The Taguchi System-Neural Network for Dynamic Sensor Product Design

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Abstract The key successful factor of the new product design (NPD) of sensor manufacturing industry is the selections of the best parameter level. For above reasons, the selection of best parameter level sometimes causes more cost increasing and job reworking. Previous studies focus on try and error test and structured approach for the replacement and management of selection of the parameter level in product design, but rarely on a dynamic environment. Therefore, this work presents a novel algorithm, the Taguchi System-two steps optimal algorithm, which combines the Taguchi System (TS) with neural network (NN) method, which is shown how product adjusted under a dynamic environment in product design. From the results, the proposed method might possibly be useful for our problem by selecting of parameter level size and adjusting the parameters by NN in the DSPDS is observed in this study.

Keywords Taguchi system (TS) · Dynamic product design system (DPDS) · Dynamic sensor product design system (DSPDS) · Neural network (NN) · New product design (NPD)

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1 Introduction

The selection of best parameter level is the most important job in sensor product design areas. From previous papers, the TS method has been successfully combination of various kinds of other's method and tools by adjusting the parameters and parameter levels [1–10] (Kun et al. 2011). Besides, the NN has been successfully provided in dynamic environments [11, 12].

Therefore, this work presents a novel algorithm, the Taguchi System-neural network, which combines the Taguchi System (TS) with the NN method, which is shown how product adjusted under the dynamic environment in product design. The remainder of this paper is organized as follows. Section 2 describes the TS algorithmic process for selecting of parameter level and presents the NN method in a dynamic environment. Section 3 illustrates the algorithm's effectiveness and shows the analysis. Section 4 discusses the results. Conclusions are finally drawn in Sect. 4, along with recommendations for future research.

2 The Taguchi System-Neural Network Algorithm

The process of TS-NN algorithm will be generated in this section. Besides, the results which will be discussed in the later part of this section. And, the proposed algorithm starts with the following. First, to establish the TS model, one set of data is chosen from a system. The parameters of the original data are selected to calculate the signal-to-noise (SN) ratios. The most important task is to determine which parameter levels are selected. Second step, the NN algorithm is applied, which is completed using the next two detail steps. First, establish the structure, which is form by the formula $Y_i = \beta M_i$ is applied to a DSPDS.

In sum, the algorithmic procedure has the following three steps.

Step 1. Construct the Taguchi System

First, the levels of the important parameter of the product are chosen based on the SN ratios, which is shown in Eq. (1).

$$\eta = 10 \log_{10} \frac{\overline{Y}^2}{S^2} \tag{1}$$

The process is as follows.

(1) ***Estimate the parameters of product:***
Assess the parameters.

(2) ***Decide parameter level number of product:*** Set and select the parameter level number of product from the data set as control parameters. For example, there is a product, which parameter may have three levels. The number "1" denotes level 1, which is defined the level 1of the parameter, the number "2" denotes

level 2, which is defined the level 2 of the parameter, the number "3" denotes level 3, which is defined the level 3 of the parameter.

(3) ***Compute the SN ratios of product:***
Compute the SN ratios of parameters.

Step 2. Establish the dynamic system

(4) ***Construct the dynamic system:***
The NN algorithm is utilized to construct and verify the DSPDS.

Figure 1 presents the TS-NN algorithm.

