A Multiagent Model for Intelligent Distributed Control Systems

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Abstract. One approach for automating industrial processes is a Distributed Control System (DCS) based on a hierarchical architecture. In this hierarchy, each level is characterized by a group of different tasks to be carried out within the control system and by using and generating different information. In this article, a reference model for the development of Intelligent Distributed Control Systems based on Agents (IDCSA) inspired by this hierarchical architecture is presented. The agents of this model are classified in two categories: control agents and service management environment agents. To define these agents we have used an extension of the MAS-Common KADS methodology for Multi-Agent Systems (MAS).

1 Introduction

Presently, there is great interest in the development of integrated automation systems that permit monitoring different plant operation variables in a broad and dynamic way and to transform such variables in control commands that are later integrated into the plant through actuators. Moreover, they should take into account production and economic criteria that can be applied as control commands or as part of a plant programming function. The integrated structure should permit the flow of information at all levels (management, operation, etc.) concerning the plant, the products obtained, and all the relevant information. On the other and, a MAS can be defined as a network of "problem- solvers" that work together to solve problems that could not be worked out individually [1]. The main preoccupation of the MAS is the coordination between the groups of autonomous agents, perhaps intelligent, to coordinate their objectives, skills, knowledge, tasks, etc.

In this work, a reference model for Intelligent Distributed Control System (IDCS) based on Agents is proposed. Our model will be made up of entities called agents, that work together dynamically to satisfy the control systems local and global objectives and whose design can be made completely independent of the system could be developed. The description of the agents in this reference model is based on the MASINA methodology [5] which has an extension of MAS-Common KAD methodology to incorporate other characteristics of agents such as emerging behavior, the reasoning, and the possibility of using intelligent techniques (expert systems, artificial neuronal networks, genetic algorithms, fuzzy logic, etc.) for carrying out their jobs.

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2 Reference Model for Intelligent Distributed Control System Based on Agents (IDCSA)

The control jobs and information management needed in automation processes can be distributed and expressed through a hierarchical logical structure. Figure 1 shows hierarchical reference architecture to develop a Distributed Control System (SCD), that permits the automation of an industrial plant [3].

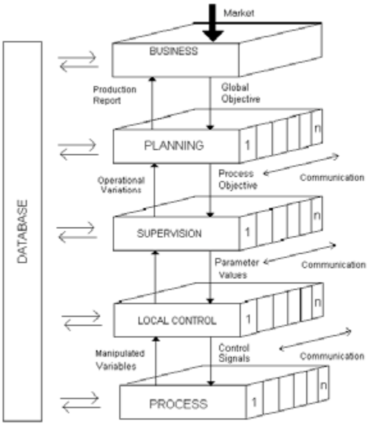

Fig. 1. Reference Model for Distributed Control Systems

At the business and planning levels decisions are made at the managerial level, and the control process jobs are carried out at the lowest levels. The Supervisory level adjusts the parameters of the controllers, the control signal is obtained at the Local Control level, to later be incorporated at the plant at the Process level. This SCD model is complemented with a group of agents in each one of the levels of the hierarchy, this is the IDCSA model shown in Figure 2. These agents carry out diverse jobs looking towards reaching the specific control objective.

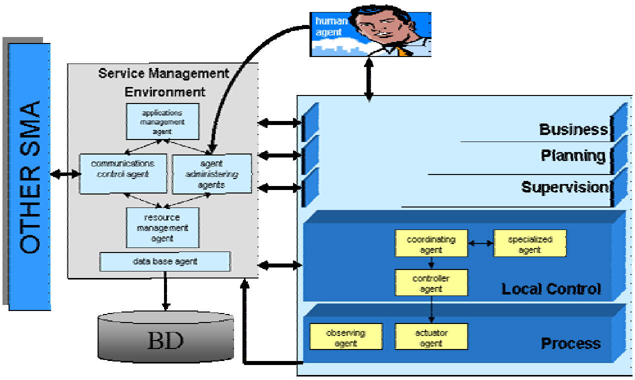

Fig. 2. IDCSA Reference Model

The incorporation of the MAS to the reference model permits the control to emerge from the interactions of those entities (agents). The IDCSA is seen as a network of autonomous agents, with different responsibilities according to the level to which it belongs. As such, the details of each agent (objectives, communication, jobs, intelligence, etc.) come according to the levels to which the given agents belong in the IDCSA model. This way, the agents are distributed through the control hierarchy and can be geographically dispersed. The dynamic interaction of the multiple agents happens between levels and in the interior of the levels. In the IDCSA model two categories of agents exist:

