‘Grey Model’-Based Simulation Tool for Predictive Product Quality Control

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ABSTRACT

A modified grey model is represented for predicting the product quality index and generating the grey process control chart. The model considers the first sample datum in the numerical solution of the whitened differential equation. This datum is introduced by the refitting smoothed cumulative values and numerical solution of the whitened equation with the last value as initial point. Values predicted in this manner and those predicted in the regular GM (1,1) model were calculated with a specially elaborated MATLAB program. The numbers obtained were compared with reference data. The modified model demonstrates higher accuracy compared to the regular GM as demonstrated by several actual examples. The proposed model is used to design a special simulation tool. The graphical interface of the tool allows to the user to introduce the sample data, control limits and required mean value. After this, the tool outputs the predicted quality index with its error and generates a process control chart with the predicted product quality index.

KEYWORDS

Graphical Interface, Grey Model, Process Control Chart, Product Index Prediction

INTRODUCTION

In modern industry, many different product parameters should be permanently checked during their manufacturing to ensure the product quality. It requires complete information regarding each of controlled parameters. A grey system methodology (Deng, 1982) has been successfully used applying incomplete information about parameters tested during the process control (Guo & Dunne, 2006) and has led to a reduction to time and expense. Grey models (GM) are especially valuable when we need to predict the forthcoming parameter value based the few numbers of previously measured/obtained data. For this purpose, various modifications of the GMs are used, e.g. (Lin, Lee, & Chang, 2009; Xie & Liu, 2008; Gui et al., 2013). The main model in grey theory prediction (Liu, Dang, & Fang, 2004) is GM (1,1) model where the first number in brackets denotes the differential equation order and the second is the number of variables of the model. This model can use a smaller number of data than more universal GM(1,N), GM(2,1) models or their various modifications (Guo, 2005). In the process of product manufacturing, the samples are taken for testing and it is desirable to make such operations as small as possible. Therefore, the GM(1,1) model is preferable for product quality control implementation. Size of the samples is important for prediction accuracy of the product quality - Hui, Li, and Shi, 2012, Wu at al., 2013. These studies show that smaller sample size can provide higher precision of the GM prediction.
The grey prediction models have been known for a rather long time, but their performance still can to be improved for better prediction of the product quality parameters (Chen & Tien, 1997; Guo et al., 2013; Ji & Cai, 2016; Ke, 2013, Zhang & Li, 2008, Wang, Tang & Cao, 2011) and for predictive process control chart (Guo & Dune, 2006). In latter and other noted studies, the exponential solution of the whitened differential equation is used that does not always correlate with original data. Furthermore, the adjustment applied to data does not include the first reference point that is particularly undesirable for a small number of sampled data because it further reduces the already minimum sample number and introduces additional uncertainty in the predicted product quality values. In addition, another factor preventing GM implementation in practical quality engineering is the absence of a user-friendly calculating interface. Thus, here we describe a modified GM(1,1) model that realizes a numerical solution, considers first data point, and represent finally the developed MATLAB-based special graphical interface tool suitable for practical implementation in the control of the product quality indices.

CONTROL CHART, GOVERNMENT GREY MODEL EQUATIONS, ADOPTED METHODOLOGY AND SCHEME OF CALCULATIONS

To study and demonstrate a quality parameter changes over time, a control chart is used. A control chart has data, a centerline, and two limiting lines – an upper line for the upper control limit (UCL) and a lower line for the lower control limit (LCL). Data are presented usually in time order. If the time gap is equal, the data can be presented in serial order as in Figure 1.

If the process was sampled n times and data remained into the limited range, we can expect that n+1 data will fall into that range or will come out. This can be evaluated statistically for which significant sampling is required. Therefore, this approach does not work satisfactorily with a small

Figure 1. Typical view of the process control chart (generated in MATLAB with the control chart command)
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