Towards Control and Supervision Systems based on Intelligent Agents

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Abstract: - This article presents a design approach for control and supervision systems of industrial processes based on intelligent agents. First, the general platform supporting the whole multi-agent system for control and supervision is defined. From there, applications are conceived like specialized multi-agent systems to coordinate, execute and evaluate control and supervision tasks needed for the distributed information processing and decision-making. The production units in industrial environments are also modeled as multi-agent systems implementing the logical and functional abstraction of the real processes. In this way, cooperation and negotiation for improving the production performance are achieved through the adequate interaction between the agents community.

Key-Words: - Automation, Supervision and Control, Multi-agents Systems (MAS), Distributed Intelligent Control.

1 Introduction

Nowadays, industrial processes require sophisticated systems allowing a reliable and highly profitable production. Thus, process automation systems are applications that have been characterized by requirements emphasizing safety, reliability, efficiency and quality [4]. Therefore, the automation systems are complex, large, distributed and persistent hardware & software systems, this systems being defined from the characteristics of the technical processes to be controlled. [13].

The functionalities of the automation systems can be distributed on different levels, each one of them with suitable operational characteristics: **field device level** (operational level) capturing the processes information, **supervisory control and optimization level** (tactical level), where the control tasks are executed, and **processes management level** (strategic level), where the production strategies are evaluated and developed.

Typically, the processes controllers are reactive independent systems. However, control and supervision systems must work with multiple objectives in several environments, therefore, these systems must be adaptable, flexible, independent, concurrent and collaborative.

On the other hand, new paradigms in the design of computational tools have been arisen. Particularly, the agent-oriented paradigm permits to design complex and sophisticated software systems. A software agent is a *proactive object*. Decisions about how and when to perform an action are taken by the agent itself. Additionally, the agent is able to autonomously execute an action without external invocation. This fact diverges from a passive software entity, such as software components, which waits for a remote interaction [6]. The most important properties of this paradigm are: autonomy, communication, sociability, reactability, intelligence, and mobility.

Because of the complex nature of automation systems, control and supervision systems are natural applications to be designed by using intelligent agents [12, 10, 17, 16].

2 Reference Architecture

Process automation has not typically been an early adopter of new information technologies like software agents. However, some research concerning to the application of agent technology for implementing automation systems has been emerged. [6, 7, 16, 17]. This application has been characterized by the match between the operational principles of process automation and agents, where complex and distributed engineering systems can be obtained.

In order to design a multi-agent systems for processes control and supervision, a reference architecture proposed in [8] has been used. That hierarchical architecture allows the functional distribution of automation activities on different operational, tactical and strategical tasks. In our case the intelligence agents for control and supervision tasks resides at the higher level and is here where this agents community will be placed [1, 15].

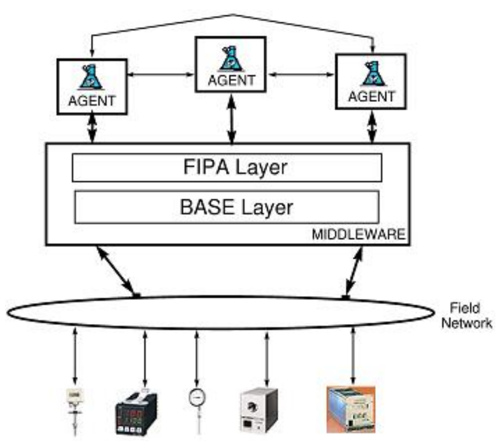

Figure 1: Functional Architecture

This reference architecture provides an approach with three functional levels: Field level, Middleware level and Applications level (see figure 1).

1. **Field level**: The Field level is concerned to the components of real processes such as pumps, oil wells, machines, etc., and the devices, such as field networks, data acquisition systems, Remote Transmission Units etc., allowing the interaction with the high levels.

2. **Middleware**

   The middleware is the basic group of software modules that implant the lowest abstractions for specifying, installing and managing the agents and objects.