Control Agents: Carry out the jobs of control, measurement, control decision making, and putting the decisions into practice, among others. The agents are:

- Coordinating Agent: make decisions and plan control jobs
- Specialized Agent: carry out specific jobs that serve to support the coordinating agent
- Controller Agent: obtains control action
- Actuator Agent: executes the control action
- Observation Agent: measures and processes the variables of the plant
- Human Agent: supervises the SCIDA

Agents of the Service Management Environment (SME): It is the base of the distribution system given that it manages the communication of the IDCSA model and permit the distribution of the control system and heterogeneity among geographically dispersed agents. The agents of the SME are [4]:

- Agent Administering Agents: coordinates the multi-agent society
- Resource Management Agent: administers the use of the resources.
- Applications Management Agent: administer the use of applications (software) of the system
- Data Base Agent: manages the information storage means.
- Communication Control Agent: establishes communication with other MAS.

3 Specifications of the IDCSA Reference Model

The models proposed in the MASINA methodology have been used according to the needs of IDCSA [5].

3.1 Organization Model

The main objective of the organization model is to specify the environment in which IDCSA will be developed. In this stage of modeling, a human organization is analyzed to determine the areas susceptible to the introduction of the IDCSA model. The model is conceived in three stages:

- Modeling of the organization environment: Describes the environment where we are going to introduce the IDCSA model.
- Evaluating the organization environment: The viability of introducing the IDCSA model to the organization is evaluated.

- Model of the Multi-Agent Society: In this stage, the following activities are developed:
  - Identify the IDCSA levels in the organization: some applications can consider the levels proposed in the IDCSA; others only require a group of them [2].
  - Agent's proposal at each IDCSA level: after identifying the levels needed, the group of IDCSA agents adapted to the functions that are carried out at each level is defined.
  - Identify the environment objects: in each one of the levels, the surrounding objects with which agents will interact to achieve their objective should be identified.

3.2 Agent Model

The agent model serves to specify the generic characteristics of the IDCSA agents. The agent model proposed is oriented towards services. Agents are capable of carrying out jobs which are offering to other agents (called services). An agent will be selected, the Observation Agent, to discuss the templates of the Agent Model (to see the remaining templates, refer to [6]).

1. General Information: i) Name: Observation Agent, ii) Type: Software Agent and Physical Agent, iii) Paper: Environmental, iv) Position: Lowest level agent of the Multi-agent System, v) Description: The Observation Agent makes up the data acquiring system: the sensor, the conditioning system and the transmitter. Through them changes in the process can be detected.
2. Agent Objectives: i) Name: Process Variable Measurement, ii) Type: Persistent, direct objective, iii) Entry Parameters: Variables that need to be measured, repository where data is stored, iv) Exit Parameters: Measured variable, v) Activation Condition: Order of measurement (non-periodic case) or period of time available for measurement, vi) End Condition: Measured variable, vii) Representation Language: Natural language, vii) Ontology: Control ontology, viii) Description: is associated with the capture of process variable values through carrying out direct or indirect measurements on given variables. The obtained signals should be filtered to eliminate measurement errors, and transported and stored in systems.
3. Agent Services: Process measurement variables, Conversion of variables, and Detection of Quick Changes

4 Agent Capabilities: contact with the process, make available to the rest of the MAS changes occurring in the environment

3.3 Job Model

The elements of this model are ingredients, capacity, environment and method. A job has associated entry ingredients that permit the job to be executed and at the same time, can produce exit ingredients as a product of the execution job. Jobs can be made using a specific technique (classic, intelligent) or hybrid techniques. Below a list of IDCSA jobs is presented. In [6] the use of each one of the agent's cases is presented, in which the jobs that are carried out is inferred.

