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AGENT BASED METHODOLOGIES IN DISTRIBUTED CONTROL

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Abstract: Agent based methodology ia a rather new approach to control complex, distributed and dislocated systems. The paper describe methods and tools for development of such control systems. The enphasise is given to application of standard agent architectures in monitoring and control tasks. Agent comunication languages. agent interactions and interaction protocols, knowledge representation, ontology and content languages are discused and illustrated by an example of experimental multi agent based greenhouse model monitoring and control.

Keywords: Complex systems, agent technology

1. INTRODUCTION

Development of technical systems has become difficult because of increasing complexity and demands that are set for those systems. Researchers are constantly developing new methods to cope with complexity (for example in communication systems or control systems). For monitoring and controlling of complex, distributed systems we should take in consideration properties of such systems [8]:

- In real-time system many events may occur at the same time. So a central control system may be unable to receive all massages representing a change of state of the technical system. In any case the control system will be unable to process them.
- There might be already an existing set of facilities or software processes that we would like to integrate.
- Often a real-time system is modified substantially during its lifetime. Distributed systems are usually easier to change and extend than monolithic systems.
- In real-time system we also often observe a spatial distribution (e.g. in communication networks the devices, such as workstations, printers and so on are spatially distributed). In these cases it seems to be "unnatural" to transmit all notifications from the devices to a central controlling system.

A new approach for solving monitoring and control tasks of such systems is so called "agent technology".

2. AGENT DEFINITION

Agents are now widely discussed by researchers in mainstream computer science, as well as those working in data communications and concurrent systems research, robotics, and user interface design. Market predictions are now estimated in billions of US$ in the next couple of years. The UK-based consultancy firm Ovum has predicted that the agent technology industry would be worth some US$3.5 billion worldwide by the year 2000 [1].

David Peterson states that the future of the Internet and internal corporate "intranets" will demand more sophisticated software tools, and one of the most promising are software intelligent agents. Agent technology will help individuals and corporations cope with complexity [2].

Table 1. Agent properties according to Franklin and Graesser

Property	Other Names	Meaning
reactive	(sensing and acting)	responds in a timely fashion to changes in the environment
autonomous		exercises control over its own actions
goal-oriented	pro-active purposeful	does not simply act in response to the environment
temporally continuous		is a continuously running process
communicative	socially able	communicates with other agents, perhaps including people
learning	adaptive	changes its behavior based on its previous experience
mobile		able to transport itself from one machine to another
flexible		actions are not scripted
character		believable "personality" and emotional state.

Wooldridge and Jennings define intelligent agents in two ways. A weak notion of agency uses term agent to denote a hardware or (more usually) software-based computer system that enjoys the following properties:

- *autonomy*: agents operate without the direct intervention of humans or others, and have
- some kind of control over their actions and internal state;
- *social ability*: agents interact with other agents (and possibly humans) via some kind of *agent-communication language*;
- *reactivity*: agents perceive their environment, (which may be the physical world, a user
- via a graphical user interface, a collection of other agents, the INTERNET, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it;
- *pro-activeness*: agents do not simply act in response to their environment, they are able to exhibit goal-directed behavior by *taking the initiative*.

A stronger notion of agency characterizes an agent using *mentalistic* notions, such as knowledge, belief, intention, and obligation. Some researchers have gone further, and considered *emotional* agents. Various other attributes are sometimes discussed in the context of agency. For example: *mobility* is the ability of an agent to move around an electronic network, *veracity* is the assumption that an agent will not knowingly communicate false information and so on [3].

Stan Franklin and Art Graesser submitted a definition: *"An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future [4]."*

The table 1. lists several of the agent properties according to Franklin and Graesser.

For Pattie Meas an ideal agent knows what its goal is and will strive to achieve it. An agent should also be robust and adaptive, capable of learning from experience and responding to unforeseen situations with a repertoire of different methods. Finally, it should be autonomous so that it can sense the current state of its environment and act independently to make progress toward its goal [5].

Peterson states that in general, an agent is a program or collection of programs that exhibits aspects of the mind (e.g., intelligence) and that acts independently on behalf of its owner. Agents are viewed as being autonomous, capable of making decisions while working toward a goal [2]. "The Agent Society" has made application taxonomy of agents: mobile agents, stationary agents, intelligent agents, autonomous agents, profile agents, community of interest agents, etc. [6]. In previous taxonomy, autonomous agents are just one of the type of agents. For Franklin and Graesser autonomous agent and agent are the same term. Their taxonomy is shown on Fig. 1.

