MULTI-AGENTS BASED REFERENCE MODEL FOR FAULT MANAGEMENT SYSTEM IN INDUSTRIAL PROCESSES

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Keywords: Multi-Agent Systems, Fault Management, Distributed Control Systems, Automation

Abstract: Nowadays, industrial necessities claims global management procedures integrating information systems in order to manage and to use the controlled-processes information and thus, to assure a good process behaviour. These aspects aim to the development of fault detection and diagnosis systems and making-decision systems. In this work, a reference model for fault management in industrial processes is proposed. This model is based on a generic framework using multi-agent systems for distributed control systems; in this sense, the fault management problem is viewed like a feedback control process and the actions are related to the making-decision in the preventive maintenance task scheduling and the running of preventive and corrective specific maintenance tasks.

1 INTRODUCTION

Automation is an important aspect that permits to improve the industrial processes performance (Williams *et al*, 1994) and Fault Management Systems (FMS) are vital part of the automations process. In (Bravo *et al*, 2003), a multi-agent based automation model is proposed, taking into account the general objects of production processes: production planning, production factors management, processes control, fault management and abnormal situations management.

In this work, an agent-based reference model for FMS is proposed, as part of the automation model proposed in (Bravo *et al*, 2003), and it is based on the generic framework proposed in (Aguilar *et al*, 2001). The FMS objectives are achieved by the coordinated interaction of the agents. This way, the agent-based FMS provides the assistance in the detection-diagnosis-decision process, as well as in the planning and running of maintenance tasks.

2 REFERENCE MODEL FOR FAULT MANAGEMENT SYSTEMS

The FMS proposed in this work is composed by two blocks Monitoring and Fault Analysis Tasks (MFAT) and the Maintenance Management Tasks (MMT).The MFAT block is concerned to the detection, isolation, diagnosis, prediction and planning. MMT block is concerned to the set up and running of the maintenance tasks according to the maintenance plan. A reference model permitting the adequate interaction between the previous blocks is showed in figure 1. (Cerrada *et al*, 2003)

3 MULTI-AGENT SYSTEMS AND DESIGN METHODOLOGY

Multi- Agents Systems (MAS) theory can be viewed as an evolution of artificial intelligence, in order to attain autonomous computational systems. Although the agent's definition has been argued into the Distributed Artificial Intelligence (DAI) researchers community, it is accorded the autonomy is the main

Cerrada M., Cardillo J., Aguilar J. and Faneite R. (2004).
MULTI-AGENTS BASED REFERENCE MODEL FOR FAULT MANAGEMENT SYSTEM IN INDUSTRIAL PROCESSES.
In *Proceedings of the First International Conference on Informatics in Control, Automation and Robotics*, pages 342-345
DOI: 10.5220/0001139703420345

characteristic describing an agent, the autonomy being the ability to accomplish a task and to reach its objectives without human or any other assistance (Weiss, 1999;Waterbury, 2002).

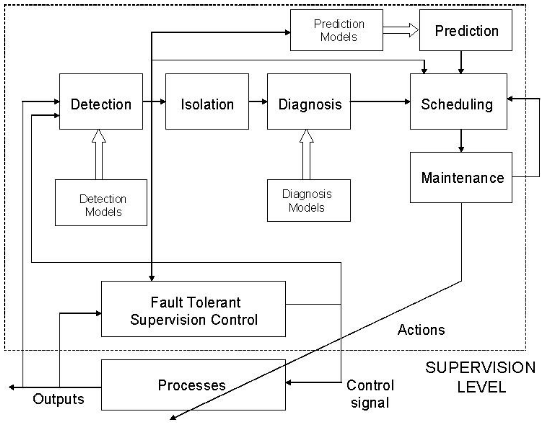

Figure 1: Reference Model for Fault Management System.

