Agent Technology for Acquiring, Monitoring and Process Control Systems in Distributed Architectures

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Abstract

The industrial plants such as the power plant, in particular the nuclear ones, have presented important changes in the conditions during the last 20 years. This situation led to the evaluation of the emergent technology of agents for developing distributed acquiring, monitoring and process control systems, according to the necessities of the medium and large size plants that present critical processes.

To the feasibility analysis, a prototype was developed with the goal of evaluating advantage and disadvantage of agent technology. From another point of view this permits to identify the complementary technology and the involved problems in the development of this systems. This system was divided into subsystems and components with the aim of getting modular and reusable software.

Different modulus were integrated in a generic architecture composed of four sub systems: Field, Supervision, Information and External System.

Keywords: Distributed Systems, Multi Agents Systems.

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1. Introduction

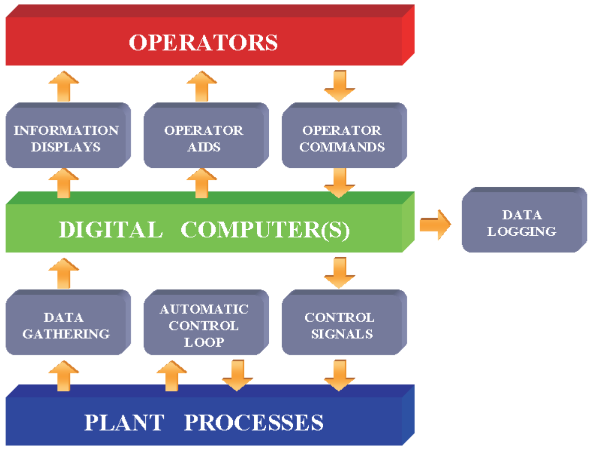
Over the past twenty years, the technological progress and the new economy paradigms have modified existing requirements for manufacturing systems. Software and hardware advancement, competitive markets and the increasing size of industrial plants, raise demand for higher levels of system automation and the use of hierarchical and distributed control that integrate fault tolerance, adaptation, learning and so on. Nowadays, these types of requirements are becoming widespread.

The implementation of a real time, distributed, intelligent, monitoring and control system presents several challenging practical issues. An example is the development of communications between multiple and separately operated subsystems running autonomously in different and incompatible platforms.

Nuclear power plants are constituted by complex systems affected by the strictest control and monitoring system requirements. For this reason, I started to study the applicability of agent technology for developing monitoring and control systems. In particular I centered my study in intelligent control architectures to be employed in critical environments where systems must be highly autonomous and able to take appropriate control actions, even in an uncertain environment.

In brief, a typical monitoring and control system presents seven types of activities or modulus, figure 1:

- Automatic control loop
- Data gathering
- Control signals
- Information displays
- Operator aids
- Operator commands
- Data logging



"Survey of OECD Members on the Use of Computers in Control Rooms of Nuclear Power Plants"
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Figure 1. Monitoring and control modulus.

Each module must present characteristics of modularity, adaptability, scalability, fault tolerance and autonomy, according to the current exigencies. Agent software is a new paradigm for developing software applications, in particular with the prior characteristics. Therefore the project was based on this mentioned technology.

This article presents the principal points developed during the project. I begin by introducing the general characteristics of my research; I then discuss the principal outline of my designed system and subsystems. Finally, I introduce a generic architecture where I have integrated the typical systems.

2. General Setting

This research was divided into 3 parts:

- Problem identification and definition
- Agent technology evaluation
- Systems design and evaluation.

During the first part of the project, I defined the possible requirements to be established in a modern distributed architecture of monitoring and control process. In order to achieve this, the following points were considered:

- Evolution in control process technologies and architectures.
- Evolution in information systems.
- Evolution in human-machine interfaces.

In the second part, I analyzed the state of the art in agent technologies, in areas of monitoring and control systems and in complementary technologies such as Java; Jack Intelligent Agent and Reactive

Agents; UML, A-UML and MAS-Common KAD (agent design methodologies); CORBA, java-RMI, Voyager (distributed objects); Object Orientated Data Base, XML and OPC.

Finally, during the last part of the project I started to design the systems and sub-systems involved, to finish with the integration of these in a generic distributed architecture.

