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A fuzzy logic approach to forecast energy consumption change in a manufacturing system

H.C.W. Lau [a,*], E.N.M. Cheng [a], C.K.M. Lee [b], G.T.S. Ho [a]

[a] Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
[b] Division of Systems and Engineering Management, School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, 639798 Singapore, Singapore

Abstract

This paper proposes an energy consumption change forecasting system using fuzzy logic to reduce the uncertainty, inconvenience and inefficiency resulting from variations in the production factors. The proposed fuzzy logic approach helps the manufacturer forecast the energy consumption change in the plant when certain production input factors are varied. Predictions given by the proposed system adopts the fuzzy rule reasoning mechanism so that any changes in the overall energy consumption will neither violate the stable power supply and production schedules nor result in energy wastage. To demonstrate how the fuzzy logic approach is applied to a manufacturing system, a case study of the energy consumption forecast in a clothing manufacturing plant has been conducted in an emulated environment. The result of the case indicates a percentage change in the plant's energy consumption after analyzing three input parameters. This finding is able to provide a solid foundation on which decision makers and systems analysts can base suitable strategies for ensuring the efficiency and stability of a manufacturing system.

Keywords: Fuzzy logic; Manufacturing system; Rule based reasoning mechanism; Energy consumption

1. Introduction

During the last few decades, the world's oil supply has been either running short or fluctuating from time to time. Although technological progress during these years has been rapid, such as the development of alternative power sources, the huge demand for oil from almost all human-related daily activities is hardly ever satisfied. Such circumstances mean that higher and higher costs have to be paid for energy, which is often generated from oil. As a result, inevitably, high energy consumption industries continue to look for other sources of power supply in a more effective and efficient way. An accurate forecasting of energy consumption is critical to them, otherwise any large forecasting error would increase their burdens about operating cost (Rousselot, Balmat, & Gut, 1993). Manufacturing is one of the business sectors that is directly affected and so manufacturers are keen to implement cost-reduction strategies.

The energy input of a manufacturing plant is enormous. It is disastrous and inconvenient for an operating manufacturing plant to run short of power. It is also an inefficient waste if the machines are kept operating during their idle periods. In their endeavours to find more and more efficient ways of consuming energy, manufacturers will closely examine the manufacturing process to try and find any step that contains room for improvement. They may also try to devise an overall production plan that can control the production system to run at its optimum level as well as stabilize the factory's power supply. In order to devise such a plan, the plant requires a reliable approach to forecasting the energy consumption changes that take place during the manufacturing process.

This study proposes the application of fuzzy logic approach to forecast the amount of energy consumption

* Corresponding author. Tel.: +852 27666628; fax: +852 23625267.
E-mail address: mfhenry@inet.polyu.edu.hk (H.C.W. Lau).

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change when comparing it to a reference energy consumption level.

Section 2 reviews some related studies of fuzzy logic theories and applications.

The development of the proposed energy consumption change forecast system by fuzzy logic approach is represented in Section 3.

In Section 4, a case example is used to demonstrate how the proposed fuzzy logic system is applied to a clothing manufacturing plant. With the present of inputs and results, a final change about the energy consumption can be drawn at the end of Section 4.

Section 5 includes the concluding remarks and suggestions for further research studies.

2. Literature review

From the manufacturers' point of view, their daily operations involve many procedures. Based on the data from the manufacturing steps, the manufacturer needs to estimate the energy consumption by collecting the past energy consumption records and the relations between the energy consumption and some of the inputs of production factors. In the scenarios which involves lots of advanced machines, Small (2006) even suggests to carry out a portfolio analysis to justify investment in advanced technology at manufacturing plants.

Research into the development and applications of fuzzy logic has been common for decades. One of the traditional fundamental concepts of fuzzy logics is that it is characterized by a qualitative, subjective nature and linguistically expressed values (Yager & Zadeh, 1992). Studies on applying fuzzy logics to systems for different sectors have been widely undertaken. Both the business and industrial sectors are concerned with fuzzy logic applications in these scopes. The application areas are generally related to process industry, biotechnology, manufacturing systems, traffic control, avionics and biomedical systems (Sevastjanov & Róg, 2003; Martins, Costa, Pires, & Dente, 2001).

In the business sector, fuzzy logic principles have been especially applied in modeling for managerial decision-making (Zimmermann, 1996) for instances, Ho, Lau, Lee, and Ip (2005) incorporate fuzzy logic concepts into the agile quality enhancement system to achieve the optimization of the performance of organizations. Collan and Liu (2003) use a fuzzy approach for supporting capital budgeting and investment decision making.

According to Maravelakis, Bilalis, Antoniadis, Jones, and Moustakis (2006), it is better able to interpret qualitative characteristics than other conventional methods. Furthermore, with fuzzy logic, the parameters of a model can be represented by words and the overall output can be given by their synthesis. They applied this fuzzy logic approach to the assessment of the innovative attributes in SME's. Under the fuzzy logic approach, three linguistically expressed membership functions have to be defined from various sets of the company's data.

Srino, Shayan, and Ghotb (2006) applied the fuzzy logic approach to generate a fuzzy scheduling model to solve operation allocation, operation scheduling and also tool allocation problems in flexible manufacturing systems (FMSs). Such systems are looking for achieving the flexibility of low volume production while retaining the efficiency of high volume mass production (Roh & Kim, 1997). In their study, Srino et al. define four fuzzy input variables which include machine allocated processing time, machine priority, due date priority, and setup time priority. The job priority is set to be the fuzzy variable, showing the priority status of a job to be selected for the next operation on a machine. Following these settings, the model is applied to select machines in assigned operations. The performance measures of the fuzzy logic approach are found to be better than the existing methods used in most of the criteria. This shows the contribution of fuzzy logic in the industrial sector such as bringing effectiveness and efficiency to FMS scheduling.

Fuzzy logic concepts have also been applied in many ways to energy consumption-related topics. Jabera, Mamlook, and Awad (2005) analyzed the data on energy users by fuzzy logic techniques condensing large amounts of data into a small set of variable rules and the results were employed effectively in evaluating energy conservation programs. On the other hand, Jeong, Lee, and Kim (2005) used a fuzzy logic algorithm to determine the relative output power in the fuel cell/battery hybrid system. This involved two input fuzzy sets: the external power requirement and the battery state of charge. Their results showed the operating efficiency of the hybrid system was improved and the battery state of charge was maintained at a reasonable level. Their studies also showed the feasibility of applying fuzzy logic to manufacturing purposes.

3. The infrastructure of the energy consumption forecast system

The energy consumption forecast system was developed for managing the energy supply in an effective and efficient way. The proposed system estimates the amount of energy consumption change based on the production inputs. The resulting data helps decide the follow up actions such as whether to continue or temporarily shift the power system based on the rules gathered in the knowledge base. The energy consumption forecast system has made use of the fuzzy sets to manage the data and then make a proper decision. In short, the energy consumption forecast system consists of six phases which are: situation analysis, knowledge acquisition, data collection, fuzzification, a fuzzy inference engine and defuzzification. Fig. 1 shows the conceptual model of the energy consumption forecast system and indicates the inputs and outputs of the processes involved.

The procedures comprising fuzzification to defuzzifcation can be grouped together to form the fuzzy system, which embraces the fuzzy logic principle. Leung, Lau,