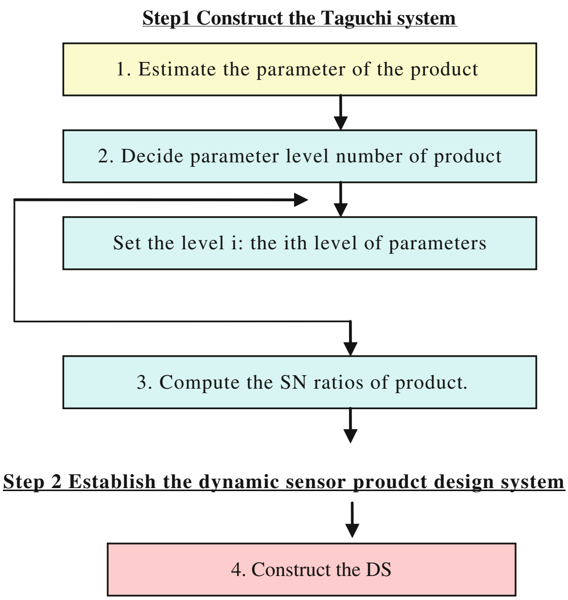
3 Verification

The procedure of TS and NN will be verified and discussed in this section by a speed sensor of winding machine.

3.1 Establish the Taguchi System

The proposed case is a company that produces speed sensor of winding machine. It is the important part in many kinds of machine. For establishing the TS model, the

Fig. 1 Taguchi System-NNalgorithm



parameters, the level numbers of parameter, and the observation values are collected and coded from v_1 to v_4, L_1 to L_3 and y_1 to y_3.

In total, 27 data are selected from the data set. The TS-NN algorithm is applied as follows.

At first, the original data and the SN ratios of these parameters are calculated (Table 1).

Consequently, the levels of the parameters are selected form the data set. The expected value of the SN ratios is an optimal state.

3.2 Modeling the Dynamic System

The process of NN will be generated and discussed in this section.

3.3 Establish the Dynamic System

The NN algorithm is applied to determine whether the DS is good. The processes are as follows.

Step 1. Modeling the DS

The NN algorithm is used to create a DS. Thus, the second set of input and output data is selected, and a neural network model is constructed to map the model.

Step 2. Training and testing the NN algorithm

The relationship model between parameters and responses is developed using an NN, in which 16 inspection data are used for training and 11 lots are used for testing. The model structure is selected using 4-4-4 (input-hidden-output) (Table 1). Then, to determine the options of the NN structure, the architecture 4-4-4 is chosen to get the convergent performance. Restated, the RMSE of training error is 0.01, and the testing error is 0.01.

These two RMSE values for training and testing are convergent (Fig. 2).

Table 1 The SN ratios of experiment results

Level	v_1	v_2	v_3	v_4
1	43	40	42	48
2	42	52	48	52
3	48	52	53	44
Delta	11	10	9	8
Rank	2	1	3	4

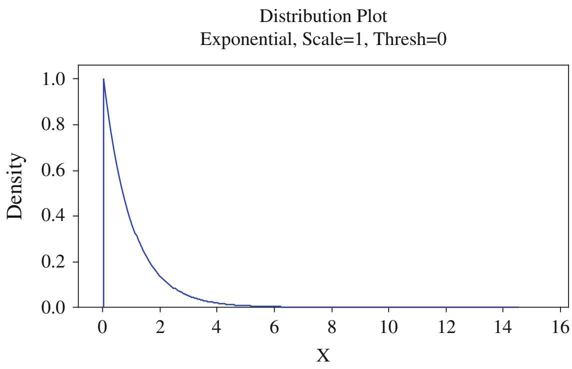


Fig. 2 The testing values of the 4-4-4 RMSE structure

According to data for the confirmation set, the formula for desirable functions is $Y_{ij} = F(v_1, v_2, v_3, v_4)$, which is applied for a DSPDS can map in 4-4-4 (input-hidden-output) NN structure successfully.

4 Conclusion

In above analysis, the levels of parameters which based on SN ratios are successfully selected. In another word, the TS algorithm is successful applied to a product design in the selection of parameter level. In modeling a DS, the NN algorithm shows that the 4-4-4 structure is the optimal architecture, and the RMSE value for training and testing are converge at 0.01. However, the methodology of the TS can easily solve the selection of parameter level in PD problems, and is computationally efficient.

We conclude that the propose algorithm can be applied successfully to dynamic environments for solving the PD problems.

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