3. General Systems Definition

The first part of the work consisted in defining the main characteristics of a modern control and monitoring system architecture. The following characteristics were considered:

- Distributed systems: It is natural to adopt a distributed architecture consisting of software agents specialized in different activities.
- Modularity: In the agent-based approach, software agents should be kept simple for easier maintenance, initialization and customization.
- Flexibility: Software agents can interact in new configurations even on demand.
- Robustness: distributed systems can operate adequately even when some of the agents are temporally out of service.
- Legacy systems: A preferable way of updating legacy systems is to construct agent wrappers around existing systems.

These considerations motive the development of distributed software agent systems. Consequently, the critical question was how to structure and organize these multiple software agents. In this way, the architecture was divided into six subsystems to allow an easier reuse of these software components. These subsystems are the following:

- **Communication distributed system**
- **Information management system, (IMS)**
- **Acquirement system**
- **Control system**
- **Control software system**
- **Intelligent Human Machine Interface system**

3.1 Communication distributed system

Developing a well-structured distributed system requires a framework that assists interactions between independent software components, and a methodology that helps to structure these interactions. Thereby, I developed a decentralized framework, that offers the necessary level of component integration to permit them work all together.

This framework is based on 2 kinds of interactions: *agent-software component* and *agent-agent*, figure 2.

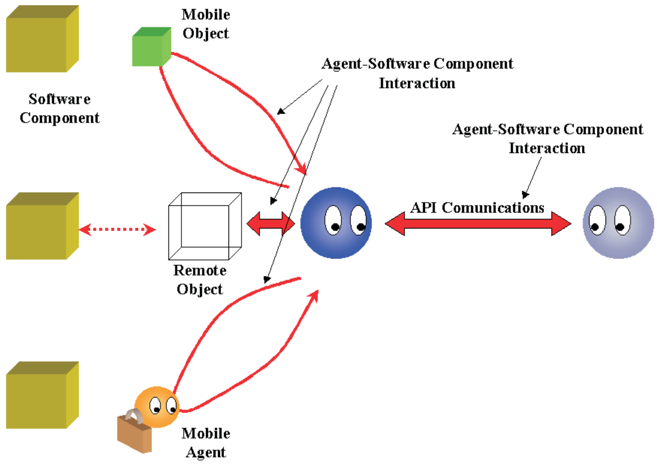

Figure 2. Agent-Agent and Agent-Component interactions.

3.1.1. Agent-Component Software Interaction

This type of interaction uses distributed-object computing. Among the prominent alternatives are CORBA, Java-RMI, DCOM and Voyager, but to reduce the overhead introduced by the three prior options the development was centered in Voyager. The interaction model consists of the following:

- **Remote Object interaction:** Voyager permits the creation of a remote-enabled class from a regular Java class. Its instance can be created outside the local address space and this remote object can be accessed through a virtual reference.

- **Mobile Object interaction:** A serializable object can be moved to a remote host to interact with the local object, reducing the network traffic and increasing the throughput.

- **Mobile Agent interaction:** An agent is a special object that has autonomy. It can independently move to a remote object or program.

3.1.2. Agent-Agent Interaction

In this case, the interaction is based mainly on the API of the Agent Development Environment.

3.2. Information Management System

Process control applications present sensor and control devices that generate a continuous stream of data. These components send the data to a database from where the process control system reads it. This data can be classified in Real Time Data and Historic Data.

The IMS developed is based on the interaction of a Real Time Object Repository (RTOR) for the real time data with an Object Data Base Manager System (ODBMS) for the historic data, figure 3.

The filling of the ODBMS is achieved through a mobile agent who collects information in each RTDB to deposit it in the ODBMS.

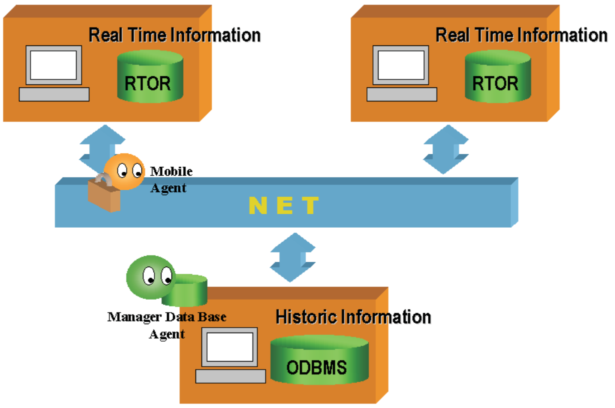

Figure 3. Information Management System.

