ABSTRACT

This dissertation develops the Selection-Integrated Optimization (SIO) methodology, which finds its application in adaptive systems and product family designs. Many engineering systems are required to operate under changing operating conditions. A special class of systems called *adaptive systems* are intended to achieve a high performance under changing environments. Adaptive systems acquire this powerful feature by allowing their design configuration to change with operating conditions. Optimizing such systems can represent a powerful integral part of their design process. In the optimization of adaptive systems, designers are often required to select (i) adaptive and (ii) non-adaptive (or fixed) design variables of the design configuration. Generally, the selection of these variables, and the optimization of adaptive systems are performed sequentially, thus being a source of sub-optimality in the design. In this dissertation, we developed the Selection-Integrated Optimization (SIO) methodology that integrates the two key processes: (1) the selection of the adaptive and fixed design variables, and (2) the optimization of the adaptive system, thereby leading to an optimum design. A major challenge to integrating these two key processes is the *selection* of fixed and adaptive design variables, which is discrete in nature. We developed the Variable-Segregating Mapping-Function (VSMF) that overcomes this challenge by progressively approximating the discreteness in the design variable selection process. This simple yet effective approach allows the SIO methodology to integrate the selection and optimization processes, and helps avoid the above mentioned significant source of sub-optimality.

The SIO methodology also finds its application in another field of active research called product family optimization. A typical product family consists of multiple products that share common features embodied in a, so-called, platform, defined in terms of platform design variables. Different products in the family are developed by customizing specific non-platform features of the platform, defined in terms of non-platform design variables. In the optimization of such product families, the specific values – as well as the choice – of the platform and non-platform design

variables are critical. The SIO methodology becomes a powerful tool that will help the designer make these critical choices.

Another important component of this dissertations is the analytical development of new Active Building Envelope (ABE) systems, as representative application of the SIO methodology. These systems actively use solar energy to compensate for passive heat losses or gains in buildings. In ABE systems, solar radiation energy is converted into electrical energy by means of a photovoltaic unit (PV unit), which is subsequently used to power a thermoelectric heat pump unit (TE unit). Successful implementation of the ABE system is expected to result in important long-term environmental benefits, such as lowering the dependance on non-renewable energy sources. In this dissertation, we uncover various characteristics of ABE systems through a modeling and optimization based study, and use the novel SIO methodology to optimally design ABE systems.