Chapter 2

A Multiresponse Optimization Model for Statistical Design of Processes with Discrete Variables

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ABSTRACT

In manufacturing and diverse industries, quality has a main role to increase the market share. Hence, producers focus their attention to design products or services with high quality to meet the customer’s expectations. Quality characteristics of products usually expressed by variables called response variables. Today’s complex systems have several performance attributes in responses and designers try to select the best combination of controllable factors that satisfies all quality characteristics simultaneously. Since there are often several conflicts in quality characteristics, such as measurement units, scale and optimality directions, there are different approaches in model building and optimization of multi response surface problems. Therefore, the study of simultaneous analysis and improvement methods of the outputs are of great importance.

INTRODUCTION

In recent service industries, designer faced by optimization of multi objective problem, in which to optimize several quality characteristic simultaneously. Multiple response surface optimization developed by (Del Castillo & Montgomery, 1993; Kim & Lin, 1998; Lin & Tu, 1995; Tang & Xu, 2002). Multi response surface (MRS) is the useful way to satisfy more than one output characteristic, which originated from Response surface methodology (RSM). RSM is a useful statistical-mathematical tool to estimate a relationship between the response and input variables and to optimize the outputs with respect to the

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inputs. By statistical definition of regression coefficient, which uses qualitative data from experiment, RSM can describe the response function and predict operating conditions (Sahu, Acharya, & Meikap, 2009). This method is defined as a collection of experimental design and product designs (Myers, Montgomery, Vining, Borror, & Kowalsk, 2004). Most application of RSM is sequential; which means some important factors are likely to be qualified in the response surface, are elected initially. This procedure of election and elimination, leads to experiment design which called, screening experiment. The main idea of factor screening is to reduce the amount of data and number of experiments runs (Myers, Montgomery & Anderson-Cook, 2009). RSM generally consists of main three stages; Data collection, model building and optimization (Bashiri & Hejazi, 2009). Future direction in RSM, proposed by Myers (1999). The recent book which published in this field, provided by Box and Draper (2007). This chapter integrates design of experiments with dummy independent variables and logistic regression to provide a new approach for optimization of complex systems with categorical variables either in inputs or in outputs. The result of the experiment has been optimized using through a nonlinear goal programming model. Finally a real example from engineering applications is analyzed by the proposed approach.

BACKGROUND

Some previous literature reviews on three phase of RSM methodology are reviewed separately as below.

Step 1: Data Collection

There are several approaches proposed in designing experiments. Response surface designs such as central composite design (CCD) and Box–Behnken can be used to fit the quadratic response surface model, which has linear and curvilinear effects for each of the factors along with all pairwise interaction effects. Box–Behnken design is known as economical design which requires only 3 levels for each factor and consists of a particular subset of the factorial design (khuri & Mukhopadhyay, 2010). Factorial design is applied to evaluate two or more factors simultaneously. This method divided into three parts such as; one-factor-at-a-time, full and fractional design which used to find the linear response (Montgomery, 2005). In order to find optimal design, several criteria proposed for multi response experiments. There are many methods of achieving optimal design such as simultaneous experiment design or sequential design (Ramachandran & Tsokos, 2015). Sequential design proposed by (Sitter & Forbes, 1997; Sitter & Wu, 1999). The most common criterion for multi response design is D-optimality, which expanded for linear multiresponse designs. (Atashgah & Seifi, 2007; Bischoff, 1993; Chang, 1994, 1997; Imhof, 2000; Kovach, 2009). Other criteria presented to find optimal design are; A-optimal, E-optimal (Wong, 1994), block design (Box & Draper, 1972; Das, Mandal & Sinha, 2003), and Bayesian design (Chaloner & Larntz, 1992; Chaloner & Vardinelli, 1995).

Step 2: Statistical Analysis and Model Fitting

Statistical model between the responses and factors determine settings on the design variable for analysis such as optimization, which produce optimal or at least acceptable values of the responses. There are several estimation techniques in RSM. Ordinary least square (OLS) is the main approach where there is no dependency among the variables. Principal component regression is another method for fitting where
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