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A neuro-fuzzy monitoring system Application to flexible production systems

N. Palluat *, D. Racoceanu [1], N. Zerhouni

Laboratoire d'Automatique de Besançon, UMR CNRS 6596, 24 Rue Alain Savary, 25000 Besançon, France

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Abstract

The multiple reconfiguration and the complexity of the modern production system lead to design intelligent monitoring aid systems. Accordingly, the use of neuro-fuzzy technics seems very promising. In this paper, we propose a new monitoring aid system composed by a dynamic neural network detection tool and a neuro-fuzzy diagnosis tool. Learning capabilities due to the neural structure permit us to update the monitoring aid system. The neuro-fuzzy network provides an abductive diagnosis. Moreover it takes into account the uncertainties on the maintenance knowledge by giving a fuzzy characterization of each cause. At the end, we illustrate the industrial usefulness of the proposed dynamic neuro-fuzzy monitoring system trough a flexible production system monitoring application.

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Keywords: UML; Neural network; Neuro-fuzzy; Diagnosis; Monitoring; Maintenance; SCADA; CMMS; FMECA; Fault Tree

1. Introduction

The improvement of the complexity of real production systems in a hard concurrent marketing context encourages the managers to give more importance to the maintenance functions. The industrial monitoring, which is one of the most significant of them, is divided into two tasks: the failure detection, and the failure diagnosis (failure localization and failure causes identification) [1]. More the system is complex, more the monitoring is difficult. An efficient monitoring system must be easy to improve due to system reconfiguration and experts/operators experiences feedbacks.

The heterogeneity of maintenance and production information is taken into account for the creation of our monitoring system. This information can be provided by:

- Failure Modes Effects and Critical Analysis (FMECA),
- Fault Tree (FT),
- Functional Analysis,
- Production and maintenance operators and managers experiences,
- Computerized Maintenance Management System (CMMS),
- Supervisory Control and Data Acquisition (SCADA),
- ....

The proposed method concern all phases of the monitoring function: the fault detection and the fault diagnosis (Fig. 1).

- *Dynamic detection tool*. The input of the detection system is given by sensors data. These data are treated dynamically. The output gives the operating mode (symptom) of the supervised system.
- *Diagnosis tool*. The input of the diagnosis system will be the degree of membership of each operating mode given by the detection. We find also external qualitative or quantitative inputs such as information given by operators to improve diagnosis. The output gives a list of possible causes ordered by credibility degree,[2] and as complementary information:

* Corresponding author.
E-mail addresses: npalluat@ens2m.fr (N. Palluat), visdaniel@i2r.a-star.edu.sg, daniel.racoceanu@univ-fcomte.fr (D. Racoceanu), zerhouni@ens2m.fr (N. Zerhouni).
[1] University of Franche-Comté, France; Image Perception, Access and Learning (IPAL); French National Center for Scientific Research (CNRS); Institute for Info-comm Research (I2R); Agency for Science, Technology and Research (A*STAR).

[2] Credibility value/degree = membership degree of a variable to a membership function. In our work, the membership degree can be seen as a belief indicator.

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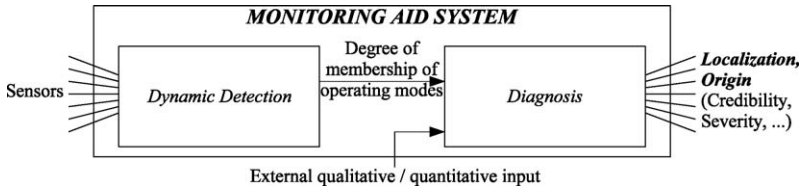

Fig. 1. Overview of the monitoring aid system.

the severity degree. These degrees help the maintenance manager to evaluate and to plan the maintenance actions.

During the process, the dynamic detection tool scans continuously the system. When a failure or a degradation occurs, an alarm is raised and the diagnosis tool starts. According to the information provided by the detection tool, the diagnosis tool proposes to the operator the possible causes of the symptom as well as the fuzzy interpretation of these causes. This point of view enables us to predict a possible failure.

Our design approach follows the Unified Modelling Language (UML) [2,3]. Several reasons led us to this choice:

(1) UML is a language normalized by OMG[3] [4] and UML specifications are free access.
(2) Interest shown by computer specialists for this modelling language.
(3) Possibility to use the same language since the requirements expression until the application generation.
(4) Ability to use the object oriented concepts to improve the design approach.

The requirements of the monitoring aid system are:

(1) ability to use an incomplete database and knowledge base;
(2) possibility to take into account new knowledge;
(3) ability to identify false alarms;
(4) easy to use;
(5) interfacing with industrial tools for maintenance management (FMECA, Fault Tree, CMMS);
(6) interfacing with industrial data acquisition tools (SCADA, Ethernet . . .);
(7) integration of the tool in an industrial platform;
(8) possibility to interface with Human-Machine Interface (HMI) on PDA, laptop . . ..

The paper is structured in four parts. The following paragraph presents the UML method to design our tool, three important use cases are developed. In a second time, we present important criteria to choose detection and diagnosis tools. In a third part, we briefly describe the two tools. At last, an industrial problem will be treated.

2. UML specification of the monitoring aid system

UML is articulated around several types of diagrams, each one of them being dedicated to the representation of the particular concepts of a software system. Our study focuses on use case. In order to develop the computing code of the monitoring aid system from the user requirements, we use the method given in Roques [5].

2.1. Use cases

Use cases enable to define the limits of the system and its relations with the environment. A use case is a specific manner to use the system. To lead to the use cases, we follow the next modelling approach:

- identify the actors;
- identify the use cases;
- structure the use cases in packages.

2.1.1. Identification of the monitoring aid system actors

In our case, human actors are:

- Maintenance Manager;
- Tool Expert;
- Maintenance Operator.

We also take into account non-human actors[4]:

- Supervisory Control and Data Acquisition;
- Fault Tree;
- Computerized Maintenance Management System;
- Failure Modes Effects and Critical Analysis.

2.1.2. Identification of the use cases

We define a set of use cases that corresponds in different ways according to the actors that interacts with the monitoring aid system.

For the Maintenance Manager, we can define a set of four use cases:

- *create a new tool*, which allows to send to the Tool Expert all necessary data for the creation of the tool (configuration and initialization);
- *update the configuration of the tool*, allowing the Maintenance Manager to add a sensor to the detection tool;
- *update the model of the tool*, updating the settings of the tool when new maintenance information come from the CMMS;
- *raise an alert*, occurring when the monitoring aid system detects or predicts a failure.

[3] OMG web site: http://www.omg.org/, OMG web site about UML: http://www.uml.org/.

[4] To simplify using UML, we do not make the distinction between methods, tools and systems; all of them are informational actors.