Chapter 10

PRODUCT VARIETY OPTIMIZATION
Simultaneous Optimization of Module Combination and Module Attributes

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1. INTRODUCTION

The design optimization paradigm provides us with a rational synthesis means for the engineering design of products, machines, etc. The essential outcome from computational design optimization is that it can generate the best solution under mathematical representation and procedures, if an original design problem is appropriately translated into a formal style. The outcome is more effective if the original design problem is complicated, since human expertise cannot precisely manipulate such content. This situation is obvious when design concerns shift from component-level to system-level optimality (e.g., Papalambros and Wilde, 2000).

Current trends in manufacturing activities are diverging further from system-level design to multiple-systems-level design. Design and manufacturing activities are restricted by various hidden aspects, such as design and development costs, learning effects and supply-chains in production, production and services inventories, as well as from the direct aspects of single-system-level performance and cost. The viewpoint on multiple products extends the optimality domain to those hidden aspects beyond the traditional ones (Fujita and Ishii, 1997). The engineering challenge of simultaneously designing multiple products has attracted a great deal of attentions in the last decade. This new field is characterized by several terms including product variety, product family, product platform, and modular product.
Among various research activities, Fujita, et al. have been exploring computational optimization methodologies for product variety design under modular architecture. After the task structure of the product variety design was organized as a base for computational design methods (Fujita and Ishii, 1997), they developed an optimization formulation and an optimization procedure for the module attributes of a series of products (Fujita, et al., 1998), and developed another optimization framework for module combination across a series of products through module diversion (Fujita, et al., 1999). They used enumeration and a successive quadratic programming method for the former since each enumerated sub-problem is defined in continuous space, and used a simulated annealing technique for the latter since the problem is combinatorial. Following these, Fujita proposed a classification of product variety optimization problems and indicated the difficulty and necessity of developing simultaneous optimization of both module attributes and combinations (Fujita, 2002). Further, they configured a hybrid optimization method with a genetic algorithm that optimizes module combination patterns, a branch-and-bound technique that optimizes module similarity directions, and a successive quadratic programming method that optimizes module attributes (Fujita and Yoshida, 2004).

This chapter describes inclusively the above series of developments for reviewing the potential roles of design optimization for product families. In the following, the contents and conditions of product variety optimization are surveyed first. A range of product variety design problems are classified into three classes of optimization problems. Second, a general form of the product variety optimality is revealed and mathematical formulation underlying on it is established. Succeedingly, the optimization techniques for three different classes of product variety design problems are shown with associating example cases, respectively. This chapter finally concludes with discussing the limitations and challenges of product variety optimization.

2. PERSPECTIVES ON PRODUCT VARIETY OPTIMIZATION

2.1 Optimization paradigm and its application to product variety design

As mentioned in the introduction, various aspects of product variety design have been intensively studied in the last decade. Since consideration of multiple products is conceptually super-ordinate to every aspect in designing a single product, research topics are widely spread from