   Because of the heterogeneous and the complexity of the automation system, the middleware proposal has a multilayer focus in order to assure the system's operability. The middleware is composed by two layers: FIPA [1]-based Interface layer, and Base layer. The Interface layer establishes the guidelines of conversation between the components of the distributed system and the multi-agent systems [5]. The base layer is the kernel of distributed system, it provides software services required by an agent in order to be able to interact with other agents and with the host server supported by a real time operating system [2, 5].

3. **Applications level**

   The higher layer is composed by the application agents. There, the agents communities are defined according to their functionalities. In this work, three agents communities have been defined: *Proccess Agent* or Business Agent, *Control Agent* and *Supervision Agent*, however, other communities such as optimization, planning and specialized management, can be defined. These communities interact with the *Middleware* through the interface layer. [5].

In the following section, the Process, Control and Supervision agents are presented.

3 Control and Supervision: Agents Approach

3.1 Process Agent (PA)

In order to get the distributed information and knowledge related to the production process, an agent modeling the production unit is defined, this way, each production unit is represented by

[1] `http://www.fipa.org`

a PA. This agent takes into account the physical and functional division of the modeled production unit. Thus, a PA could represent devices with limited service ability, such as sensors, actuators or another element of the field instrumentation, or more complex processes, such as an oil exploitation unit, a boiler, etc.

As advantage of this representation obtained from a model of the process, a PA can be used to make comparisons between the real behavior and the emulated behavior. Thus, the agent can be capable to advise about abnormal situations in order to improve the process performance and decreasing adverse effects.

On the other hand, the PA must execute and request specific tasks depending on its roles and functions. Sending and receiving activities are linked with asynchronous communications (depending on events). Information processing (knowledge) can be a synchronous or asynchronous activity.

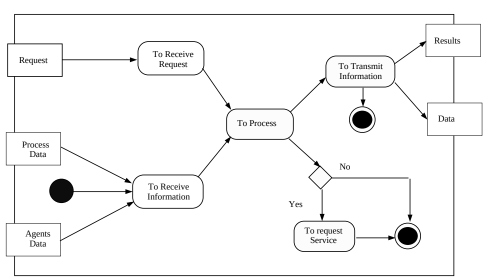

Figure 2: Activities Diagram for PA

Figure 2 shows the activities diagram for this agent. From this figure, the following main activities are defined: to receive information, to transmit information, and to request service.

3.2 Control and Supervision Agents

The main functionalities of a control and supervision system are: set point and operation parameters supervision, control commands generation based on the supervised values, sending control commands, control algorithms configuration, and management of abnormal situations (detection and diagnosing tasks, maintenance management).

3.3 Control Agent (CA)

One of the fundamental tasks of any industrial automation system is the process control. It must satisfy *security* (processes stability) requirements and *productivity* (processes performance) requirements. The field information required for the control processes is managed by PAs.

The CA is designed as a multi-agents system with three agents: Control Designer agent, Control Executor agent and Control Evaluator agent. These agents interact with the middleware and other multi-agents system to accomplish their functions.

3.3.1 Control Designer Agent (CDA)

The CDA designs and/or adjusts control plans to be executed in finite time. These plans must guarantee the adequate performance of the production process in terms of the control requirements (control strategies and controller parameters) and the processing requirements. Also, the CDA can to adjust the current controller parameters to improve the production performance. Figure 3 shows the activities diagram for the CDA.

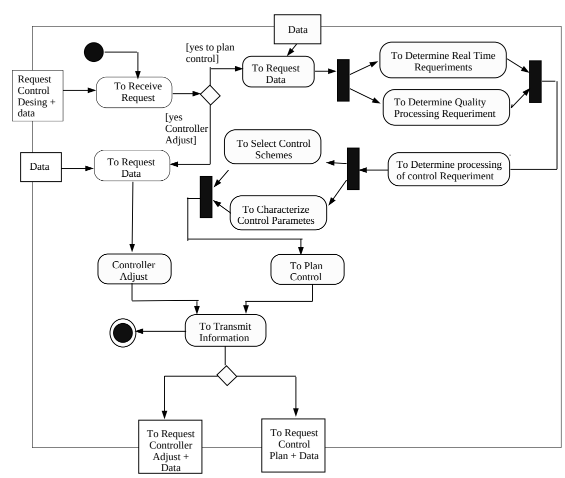

Figure 3: Activities Diagram for CDA

3.3.2 Control Executor Agent (ECA)

The ECA generates the control orders based on the current outlined control plan and control schemes. ECA receives a control request, it access the needed data and generates the control orders. The activities diagram for this agent is shown in figure 4.

