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SEDRET—an intelligent system for the diagnosis and prediction of events in power plants

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Abstract

Artificial Intelligence applications in large-scale industry, such as fossil power plants, require the ability to manage uncertainty and time. In this paper, we present an intelligent system to assist an operator of a power plant. This system, called SEDRET, is based on a novel knowledge representation of uncertainty and time, called Temporal Nodes Bayesian Networks (TNBN), a type of Probabilistic Temporal Network. A set of temporal nodes and a set of edge define a TNBN, each temporal node is defined by a value of a variable and a time interval associate to the change of variable value. A TNBN generates a formal and systematic structure for modeling the temporal evolution of a process under uncertainty. The inference mechanism is based on probabilistic reasoning. A TNBN can be used to recognize events and state variables with respect to current plant conditions and predict the future propagation of disturbances. SEDRET was validated with the diagnosis and prediction of events in a steam generator with a power plant training simulator. The results performed in this work indicate that SEDRET can potentially improve plant availability through early diagnosis and prediction of disturbances that could lead to plant shutdown.

Keywords: Diagnostic expert systems; Knowledge-based systems; Temporal probabilistic networks; Fossil power plant application

1. Introduction

There is a strong tendency to design supervision and control systems with artificial intelligence techniques (Boyen & Wehenkel, 1999; Kang & Golay, 1999; Zhang & Zhao, 1999). Current economic, social and environmental factors put stringent requirement on steam power plants to be operated at high level of efficiency and safety at minimum cost. The result has been an increase in the complexity of power control system operations (Arroyo-Figueroa, Sucar, Solis & Villavicencio, 1998). In a steam power plant, an operator has to monitor several hundred measurements and alarms. Under fault situations, the operator of the plant must be able interpret each measurement that is received by the control system, and determinate which is the condition of the equipment in order to make a proper control action. The complexity of the decisions that the operator is required to make is continually increasing along with the severity of the consequences of an error in judgement. In addition, the ability to respond quickly can often be the decisive factor in the prevention of the developing malfunction. While their abilities may match the demands of day-to-day operations, the flood of alarms and upset indications generated by a disturbance (process malfunction or fault) can overwhelm even the most rigorously trained operators.

A fossil power plant can be described by great variety of processes with multiples state variables, events and disturbances. In this domain, the state variables change over time in response to both internal and external disturbances as well as the transition of time itself. In the process is a signal exceeding its specified limit of normal functioning called an event, and a sequence of events that have the same underlying cause are considered as a disturbance. During disturbances, the operator must determine the best recovery action according to the type and sequence of the signals received. Current control systems do not provide the means for intelligent interpretation of sensor data, diagnostic problems, copying with large process disturbances or predicting the consequences of control action (Arroyo-Figueroa & Villavicencio, 1994; Falinower & Mari, 1994; Moradian, Thompson, Tomlinson & Jenkins, 1992; Shirley, Forbes & Nelson, 1990; Tsou, 1995; Wong, Ho & Teo, 1994).

In this paper, we present an intelligent system to assist an operator of fossil power plants. The intelligent system called Intelligent System for the Diagnosis and Prediction of Events (SEDRET) is a Shell based on probabilistic networks