MAS-CommonKADS is a general methodology for the agents modelling (Iglesias, 1998). In (Aguilar *et al*, 2004), the MAS-CommonKADS methodology has been enhanced by incorporating new aspects for agent modelling. The enhanced methodology MASINA (Multi-Agent Systems-based INtegrated Automation) is a new approach for MAS modelling in industrial automation processes. This new modelling approach allows the developing of the Agent Model, Tasks Model, Intelligence Model, Communication Model and Coordination Model.

4 MAS-BASED REFERENCE MODEL FOR FMS

The Conception and Analysis phase is only developed here, and the MASINA methodology is used in order to propose the models mentioned above. Actors and cases of use are listed in Table 1.

Table 1: Actor and cases of use

Actor	**Case of Use**
Detector	System Monitoring State Identification
Finder	Finding-Failure
Diagnostician	Failure Analysis
Predictor	Failure Occurrence Estimation
Scheduler	Tasks Scheduling Redefining Plans
Executor	Running Tasks Reporting Tasks

4.1 Agent Model

The roles of the mentioned actors can be embedded into the agents defined in the generic conceptual framework for the Agents-based Intelligent Distributed Control Systems (AIDCS) (Aguilar *et al*, 2002). Thus, the following agents are defined, (figure 2): Specialized Agent Detector, Specialized Agent Finder, Specialized Agent Diagnostician, Specialized Agent Predictor, Agent Coordinator, Agent Controller, Agent Actuator, Agent Observer.

Characteristics and requirements of the Agent Coordinator are presented in tables 2 and 3.

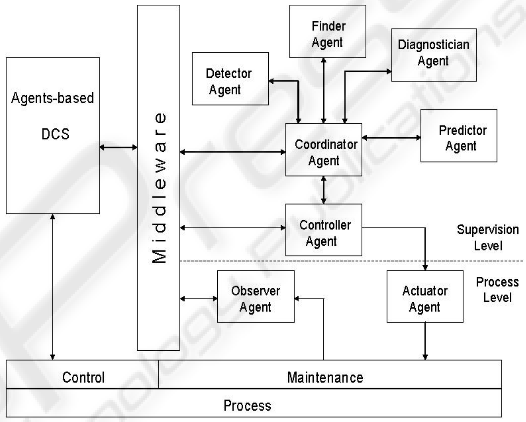

Figure 2: MAS-based FMS.

Table 2: Agent Coordinator

Agent: Coordinator
Name: Coordinator **Type:** Software agent. **Roles:** Making decision for the maintenance tasks planning. **Description:** It gathers the information, from the specialized agents, about the process' items and it schedules the maintenance tasks. The timeline should be defined according to the item's reliability, the failure effects and urgent tasks.

Table 3: Agent Coordinator Objective

Objective – Coordinator Agent
Name: To schedule the maintenance tasks according to the item's reliability, the failure effects and urgent tasks. **Type:** On-condition objective **Input Parameters:** Data from the Specialized Agents, Observer Agent, and Controller Agent. **Output Parameters:** Maintenance plan and/or corrective maintenance order (urgent tasks). **Activation Condition:** Information is received from Specialized Agents, Observer agent, and Controller agent. **End Condition:** The maintenance plan or corrective actions are stated.

Success Condition: A maintenance plan or corrective actions are proposed, permitting to achieve adequate reliability levels on the item's process.
Failure Condition: ¬Success Condition.
Representation Language: Natural Language.
Description: Coordinator Agent assesses the different setting in order to create the best general maintenance plan on a long time horizon (Long Term Plan (LTP)) and it produces the best set of corrective actions (urgent tasks) in case of emergency.

Coordinator Agent provides the following services: Maintenance Plan Proposition, Maintenance Plan Redefinition and Specialized Agent Calling

4.2 Tasks Model

Table 4 shows the defined tasks for the MAS based FMS.