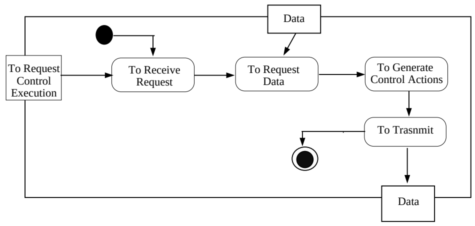

Figure 4: Activities Diagram for ECA

3.3.3 Control Evaluator Agent (CEA)

The CEA determines the performance of the current control plans and controller. For this task, it must compare the real output with the design objectives. Figure 5 shows the activities diagram for this agent. The main agent's tasks are: Measuring of control plan performance and Measuring of Controller Performance.

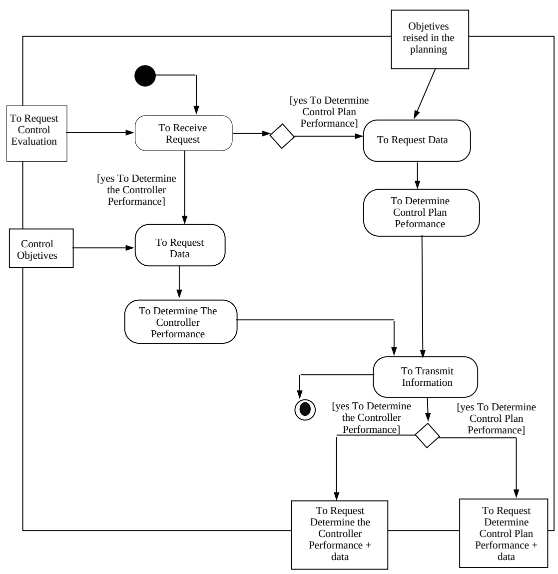

Figure 5: Activities Diagram for CEA

3.4 Supervision Agent (SA)

Supervision and maintenance activities are fundamental part in automation processes; their suitable integration with the control systems allows to obtain adequate performance and the reach of production objectives. In this sense, the architectures proposals allowing the integration of these activities on distributed platforms have been a important aspect outlined by the researchers [14, 11, 18, 9]. These architectures must guarantee the integration of the distributed knowledge, information and data, in order to provide mechanisms to support the decision-making.

SA is a MAS composed by three agents: Control Supervisor Agent, Reliability Supervisor Agent and Tasks Supervisor Agent.

3.4.1 Control Supervisor Agent (CSA)

CSA supervises the performance of production process. It uses the data related to control, production management and reliability , taking operational values that allow to evaluate this performance. The CSA could request the adjustment of the current control plans and parameters to compensate wrong outputs. Figure 6 shows the activities diagram for CSA. These activities are offers as services to the other agents.

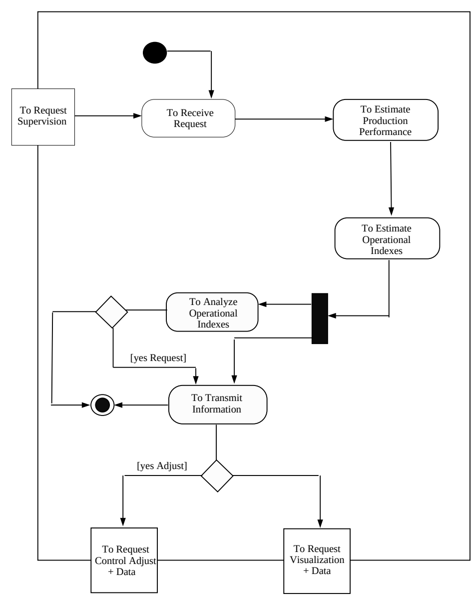

Figure 6: Activities Diagram for CSA

3.4.2 Reliability Supervisor Agent (RSA)

RSA supervises the reliability of production process. It needs real time data, maintenance plans and schemes for fault management. The RSA could request the application of maintenance tasks and/or changes on maintenance plans. In activities diagram of figure 7 the main services for RSA are defined.

