Applying Interval Fuzzy Petri Net to Failure Analysis

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ABSTRACT

In this article, the authors propose a new approach for modelling and failure analysis by combining the graphical representation provided by Petri nets and fuzzy logic. The graphical method is used for describing the relationship between conditions and events. The use of Petri nets in failure analysis enables replacing logic gate functions in fault trees. The Fuzzy logic technique allows natural language descriptions of process entities as well as an if-then rule-based definition of production. In addition, this study devises an alternative, a trapezoidal graph method in order to account for failure scenarios. Examples validating this novel method in dealing with failure analysis are also provided.

KEYWORDS

Fault Diagnosis, Fuzzy Logic, Intervals Fuzzy Petri Nets, Modelling, Uncertain Systems

1. INTRODUCTION

The conduct of industrial diagnostics and the planning of an adequate troubleshooting procedure are major consequences, since they provide the basis for timely intervention and thus keep catastrophic situations. Several studies have been published on diagnosis methods and techniques used for making decision in various fields, especially in medicine and maintenance. We can cite the expert systems used in maintenance which makes it possible to diffuse knowledge thanks to the evolution of computer science. The expert systems introduced by Zadeh integrate fuzzy logic for modelling uncertain systems. Performances of the modelling approaches depend on the means of the techniques end the model being used. Obtaining and using the model to construct a control system is a complex and difficult task (Azar, & Serrano, 2016; Azar & Vaidyanathan, 2015a; 2015b; 2015c), more particularly for the uncertain systems because of unforeseen and uncontrollable events that characterize them.

This paper deals with two of three types of quality control methods: methods for monitoring an ongoing production process and troubleshooting method for locating the cause of perturbation. The diversification of techniques and methods (Kaliannan et al., 2015; Sougui et al., 2014) for using fuzzy logic have limitations due to the fact that industrial maintenance is mainly based on subjective and uncertain knowledge. Our goal is to maintain the values of product within the limits specified and to get the process in control. Once the process is monitored and is able to stay within its specification

limits, its capability can be determined (Dhouibi et al., 2005, 2011). This work focuses on quality regulation of uncertain discrete-event systems (Cardoso & Camargo, 1999); and tries to use Interval Fuzzy Constrained Petri Nets (IFCPN) as a tool for modelling, identification and isolation. Our main contribution is to extend the functional range of ICPN applications to regulate and identify uncertain systems where the validity intervals of any parameter are fuzzy and characterized by the propagation of uncertain events (Lajmi et al., 2017; Senan et al., 2014; Kouah and Saïdouni, 2015); Cassandras & Lafortune, 2008; Belhadef et al., 2016).

This paper is organized as follows: In the first part of this work, we study the modelling of a dynamic system: we propose an approach using Statistical Process Control (Alsup & Watson, 1993; Pillet, 2000; Saadé and Vahidov, 2011) in order to build the validity ranges of fuzzy intervals and we compute robust control laws of this model (Dhouibi, 2005). The second part of the paper is dedicated to implementing a unique perturb and observe algorithm to track and maintain the maximum production without default.

1.1. Expert Systems for Industrial Diagnostics

An expert system is usually used as a base for the implementation of a real-time mechanism able for performance analysis and diagnosis of an industrial process. In this work, we are interested in decision making for industrial diagnosis to help and identify the fault and thus reduce the probability. Our goal is to propose a fault detection approach based on a fuzzy interval Petri net model able to simplify the diagnosis of the fault and initialization of the necessary corrective actions. The information concerning the faults is carried by measured signals and converted offering on the alarms list and messages to define the primary cause as well as a list of priorities of potential solutions.

2. FUZZY INTERVAL PETRI MODEL AND FAULT TREE

The production is subject to many uncertainties arising from the processes, the operators or the variations of quality of the products. A production is seldom perfectly repetitive. All authors, who treated uncertainties, studied mainly two disturbances: disturbances on the equipment and more particularly machine breakdowns or the disturbances concerning work and more particularly the change in the operational durations.

The proposed tool, IFCPN model, is introduced in order to extend some properties of the Interval Constraint Petri Nets (Dhouibi, 2005) which is considered as an extension of the P-temporal Petri Net (Khansa, 1997) and a sub-class of High Level PN (Jensen & Rozenberg, 1991; (Scarpelli & Gomide, 1993).

2.1. Interval Fuzzy Petri Nets

The concept of Interval Fuzzy Petri Nets (IFPN) (Lipp & Gunther, 1993; Dubois et al. 2000) is derived from the ICPN model where we define IS as a fuzzy interval associated with places (Khansa, 1997). This model is used to represent a fuzzy rule-based system that is capable of modeling the fuzzy production rules: if p_j and p_k (Looney, 1998; Bugarin and Barro, 1998).

The theory of fuzzy interval has found applications for modeling and controlling uncertain presentation systems (Chen, 2000; Moore, 1966) in the settings. Knowing that a conventional interval includes all possible values in a fuzzy range, we associate a degree of uncertainty for each of the possible values.

In this article, we introduce a method for calculating the limits of a given range. First, we are going to present the basic concepts of conventional and fuzzy intervals.

A fuzzy interval I_F is defined as a conventional interval to which is associated a membership function denoted μ_I:

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