1 Measurement Jobs: i) Measure: Sense and condition, ii) Process the variable
2 Control Jobs: i) Decision-making, ii) Obtain control action, iii) Process control action, iv) Execute control action
3 Specialized Jobs: i) Process specialized agent
4 Information Management Job: i) Information storage, ii) Information up-date, iii) Look for information, iv) Management of the BD
5 Location Jobs: i) Locate resources, agents or applications, ii) Assign agent/resource/application

The Observation agent will continue to be utilized to describe the templates that specify the jobs (to see the remaining refer to [6]).

Sensing: i) Objective: Process variables are registered in a device sensor, ii) Precondition: The sensor is an element of the lowest level; the only thing that is required is to have an associated process variable, iii) Control Structure: Sensing does not have sub-jobs but rather belongs to a group of jobs that correspond to measuring agents, iv) Execution Time: Continue, v) Frequency: Absolute frequency (constant), vi) Content: The variable is a signal coming from the process, which can be measured and is associated with the state of the process, vii) Surrounding: Process level, viii) Regulations: the sensor can be calibrated, ix) Method: Classic techniques for capturing data are used.

3.4 Intelligence Model

This model is implemented in those intelligent agents which have reasoning capabilities to decide about the jobs they are going to carry out to solve a situation. For that, the agent can use previous experience or accumulated knowledge through the learning process. According to agent jobs and services defined by IDCSA, their intelligent agents are: Coordinating Agents, Specialized Agents and Controller Agents. The intelligent model for these agents is generically defined around three elements:

- Experience: i) Representation: Rules, ii) Type: Based on cases
- Learning Mechanism: i) Type: Adaptive, ii) Representation Technique: Rules, iii) Learning Source: Process, exit and or failure conditions occurring in the proposal of a control action, proposal of new control and decision-making parameter values in coordination jobs, iv) Up-Dating: Feedback (using previous experiences for updating knowledge)
- Reasoning Mechanisms: i) Information source: Previous results obtained for system control agents, ii) Activation Source: control and coordination jobs, iii) Type of Inference: Based on rules, iv) Strategic Reasoning: Coordinate strategies for the proposed selection of appropriate control algorithms and for decision-making in the supervisory and planning level. Confront unknown situations to enrich the experience.

3.5 Coordination Model

In general, this model describes the coordinating mechanisms between agents. Basically, this model describes the way activities are organized in the IDCSA to reach the objectives. It deals with the planning process and conflict resolution mechanisms that occur between agents. The model is complemented with a description of protocols, ontologies, and communication mechanisms (direct and indirect). In the IDCSA, only predefined planning mechanisms are used. The proposed coordinating model is oriented to services. A service can have associated specific properties (cost, duration, etc). For the IDCSA case, conversations generated from the predefined planning process are: i) Obtaining control action, ii) Manage level objectives, iii) Sound alarm, iv) Coordinate humans. Below, the first conservation alone is described:

1 When communication exists with the coordinator, the control agent is only in charge of generating the control action (the associated interactions are shown in Table 1)
2 When no communication exists with the coordinator, the control agent has the possibility of auto-regulating itself. In this case, the control agent, making use of the intelligent model, can identify parameters of the current situation and attempt to define the parameters that remedy said situation.

Table 1. Interactions of the Conversation "Obtaining Control Action"

Interactions	Services
Request: Control-Data Base	Search for information
Transmit: Control-Data Base	Store decisions
Transmit: Control-Coordinator-Inferior Levels	Coordinate goals
Transmit: Current Control (level of local control)	Conversion of Control Signals to physical values

3.6 Communication Model

This model describes each interaction between agents (speech acts). In the case of IDCSA, a predefined planning process was used, which determines direct communication carried on between agents. Each interaction between two agents is carried out through sending a message, and has a speech act associated with it (see table 1).

4 Conclusions

This work proposes a reference model for distributed control systems based on MAS whose architecture is inspired in a hierarchical scheme. The use of MAS incorporates collaborative, organizational and intelligent aspects that permit the control system to have emerging behavior. The use of MASINA methodology permitted the specification of the IDCSA model. The IDCSA model allows model distributed control system in a way that we can include intelligent components in our system. Two main aspects can be considered in our model: we can distribute the different control tasks among the control agents of IDCSA, and the intelligence is part of the control agents.

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