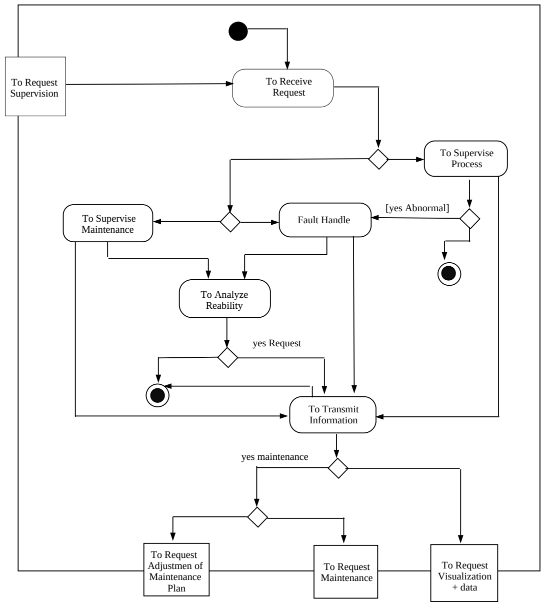

Figure 7: Activities Diagram for RSA

3.4.3 Tasks Supervisor Agent (TSA)

TSA gives two services: Evaluation of decision-making and Evaluation of tasks performance. For the first one, it reviews the historical data related to the operational and reliability indexes, and it applies methods to evaluate the decision-making with respect to the changes requests of control plans and maintenance plans. For the second one, it evaluates the tasks performance of supervision applications based on the properties of the associated service (reliability, quality, among others). Figure 8 shows activities diagram for this agent.

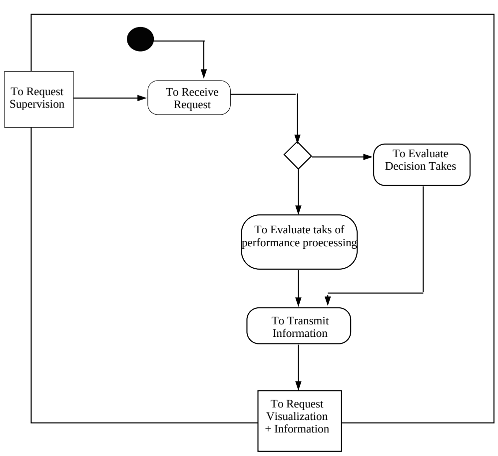

Figure 8: Activities Diagram for TSA

4 Conclusions

This contribution provides a model that support the implantation of control and supervision systems based on MAS. The proposed model involves the creative participation of the different actors identified from the productive process, mainly process, control and supervision, in order to obtain a high performance of the production process. These actors are designed as intelligent agents which coordinate, execute and evaluate control and supervision tasks.

Our approach requires a middleware that has been designed based on FIPA standard. All process information is encapsulated in a generic agents called process agents. All aspects related to the design, the execution and evaluation of the control tasks are considered services offered by a Control Agent. The aspects related to the supervision and evaluation of the controlled process have been defined as services of a Supervision Agent. Both, Control and Supervision agents are proposed as multi-agent systems.

The defined interaction diagrams allow to visualize the scheme of coordinated decision-making and it shows the cooperative aspects inherent to the operation of the control and supervision agents.

Finally, we used the MASINA methodology with UML diagrams to outline a formal software model for MAS specification [3]. This specification model can be used as initial point to make an implementation project by using development tools of objects paradigm (Class definition, components, methods, etc.).

Acknowledgments

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