AGENTS-BASED DISTRIBUTED PROCESSES CONTROL SYSTEMS

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ABSTRACT

Large industrial distributed systems have revealed a remarkable development in recent years. We may note an increase of their structural and functional complexity, at the same time with those on requirements side. These are some reasons why there are involved numerous researches, energy and resources to solve problems related to these types of systems. The paper addresses the issue of industrial distributed systems with special attention being given to the distributed industrial processes control systems. A solution for a distributed process control system based on mobile intelligent agents is presented. The main objective of the proposed system is to provide an optimal solution in terms of costs, maintenance, reliability and flexibility. The paper focuses on requirements, architecture, functionality and advantages brought by the proposed solution.

Keywords: distributed process control system, intelligent agents, multi-agent system, collaborative process automation systems, SCADA system, diagnosis, reliability

1. Introduction

Improving of many products characteristics can be achieved by using high performance control systems to maintain productions parameters at established levels and through careful monitoring of the production flow. Both options are considered dependent on how processes and technological flows are organized.

In many situations we deal with large technological flows and processes spread over large geographical areas, in some cases covering regions, entire countries or at continent level. Following there is presented some illustrative applications for the small-scale case:

- facilities in the chemical and petrochemical industry;
- pharmaceutical manufacturing;
- water management systems;
- metallurgical process plants;
- traffic monitoring and coordination;
- wireless sensor networks, etc.

As examples for commonly used large-scale applications we can mention:

- electric power transmission and distribution systems;
- electrical generation plants;
- renewable energy production facilities;
- environmental control systems

Theoretically, not only spatial distribution is a problem but also complexity and special requirements for these systems. This constitutes a reason why their monitoring and control requires the adoption of appropriate solutions.

Currently, both at theoretical and practical level, there are many solutions and implementations based on Supervisory Control and Data Acquisition Systems (SCADA), which cover as the first objective the industrial, infrastructure, or facility-based processes control and monitoring.

Besides this, the interest of engineers and researchers are turning to other basic functions, among which, some of them briefly are illustrated as follows:

- real-time performance management;
- alarm management;
- virtual instrumentation availability;
- etc.

Improved performance of hardware devices as well as communications systems can be considered as a starting point in the growing importance of software, which can be seen for example by following directions of development:

- business model based software and value-added services and
- Collaborative Process Automation Systems (CPAS).

This paper is focused on the direction of collaborative process automation systems, for which an implementation solution based on intelligent agents is presented.

The upcoming part of the paper is organized as follows: Section 2 describes the intelligent agents as a solution for problems solving and control, In Section 3 our solution is described, Section 4 outlines the advantages of the solution proposed by authors.

2. Intelligent Multi-Agent Systems

The cognitive systems represent an important current research field. Numerous studies and researches are focused on particular sub-domain of agent-based systems. This offers a solution for many difficult and complex problems solving [1, 2, 3, 4, 5, 6, 7, 8].

Agents, in general, represent systems able to perform computations that have been used as a solution for problems/tasks solving in many domains. An intelligent agent is characterized, as main properties, by [9]:

- increased autonomy in operation;
- capacity of communication and cooperation;
- reactive – in terms of responsiveness, agents should perceive their environment and respond to changes that occur in it;
- goal-oriented - agents should not simply act in response to their environment, they should be able to exhibit opportunistic;
- self-configurable.

These proprieties are necessary in the features of the agents with capacities specific to the intelligent systems, like autonomous learning [9, 10, 16]. Autonomous learning allows the agents to adapt for performing efficient problems solving.

A specific class of agents is represented by the software mobile agents [11, 12, 13, 14, 15, 16, 17]. The software mobile agents may be seen as a relatively new paradigm in the area of distributed programming and a useful supplement of traditional software approaches. Mobile agent technology has been applied to develop solving methods for various kinds of parallel and distributed computing problems. The features of the mobile agents with intelligence is more limited from practical reasons, such as [18]:

- limitations in communication capacity;
- intensive computational and memory resource usage on the hosting platform;
- specific security issues to the mobile agents.

The intelligence, in a cooperative multi-agent system could be considered at the level of the system where the agents operate [9]. Complex problem can be solved by efficient cooperation though agents. The efficiency of the cooperation in the multi-agent platform defines the intelligence level of the system. This could be higher than that of the agents itself. In the literature [18, 19] there are described multi-agent systems, some of them made up of relatively simple agents that could be considered intelligent at the level of the system in that they operate.

3. Distributed Process Monitoring and Control by an Multi-Agent-Based System

Building distributed process monitoring and control systems (DPMCS) can lead to reliable and high-performance scalable systems. Such an approach offers the possibility to optimize the processes over communication networks, finally obtaining a more reliable and higher-performance system [20].

Implementing such an approach can be put in front of other problems to be solved, common to the monitoring and control in distributed systems:

- heterogeneity of systems – that can increase the system complexity on interconnections sides;
- size and complexity, that may lead to
- high costs;
- available standardization only in certain directions. For example on generalized using of virtual instrumentation there are limited solutions [22];
- limitations in systems evolution, especially regarding future technologies.

The structure of a DPMCS mainly consists from network of nodes and backbones. Each node will have specific function either process controlling, process parameters monitoring or both.

Such an approach permits the design and implementation of a CPAS system. As a solution mobile intelligent agents approach will be adopted.

