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Multiple intelligences in a MultiAgent System applied to telecontrol

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ABSTRACT

This paper presents a control system, based on artificial intelligence technologies, that implements multiple intelligences. This system aims to support and improve automatic telecontrol of solar power plants, by either automatically triggering actuators or dynamically giving recommendations to human operators. For this purpose, the development of a MultiAgent System is combined with a variety of inference systems, such as Expert Systems, Neural Networks, and Bayesian Networks. This diversity of intelligent technologies is shown to result in an efficient way to mimic the reasoning process in human operators.

1. Introduction

The main feature for the correct functionality of a control system is the expert knowledge and how it is applied by humans. These concepts should be applied heavily in the development of these systems but they are often forgotten or minimized in order to obtain reliability. To improve these systems, it is necessary to establish mechanisms of intelligent human-like self-control.

MultiAgent Systems enable suitable models to be built for the prediction of complex and dynamic systems in real time (Saleem, Nordstrom, & Lind, 2011). Inference engines attempt to mimic the behavior of the human brain by using various types of algorithms and strategies (Dopico, De La Calle, & Sierra, 2008). The combination of both these technologies should therefore allow the construction of systems capable of solving problems satisfactorily without previous knowledge of all the variants of solutions.

The work discussed here belongs to the field of distributed control systems, particularly in the automatic telecontrol of solar power plants (Li, Karray, & Basir, 2010; Yang, Yang, Zhao, & Jia, 2009). Furthermore, control systems based on MultiAgent theory, and restricted to specific domains have been developed. For instance, one of the early works (Junpu, Hao, Yang, & Shuhui, 2000) discusses the reliability of agent-based distributed hierarchical intelligent control. Another study examines the modeling of MultiAgent control for energy infrastructures (Sebastian Beer, 2009) that presents an agent-based control system for distributed energy resources in low voltage power grids.

Regarding the different possibilities to build an inference engine, studies and applications have achieved excellent results for control systems based on Expert Systems (Liebowitz, 1997). These solutions provide a fast output and precise, and decrease state transitions in the real environment to control. Other options in inference systems might include Neural Networks (Cochocki & Unbehauen, 1993) or Bayesian Networks (Costaguta, Garcia, & Amandi, 2011), to reinforce the initial heuristic rules of any control system based on this kind of logic. Finally, another significant option is the use of inference systems based on Fuzzy Logic (Leondes, 1999).

MultiAgent control system architectures have been considered to reduce the computational complexity and manage the huge amount of distributed data and coupling problems among many subsystems. In many cases, implementations include only one intelligent aspect (Gadallah & Hefny, 2010; Ouidad, 2006), and often in a superficial way. This is due to the fact that intelligence and learning are very complex features to implement at software level. The inherent complexity of distributed systems causes a lack of interest in their implementation, due to requirements and reliability in such responses.

Within this domain, the most important aspect that we discuss concerns the application of real and useful intelligence models in conjunction for control systems based on MultiAgents. Studies Lorenzi, Bazzan, Abel, and Ricci (2011) and Miyashita and Rajesh (2010) use assumptions in the recommendation or coordination techniques in the making-decision, being discarded inference systems for their requirements. In this paper we focus in the orga-

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nization of the elements of inference and the flow of information within the system, with the aim of creating an optimized and intelligent control system that meets all requirements exposed.

The purpose of this research is to determine the best combination of the points indicated, and to provide a viable solution through optimizing and ensuring the use of distributed artificial intelligence technologies. The result of this research is the CARISMA system, which is a new MultiAgent System application for the development of integrated systems and automatic control with distributed intelligence. This software is designed for application in the field of industrial control systems for facilities based on solar photovoltaic energy sources.

This paper is organized as follows: Section 2 shows an overview of our system, while in Section 3 the proposed architecture for a MultiAgent System applied to a control system of a solar power plant is set out. In Section 4, the implementation and integration of the inference systems are presented together with the MultiAgent System developed. Section 5 shows the tests performed and the results obtained. Finally, the concluding remarks are found in Section 6.

