Jiao & Zhang, 2005). Also, functional requirements in existing products can be clustered based on the similarity between them. This process can be achieved by using clustering methods such as the k-means algorithm, hierarchical algorithms, pattern recognition, Bayesian statistics, neural networks, and support vector machines. Agard and Kusiak (2004) proposed a three-step method for the design of product families based on the analysis of customers' requirements using a data mining approach. In the first step, data mining algorithms are used for customer segmentation. The second step provides a function structure to satisfy the diversified requirements. A product structure and distinguished modules for the product variability are designed in the final step. Moon et al. (2006) introduced a methodology

for identifying a platform and modules for product family design using fuzzy clustering, association rule mining, and classification. Ma et al. (2007) presented a decision-making support model for customized product color combination using the fuzzy analytic hierarchy process (FAHP) that utilizes the fuzzy set theory to integrate with AHP.

Sharing and reusing product design information can help eliminate such wastes and facilitate good product family design. To share and reuse the information, it is important to adopt an appropriate representation scheme for components and products. An ontology consists of a set of concepts or terms and their relationships that describe some area of knowledge or build a representation of it (Swartout & Tate, 1999). Ontologies can be defined by identifying these concepts and the relationships between them and have simple rules to combine concepts for a particular domain. Representing products and product families by ontologies can provide solutions to promote component sharing, and assist designers search, explore, and analyze linguistic and parametric product family design information (Nanda et al., 2007).

MAIN FOCUS

This chapter describes a methodology for identifying a platform along with variant and unique modules in a product family using an ontology and data mining techniques. Figure 1 shows the proposed methodology that consists of three phases: (1) product representation, (2) module determination, and (3) platform and module identification. An ontology is used to represent products and components. Fuzzy clustering is employed to determine initial clusters based on the similarity among functional features. The clustering result is identified as the platform while modules are identified through the fuzzy set theory and classification. A description of each phase follows.

Figure 1. Methodology for platform and module identification