Due to the highest complex relationships among the data of a large scale manufacturing plant, it is necessary to define an Information Plant Model (IPM) that permits an easier management of this data. This model consists of a physical-functional and a temporal model.

- Physical-functional model: It maintains a complete hierarchical model of all components in the plant such as control and sensor devices. Each block defined can represent a physical or functional component, which is labeled as a Block Identification Code BIC, figure 4.

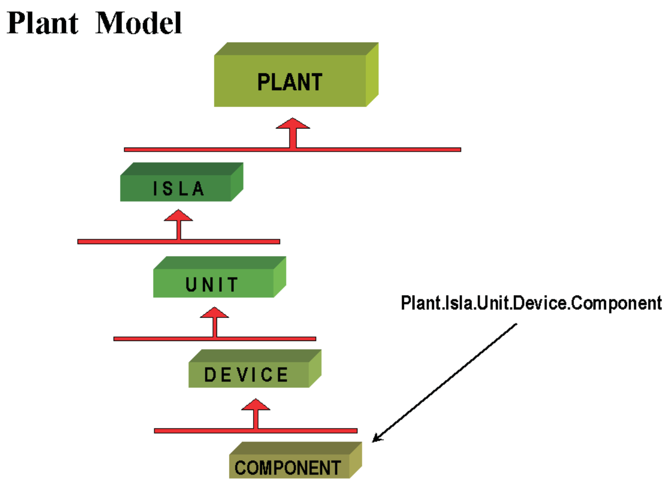

Figure 4. Information Plant Model. Physical-functional model.

- Temporal model: It permits to maintain time detailed data series of the plant's state. This consists of primary time decomposition for reference and has secondary time decomposition that is the timestamp of the data, figure 5.

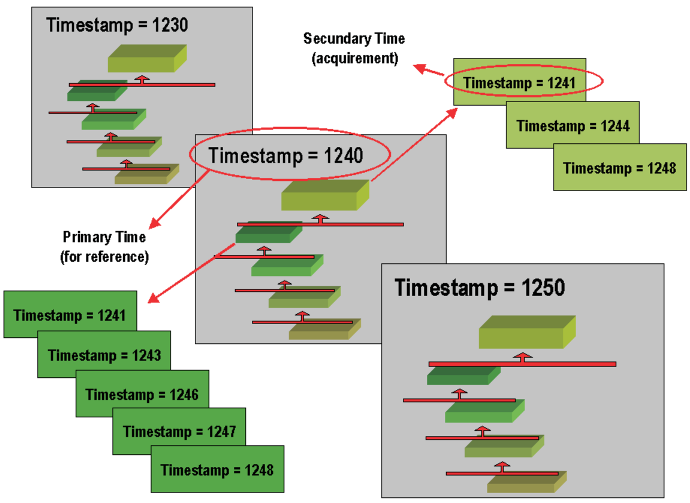

Figure 5. Information Plant Model. Temporal model.

The IPM permits the management of distributed data. This is done through a division of the plant representation. Each acquisition node (see later), presents a local model, which is linked to the distributed model, figure 6.

Consequently, the definition of all elements in the architecture is referenced to the IPM.

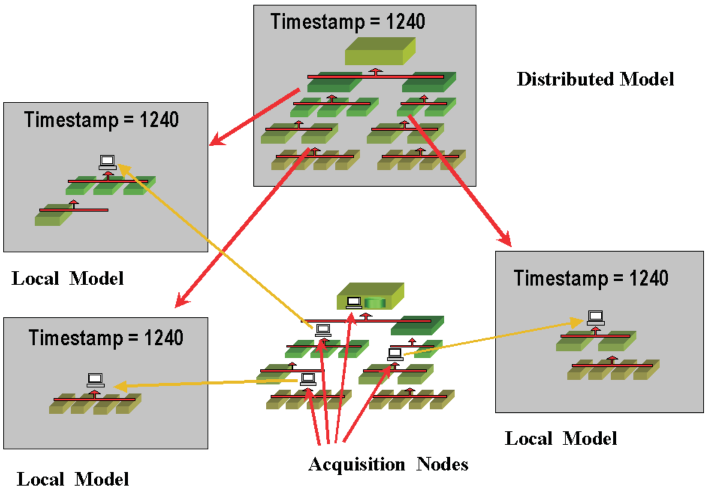

Figure 6. Information Plant Model. Distributed Information Model.