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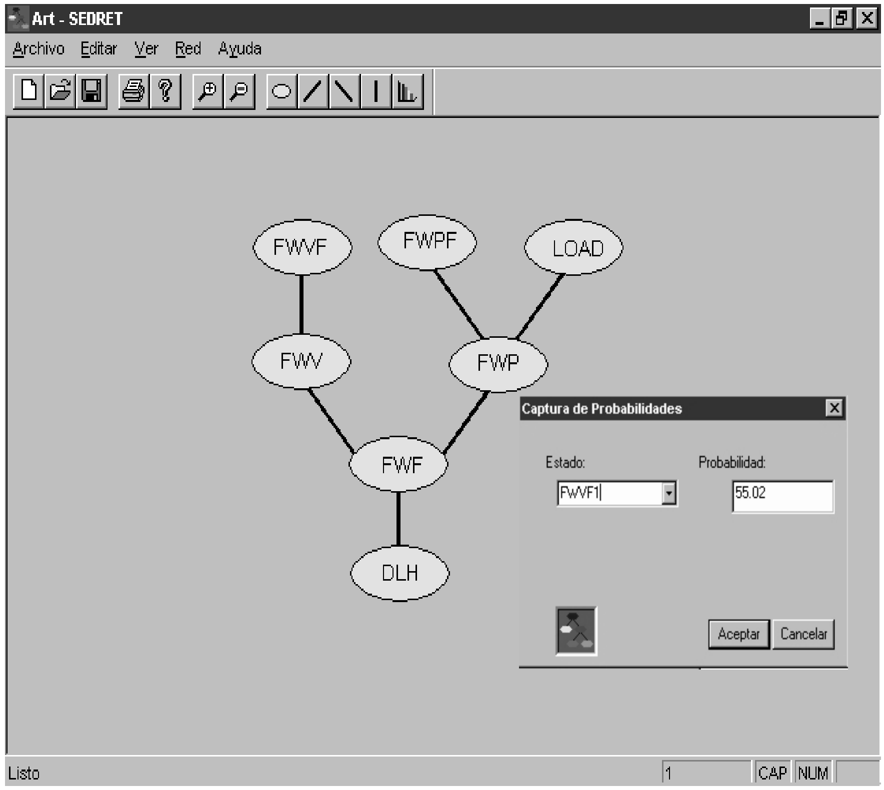

Fig. 1. Temporal nodes Bayesian network for the drum level system.

to deal with uncertainty and time. The research goal is to develop a real-time knowledge based system to act as an operational and diagnostic aid to operators of power plants.

The paper is organized as follows. First, we show how the probabilistic network can deal with uncertainty and time, and present a novel methodology called Bayesian network (BN) with temporal nodes (TNBN). Afterwards, we present the design and development of an intelligent system to assist an operator of fossil power plant based on a TNBN. Finally, we illustrate its application in a fossil power plant with a detailed example: the diagnosis and prediction of events in the drum system of a steam generator.

2. Temporal nodes Bayesian network

In the large-scale industry, such as fossil power plants, the process information is generally imprecise and incomplete, and it changes over time. These problems suggest that any successful representation should handle uncertainty and time in a principled and unambiguous way. An ideal representation should be sound and complete, facilitate efficient inference, as well as be amenable to explanation methods. We propose a novel representation based on a probabilistic network for dealing with uncertainty and time, called Temporal Nodes Bayesian Network (TNBN) (Arroyo-Figueroa & Sucar, 1999).

Bayesian networks are a robust and sound formalism to represent and handle uncertainty in intelligent systems in a way that is consistent with the axioms of probability theory (Pearl, 1988). A BN is a graphical structure (Directed Acyclic Graph) composed of nodes and arcs, used for representing expert knowledge. In this graphical structure, each node corresponds to an entity of the real world (variable: hypothesis or evidence) and each link gives direct information about the dependency relationships between the variables involved. These dependency relationships are parameterized by conditional probabilities required to specify the underlying distribution. In particular, the qualitative knowledge is represented by the topology of the network and the quantitative knowledge is represented by the joint probability distribution of the variables. A BN has a number of important properties, including a declarative semantics as an extension of probability theory, efficient and complete inference algorithms, and several machine learning and explanation methodologies. There are several exact and approximate inference algorithms for BNs, and special case algorithms and corresponding conditions that allow tractable inference. The inference mechanism is based on probabilistic reasoning. This consists of instantiating the input variables, and propagating their effect through the network to update the probability of the hypothesis variables. However, BNs were not designed to model temporal relationships between the process variables (Aliferis & Cooper, 1996; Santos & Young, 1996). The main problem is to represent each variable with its interactions with