Table 4: MAS-based FMS Tasks

Agent	Tasks
Observer	Abrupt o functional failures identification. Operational index estimation. Maintenance state estimation
Detector	Statistical estimation about failures occurrence. Selection of detection techniques. New detection methods incorporation.
Finder	Finding Failure
Diagnostician	Failure modes and failure causes identification. Statistical estimation about failures modes. Statistical estimation about failures causes. Failure consequences analysis. Diagnosis models readjustment. New diagnosis models incorporation New failure modes identification New failure causes identification
Predictor	Reliability curves estimation of the process' items. Reliability index estimation of the process. New prediction models incorporation
Controller	ST maintenance plan proposition ST maintenance plan processing
Coordinator	LT maintenance plan proposition Resources Evaluation. Application order of DIDP tasks Application order of corrective action Maintenance plans redefinition
Actuator	On-time maintenance tasks run Urgent tasks run

4.3 Intelligence Model

Excepting the Actuator Agent, all agents in the FMS may be sensitive to be intelligent. A general structure of the intelligence model is presented bellow:

Experience
Representation: Rules.
Type: Based on cases.
Reliability: It is related to the data completeness.
Processing scheme: Knowledge parameters tuning and new models incorporation.
Learning Mechanism
Type: Adaptive
Representation: Rules, neural techniques, genetic techniques.
Learning Sources: Success or failures during DIDP tasks.
Update Mechanism: Experiences feedback.
Reasoning Mechanism
Information Source: Previous results from de FMS's agents.
Activation Source: Scheduling tasks, DIDP tasks.
Type of Inference: Based on rules.
Task-Objective Relationship: It decides if the used algorithm is adequate for DIDP tasks or if an adequate maintenance plan is proposed.
Reasoning Strategy: It can be deductive or inductive: evaluate the causes of success or failure in DIDP tasks or confront unknown situations.

4.4 Coordination Model

This model describes the communications scheme of the MAS: conversations, protocols and associated languages. The following conversations have been defined: On-Condition Maintenance, Maintenance Plan, Urgent Maintenance Tasks, Maintenance Plan Redefinition, Maintenance State, Functional Failure Identification. The conversation *Maintenance Plan Redefinition* (MPR) is presented in table 5.

Table 5: Conversation "MPR"

Objective: To redefine the execution timeline of the maintenance tasks that have not been put up and running on the process.

Agents: Coordinator, Data-base (MAS-based Middleware), Human.
Beginner: Coordinator Agent
Speaking interactions: Expecting Maintenance Tasks Search, Alarm, Maintenance Plan Shipment
Precondition: A particular maintenance task has not been put up and running on the process.

End Condition: A new timeline has been proposed and a new plan is sent to Data-Base, else, an Alarm is sent to the Human Agent (User).
Description: This conversation permits the information search on the Data-Base about the maintenance tasks that have not put up and running (Expecting Tasks)

4.5 Communication Model

A set of 21 speaking interaction has been defined and they are suitably arranged into the conversations in the Coordination Model. In the case of the previous conversation *Maintenance Plan Redefinition,* the following speaking interactions are performed: Expecting Maintenance Tasks Search (Table 6), Alarm and Maintenance Plan Sending

Table 6: Speaking Interaction

Speaking Interaction: Expecting Maintenance Tasks Search. **Type:** Query. **Objective:** To search in the Data-Base the expecting maintenance tasks that have not executed on the process. **Agents:** Coordinator, Data-Base (MAS-based Middleware) **Beginner:** Coordinator Agent. **Precondition**: An active flag about expecting tasks. **End Condition**: The Coordinator Agent receives, from the Data-Base Agent, the whole information about the expecting tasks. **Conversations:** Maintenance Plan Redefinition, Urgent Maintenance Tasks. **Description**: The Coordinator Agent requests the whole information about the expecting tasks reported by the Observer Agent.

4.6 Conclusions

In this work, the conception and analysis of a Multi-Agents System-based reference model for Fault Management System has been proposed. This model has been developed into a generic framework proposed for Intelligent Distributed Control Systems. In this sense, the system performs a set of tasks (actions) permitting the maintenance tasks planning and the application of specific maintenance tasks as fault detection, isolation, diagnosis and prediction. The enhanced methodology MASINA has provided a set of models permitting to describe the main characteristics of the MAS. The resulting models have a generic structure that permits to incorporate it into the automation process of a distributed control systems.

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