Finally, the information is collected through mobile agents from each remote terminal, figure 7.

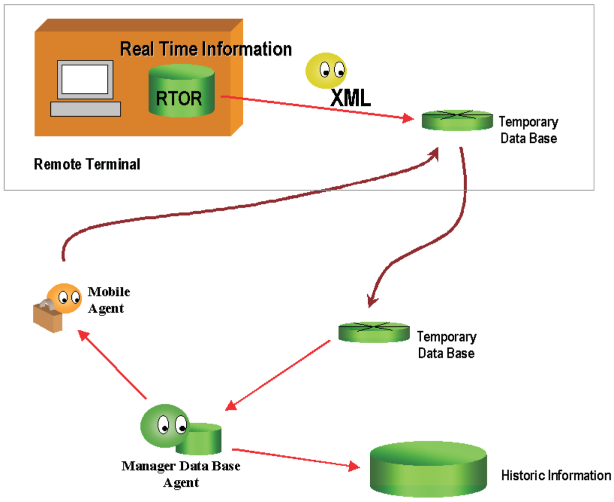

Figure 7. Information Plant Model. Distributed Information Model.

3.3. Acquirement system

Due to the large scale of manufacturing plants, it is necessary to use a distributed acquirement system. This approach permits to subdivide the problem reducing its complexity. The developed system in this work consists of nodes of acquisitions constituted by sensor agents and a RTOR, figure 8.

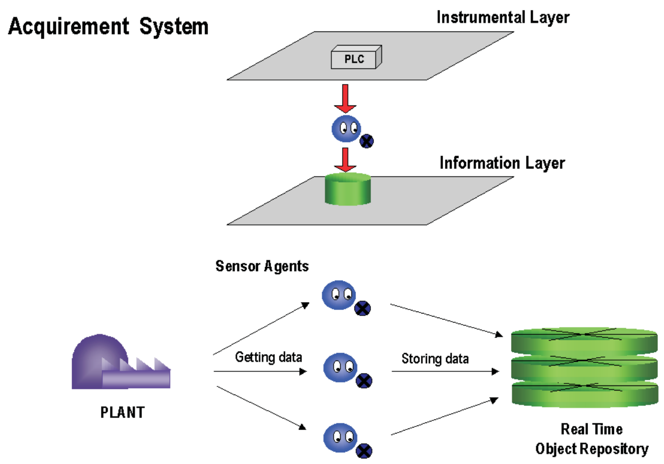

Figure 8. Acquirement system.

Each sensor agent presents the goal of getting the instruments state and place the data in the RTOR.

3.4. Distributed Control system

Distributed control permit to develop small-specialized reusable and less complex control systems. It gives to the system a more fault tolerant behavior.

The control system developed consists of nodes of control, which are formed by the acquirement system, and specialized agents, figure 9. Theses specialized agents are:

Actuator agent: It transfers the control signal to the control device.
Process control agent: It generates control consigns to the Actuator agent.
Supervisor Process agent: It defines the plant operation mode.

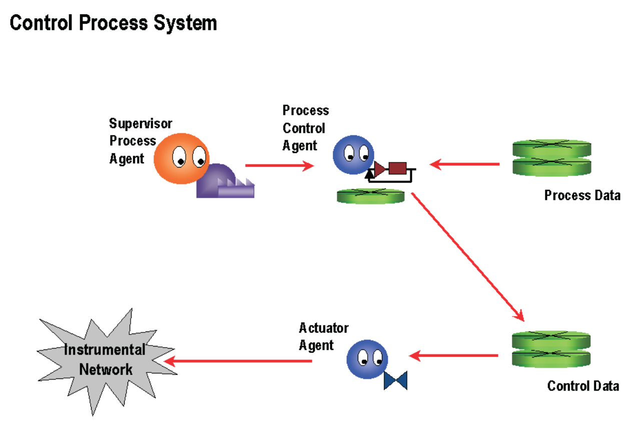

Figure 9. Distributed Control system.

3.5 Control software system

Process control systems require the highest level of reliability because of the potentially dangerous of the processes they control. Thereby a ***software supervisor agent*** was introduced to control the correct behavior of all agents.

