行政院國家科學委員會補助專題研究計畫成果報告

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計畫編號：NSC 89-2213-E009-039
執行期間：88 **年** 8 **月** 1 **日至** 89 **年** 7 **月** 31 **日**

計畫主持人：蘇朝墩

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行政院國家科學委員會專題研究計畫成果報告

應用類神經網路和基因演算法求解最佳參數設計

Optimal Parameter Design via Neural Network and Genetic Algorithm

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國立交通大學工業工程與管理學系

一、中文摘要

本計劃探討參數設計最佳化問題。由於參數間可能會存在非線性關係和交互作用，使得參數設計之最佳化工作更為困難。一般業界大都使用田口方法，然而田口方法亦存在一些缺失。本計劃提出一改善參數設計最佳化的方法，包括二階段：階段一利用類神經網路建立一適合函數（fitness function**），此函數可以用來預測回應值。階段二應用基因演算法來搜尋最佳的參數組合。另外，本計劃將利用一案例說明所提方法的有效性。**

關鍵詞：田口方法、參數設計、類神經網路、倒傳遞網路、基因演算法

Abstract

This project addresses parameter design optimization problems that are complex owing to that nonlinear relationships and interactions may occur among parameters. To resolve such problems, engineers commonly employ the Taguchi method. However, the Taguchi method has some limitations in practice. Therefore, in this project, we present a novel means of improving the effectiveness of the optimization of parameter design. The proposed approach includes two phases. Phase 1 formulates a fitness function for a problem by a neural network method to predict the value of the response for a given parameter setting. Phase 2 applies a genetic algorithm to search for the optimal parameter combination. A numerical example demonstrates the effectiveness of the proposed approach.

Keywords: Taguchi method, parameter design, neural network, backpropagation network, genetic algorithm

二、緣由與目的

The optimization of parameter design problems has been extensively performed in industry. Engineers frequently encounter parameter design problems, particularly in product development, process design and operational condition setting. Parameter design problems are complex owing to that nonlinear relationships and interactions may occur among parameters. Although engineers conventionally apply the Taguchi method to resolve these problems [1,2], the Taguchi method has some limitations in practice. First, this method can only find the best one of the specified parameter level combinations. Once the parameter levels are determined, the feasible solution space is constrained concurrently. Second, while only addressing the discrete control factor the Taguchi method can not identify the real optimum when the parameter values are continuous. Third, the adjustment factor can not be guaranteed to exist in practice. Fourth, the Taguchi method can not handle interactions among parameters. Fifth, for a new product development or process design, the Taguchi method uses screening experiments to diminish the range of control factor levels, thereby decreasing the solving efficiency owing to an increasing number of experiments [3].

An alternative means of using the neural network has recently been proposed to improve Taguchi's parameter design [4,5,6], capable of effectively treating continuous parameter values. However, the method can not efficiently seek the optimal parameter combination.

To resolve the limitations of previous methods, this project presents an artificial-intelligence based technique which combines the neural network with the genetic algorithm. Neural network is a parallel computing system, capable of accurately representing a complex relationship between inputs and outputs. Genetic algorithm is a stochastic optimization technique, which imitates the process of Darwinian evolution to improve the solution.

The approach proposed herein has two phases. First, the neural network approach is applied to map out the relationship between inputs and outputs; the trained neural model is also used to accurately predict the response (output) at a given parameter setting (input). Second, the genetic algorithm is applied (through the trained neural model) to search for the optimal response and the corresponding parameter setting. The searched parameter setting is not limited to a discrete value. In addition, the adjustment factors no longer need to be identified. Moreover, it is more efficient in obtaining the optimum than previous methods. Furthermore, a numerical example demonstrates the effectiveness of the proposed approach.

三、結果與討論

In this project, the proposed approach consists of two phases. The first phase in the proposed approach involves identifying the fitness function. Owing to that a better combination may exist among the factor levels, a model must be developed to establish the relationship between the control factor value and response. A backpropagation network is trained to derive the relationship between the control factor value and response. The trained network can accurately predict the behavior of possible control factor combinations. Thus, inputting the control factor values into the trained network allows us to obtain the corresponding response. The trained network is used as the fitness function in the GA. In phase two, GA is directly applied to solve the problem. GA can be used to obtain the optimal value of the control factor from the possible solution spaces. Herein, the possible solution is represented by a chromosome. Each gene in the chromosome represents the value of the control factor. For instance, a system has five parameters A, B, C, D, and E. A chromosome (3, 1, 4, 5, 8) can represent the values of the five parameters (A, B, C, D, E), respectively. The essential genetic operations are conducted to obtain the optimal response, which is evaluated by the fitness function. Therefore, the optimal condition of the problem can be obtained. The detailed procedure is summarized as follows:

Phase 1: Identify the fitness function to predict the response.

Step 1. Collect the training and testing patterns by randomly selecting the data from the orthogonal table.

Step 2. Develop a backpropagation network model to derive the relationship between control factor values and responses. This trained network is referred to herein as the fitness function.

Phase 2: Determine the optimal condition.

Step 3. Set the GA operating condition.

Step 4. Create an initial population by randomly selecting the values of the control factors.

Step 5. Repeat *steps 6*－*10* until a stopping condition is reached.

Step 6. Calculate the predicted response value by inputting the control factor values to the fitness function (in *step 2*).

Step 7. Select the control factor values by the predicted response values.

Step 8. Crossover the fitness control factor values and replace the nonsurvival control factor values.

Step 9. Mutate the control factor values to yield next generation.

Step 10. Call the current parameter settings the optimal condition.

Step 11. Obtain the predicted response value by inputting the optimal control factor value to the fitness function.

This project presents a numerical example of a gas-assisted injection moulding process with a single response [7] to demonstrate the proposed approach's effectiveness.

四、計劃成果自評

Parameter design problems are difficult for engineers to develop products and processes since complex nonlinear relationships may exist among the parameters and responses. Although conventionally employed to solve such problems, the Taguchi method cannot attain the real optimal condition when the parameter values are continuous. Moreover, a neural network-based method can conquer the continuous parameter values, which is occasionally inefficient in term of obtaining the optimal condition. In this project, we present an efficient approach to overcome these problems. Based on artificial-intelligence techniques, the proposed approach combines the neural network with the GA to optimize the parameter design. A numerical example demonstrates the proposed approach's effectiveness. The proposed approach possesses five merits of considerable importance: 1. The proposed approach can treat both quantitative parameters and qualitative parameters; 2. The proposed approach can effectively deal with the interactions among the parameters; 3. As long as the historical experimental data are sufficient, no additional experiments are necessary and the data can be directly applied to the proposed approach; 4. The proposed approach is an improvement over previous parameter design techniques, and it is more efficient to find the optimum; 5. The proposed approach is relatively simple and is fairly easy for engineers to apply to diverse industrial applications. Restated, it does not require much statistical background for engineers. In addition, applying the proposed approach allows engineers to directly use neural network software and GA software to optimize the problems without any theoretical knowledge of neural computing and GA.

The above research result has been accepted for publication in *International Journal of Industrial Engineering* (**SCI**, **EI**).

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