2. System overview

The combination of certain technologies, to which reference is made in the introduction, leads to the integration of inference engines in the MultiAgent System. This combination is intended to provide the agents with the individual and collective intelligence necessary to resolve problems common to the entire system.

The system has been developed within the so-called "CARISMA Project: MultiAgent System for Remote Control of Solar Photovoltaic Power Plants". The objective is to control and monitor solar panel farms: in an automated way whenever possible and, the cases when it is not possible, to provide human telecontrol operators with control recommendations. To this end, small hardware devices are distributed with associated sensors and actuators in various areas of a solar farm in order to do this. This MultiAgent System employs the set of devices in order either to make decisions of automated control or to send recommendations to technicians of the solar plant based on the data and knowledge available.

2.1. Platform, environment and language development

We have made a study of the existing platforms, environments and development languages in order to facilitate the development and implementation of a MultiAgent System and the integration of several inference systems. Currently there are several platforms, frameworks and libraries that can help towards the development of MultiAgent Systems (Weyns, Parunak, Michel, Holvoet, & Ferber, 2005). These tools minimize development time and enable work to be carried out under accepted standards in MultiAgent System development.

Each of these platforms offers certain features according to the requirements of diverse applications. From among all the platforms available for MultiAgent System development, JADE (2004) has been selected since it encompasses both the features (standarization and use of generic language) required for our purpose.

3. MultiAgent System architecture

Based on the philosophy of the development of the JADE platform an architecture for MultiAgent System of the CARISMA project on the JADE platform has been created. This architecture is in accordance with the required specifications for a control system (Oviedo et al., 2010, chap. 1).

In order to design this architecture, the methodology proposed by the JADE developers (Bellifemine, Poggi, & Rimassa, 2001) has been followed in a flexible way in order to minimize the costs involved in the initial system architecture specification.

3.1. Types of agents defined in the system

From the study carried out for the modeling of intelligence, learning and socializing, the following agents have been defined in our system:

- *Teleoperator Agent*
  This is an agent who holds overall control of the platform. The main functions are to configure various aspects of the system, such as: coverage areas, which agents belong to each zone, interface for access to other agents in the system, and interface for human user access. In terms of making decisions and offering recommendations, this is the agent that has global knowledge of the platform.
- *Coordinator Agents*
  The responsibility of these agents is to coordinate global solutions for an alarm situation or fault in a particular area. Examples of tasks assigned to these agents include communication failures and recommendations of solutions to other agents in this area.
- *Operator Agents*
  These agents are responsible for controlling several Sensor-Device Agents that are assigned by the human operator, or for taking an action on a Sensor-Device Agent. They provide a number of communication mechanisms to communicate faults to other agents (coordinators or operators).
- *Sensor-Device Agents*
  Reactive agents responsible for obtaining data from sensors and performing actions on the actuators. These agents are unique and customized to the type of device to be monitored and controlled.

In addition to these four agents, in the system a fifth agent functionality and platform boot, called "Remote Agent" (RA), exists. This agent is responsible for creating and operating the structure of agents in different physical systems that make up the software platform (embedded systems, servers, etc). The agent's life cycle is limited to the system boot, creating a temporary container when the functions are performed, and it disappears along with its container when the functions have been completed.

3.2. MultiAgent System overview

The designed architecture is intended to integrate the various types of agents described: Teleoperator Agent (TA), Coordinator Agent (CA), Operator Agent (OA), and Sensor-Device Agent (SDA). The number of Coordinator Agents, Operators and Sensor-Devices remains unlimited. It is possible to define the number of agents of each type in the system startup and remove or create them dynamically with the system running. Moreover, the number of Teleoperator Agents is limited to a single agent whose existence in the system is compulsory.

An example of the network topology defined is shown in Fig. 1. In this example, three zones or areas of communication have been defined, although the network may expand or shrink according to the number of solar panels to control or the complexity of the system control.

The Teleoperator Agent constitutes the starting point to the system, and provides a user interface that allows global configuration of the platform (shown in Fig. 2). Additionally, this interface enables the overall management of knowledge in the system. Coordinator Agents perform the semi-global coordination of solutions for fault or alarm conditions detected from multiple points in different areas of the system. Operator Agents are responsible for monitoring the