3.6 Intelligent Human Machine Interface system

The human machine interface system IHMIS consist of nodes where the user can control the process states, figure 10. A great deal of information interchange exists between the plant control nodes and the IHMIS nodes, due to the decentralization characteristics of the process control system. Therefore, a visualization plant model was developed which involved three elements:

- Model Identification Code MIC: It permits to identify the model.

- Graphical Model Definition: A DTD contains the graphical representation of the respective model.

- Data Model Definition: It defines a DTD of the data structure of the data representation.

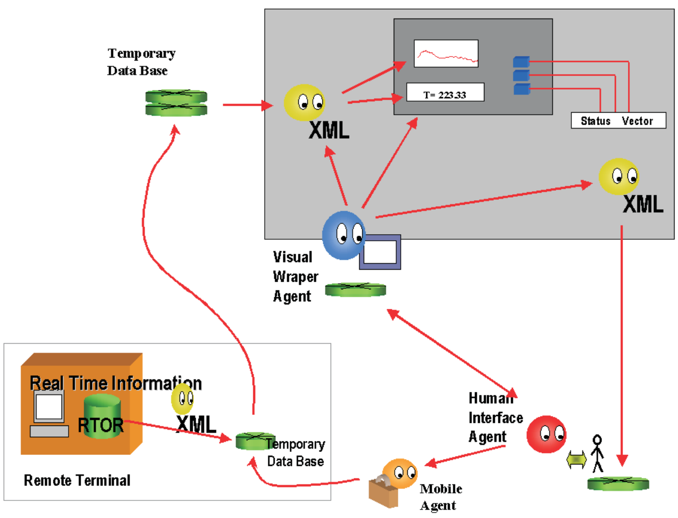

Figure 10. Intelligent Human Machine Interface.

Mobile a gents collect t he information for I HMIS, getting the data for the respective model, traveling among Field Terminal.

4. Generic Architecture of a Monitoring and Control System

The systems described were integrated in a generic architecture to verify the concept. This architecture is constituted by the following systems, figure 12.

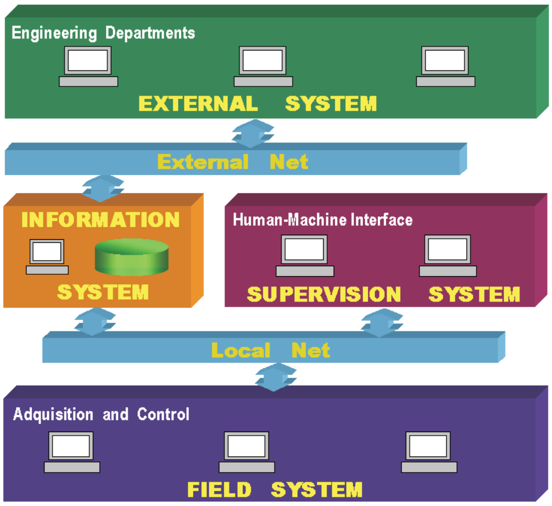

Figure 12. Generic Architecture.

- Field System. Acquisition and control nodes compose this. Each node is assigned to a part of the plant.
- Supervision System. It is the human-machine interface and is constituted by nodes for the operator interaction.
- Information System. It is the information management system. This centralizes the plant information for the supervision system and the external systems.
- External System. It provides information services to external users such as engineering departments.

Presently, I am evaluating each system conceptually and the generic architecture.

5. Conclusions

The central goal of this work was to analyze the applicability of agent's technology in the development of distributed monitoring and control process systems. The main conclusion was that this technology expedites the design and construction of this kind of systems.

Regrettably, it is necessary to wait for the networks and computers enhancement in order to get the true profits of agent technology. Nevertheless, the qualitative test of the prototype gives interesting results about the flexibility and adaptability of the architecture designed. It was possible to adapt it to the requirements of the Atucha I Power Plant and the Australia's Research Reactor; both of them present different necessities.

In addition, the typical time intervals involved in the acquiring information activities are around 5 to 100 milliseconds, which match with the existing necessities of the power plants monitoring systems. Moreover, the typical traveling times of the mobile agent are in order of 200 to 500 milliseconds. These are very acceptable times for the actualization period time of the visual human-machine interfaces.

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