The proposed system mainly besides the classical functions will implement a decision support component. This module will be useful for diagnosing of system's problems. The system is designed to operate in a transparent manner, so that a problem raised in a node of the system, depending on the situation, will benefits for assistance at the nearest level of management or operational management.

Implementation of such a solution is subject to a series of issues, some of them common also to other decision support projects available on other domains:

- access to the most relevant technical knowledge;
- availability of quality data;
- the way that data are stored;
- design and implementation of decision support and learning algorithms;
- interconnecting subcomponents in a heterogeneous communication system.

A key factor in achieving a successful system would be a decision support system approach based on the decision making from perspective of the following levels: alerting, interpreting, critiquing, assisting, diagnosing and managing [1,21].

Certainly, in a first phase, in many cases due to the complexity and volume of required data and knowledge it is not possible to achieve the proposed goal, but the system will function based on support from specialists, and then after knowledgebase completion will become autonomously.

The proposed system is designed for monitoring, control and to support the decisions at various levels of interests, addressed to the corresponding management levels. The architecture of the system is shown in Fig 1.

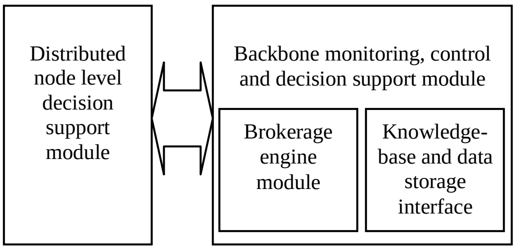

Fig. 1 – DPMCS architecture

The system architecture is based on two main modules: distributed node level decision support module as supervised level and backbone monitoring, control and decision support module as supervising level.

Distributed node level decision support module aims at analyzing the process data, then processing them and generating alerts, warnings or alarms that are transferred to the next level of decision if it is not possible to process an appropriate decision.

Backbone monitoring, control and decision support module process and store data history received from the subordinated levels. Communication between system layers is based on priority, which is dynamically established. At this level are generated the supervising decisions and transferred to the subordinated levels. This module is able to collaborate with other ones of the same type in decision making process through brokerage engine.

Knowledge-base and data storage interface is useful in case of systems that work with large amount of data to offer support on semantic data storage on service oriented distributed database.

The DPMCS architecture implemented with the support of mobile multi-agent system is shown in Fig 2.

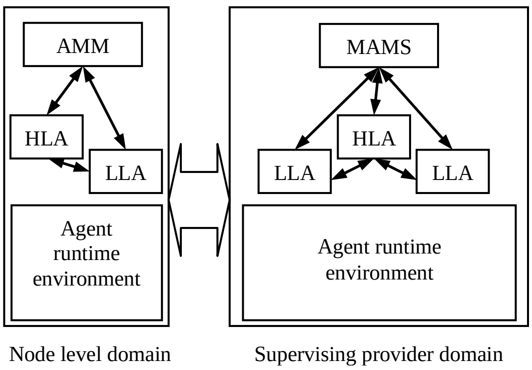

Fig. 2 – Agent-based DPMCS architecture

Conceptual, system consists of two parts: a node level domain and a supervising provider domain.

The node level domain consists from an agent runtime environment specific to the platform where agents are loaded, an agent management module (AMM) and agents downloaded from the main system.

The AMM is used to take care of agents running on user domains, in terms of creating or destroying agents as needed.

Node level domain supports two types of agents: higher level agents (HLA) and lower level agents (LLA). As main features HLA provide the following functionalities:

- event analysis based on own knowledgebase; or on collaboration with other agents;
- generating alerts and alarms based on corresponding occurred event;
- negotiation for direct communication with agents from suitable supervising domain when an adequate solution may not be found.

Agents from LLA category provide the following functionalities:

- obtaining data from data acquisitions devices or from human operators though dedicated interfaces, usually mobile devices;
- primary data processing that consist on
  - data filtering, conditioning and recording;
  - event detection.

All these agents communicate in multi agent system environment with similar or with different level agents. All communications are managed by the multi-agent system.

Lower level agents are designed to detect events based on user inputs or based on data obtained from hardware devices that are provided to the higher level agents.

A higher level agent may have one or more lower level agents associated to it depending on the number of sources necessary for generating alerts, alarms or decisions.

Supervising provider domain through multi agent management module system (MAMS) manages lower and higher level collaborative agents.

Higher level agents mission are to find the best suitable solutions for problems arising from node level domain. Solution may be found on own knowledgebase, after negotiating with other agents from own domain or other supervising domains. In case of failure it generates alerts and alarm direct to a most appropriate agent associated to a human operator or operational management.

4.Conclusions

Paper presents the design of a distributed process monitoring and control systems based on mobile multi-agents approach.

The proposed system is distinguished by a number of advantages such as:

- a scalable solution;
- deals with a decentralized control and monitoring approach, and as consequences
- avoidance of a single point of failure, so a higher robustness and reliability;
- the proposed architecture is suitable for large and heterogeneous solutions.

Implementation of agent-based DPMCS can benefit from development of available multi-agent platforms but may require special attention on resource planning for the system.

In case of intensively use of embedded systems based on system-on-a-chip on nodes level, will arise an impediment in the use of dedicated platforms for multi-agent systems. In that case is needed for development of multi-agent support on specified devices. Authors see as a feasible solution the development of an agent description language to permit agent deployment on platform with constraints on availability of resources.

If it is desired to implement control functions in DPMCS then a study on stabilization and real-time response of the system should be considered to be undertaken.

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