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Design and simulation of manufacturing systems facing imperfectly defined information ☆

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Abstract

Due to the constant evolution of the environment and to the complexity of the needs, the specifications of a manufacturing system are often imperfectly known. The initial design data are uncertain, inaccurate and even vague. We propose to represent the quantifiable needs using fuzzy quantities. The data are propagated during the activity of engineering to lead to the parameters of the target system. In this context, simulation techniques, based on fuzzy parameters, are used to verify the exactness of the design. We choose to use a commercial discrete event simulator and Response Surface Methodology to perform fuzzy simulation.

Keywords: Manufacturing system; Fuzzy design; Fuzzy simulation

1. Introduction

An assumed optimal design approach cannot give a satisfactory result if the data which are available at the beginning are incorrect or too inaccurate. The

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analysis of the technical and economic environment of a company is not an easy task and induces important uncertainties. Rapid environment evolution generates a shift between the moment of the analysis of the needs and that of the realization of the system. The construction of a precise model is limited by the ignorance of some characteristics of the future equipment. A fortiori, the social factors disturb the study seriously. Thus, the mission of the designer, assisted by traditional tools, seems very hazardous. Therefore using a robust approach is essential.

The probability theory based techniques allow only uncertainty to be quantified ('*the probability of getting an annual order volume of N units, for product A, is equal to P*'). Actually information is also vague ('*the annual volume of orders for product A is situated between N1 and N2*'). Many evaluations are vague ('*the annual volume of orders for product A is approximately equal to N*') and cannot be immediately quantified. Currently, the fuzzy set theory [25] is the best-adapted formalism, to integrate the whole set of imperfections. Possibility theory [26] takes the place of probability theory, as soon as subjective information is taken into account. Fuzzy logic may represent linguistic data, which cannot be easily modelled by other methods [6].

As manufacturing system design starts from rather uncertain, inaccurate and even vague information, one can expect a large use of fuzzy set theory. Actually fuzzy modelling is widespread in some circumstances and rare in other ones. That is due, on the one hand, to historical grounds, on the other hand, to the fuzzy calculation complexity.

First, fuzzy set theory may be considered as a part of Artificial Intelligence and used for decision-making. It can be combined with other tools such as neural networks [3] or game theory [5]. The fuzzy approach has been used to assist the design of manufacturing systems. Application to plant layout has been proposed [15]. Fuzzy set theory is particularly well adapted when human operator are involved [27]. Fuzzy methods may also be used to choose the most efficient maintenance approach [1]. The common feature is the use of fuzzy expert rules in order to deduce a convenient solution.

Then, fuzzy arithmetic is a helpful support for planning when the delay values are not perfectly known. Probability theory can certainly be used when statistical data are available but become ineffective when information is vague. The crisp intervals that are used in Program Evaluation and Review Technique, Critical Path Method or Gantt chart are merely replaced by fuzzy intervals when information is imperfect. Both process characteristic such as processing delays and objective such as delivery dates can be modelled. An overview of such approaches can be found in [8]. Various applications have been issued from that concept. In project management the inaccuracy of activity durations can easily be represented by fuzzy intervals [23]. The problem of production planning, involving not only time variables but also actual and objective costs is somewhat more complex. For instance, a method for aggregate production planning is proposed in [24]. The poor prediction of order arrival dates is certainly the main problem for scheduling. Again, fuzzy logic and possibility theory allow dealing with such a problem [9].