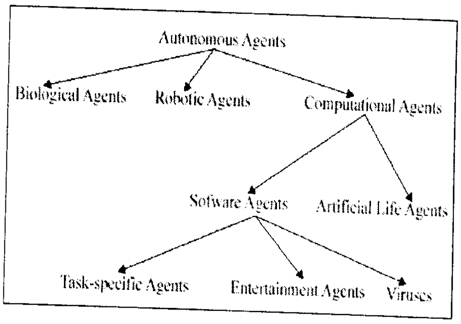

Fig. 1. Agent taxonomy by Franklin and Graesser

It is interesting to mention another definition (Genesereth and Ketchpel) too: *"Agent-based software engineering is often compared to object-oriented programming. Like an object, an agent provides a message-based interface independent of its internal data structure and algorithms. The primary difference between the two approaches lies in language of the interface. In general object-oriented programming, the meaning of a message can vary from one object to another. In agent-based* *software engineering, agents use a common language with an agentindependent semantics [7]."*

It is easy to notice that there are disagreements about definitions of agents, taxonomy or terms that are connected with them, but that was not a problem in practical of agent technology. Such applications are already in commercial use, mostly for web searching, monitoring and finding information (www.agentware.com - Agentware, www.netperceptions.com - GroupLens, www.opensesame.com - LearnSesam etc.).

Artificial intelligence and agent terms are strongly connected. Most researchers find intelligence to be an important feature for an agent. But finding unique definition for agent intelligence is hard as finding unique definition for agent itself.

3. USE OF AGENTS IN MONITORING AND CONTROL OF COMPLEX, DISTRIBUTED SYSTEMS

In Laboratory for Robotics and Intelligent Systems (LaRIS), Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, UNIVERSITY OF SPLIT, the project of using agents and intelligent agents in supervision and control of complex, distributed systems is going on. The research tasks could be stated in four questions:

- How to formulate, describe and allocate assignments for agents?
- How to make communication and interaction between agents?
- How to ensure that agents behave coherently, e.g. avoiding harmful interactions?
- How to resolve conflicts between agents?

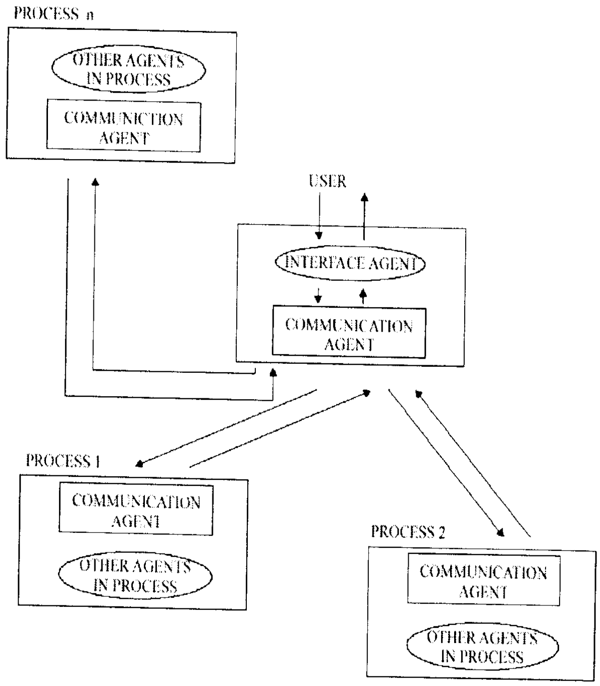

Fig. 2. Block scheme of a distributed system

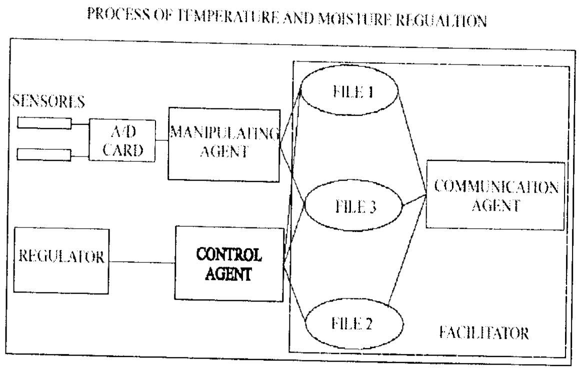

Figure 3. Temperature and moisture regulation process

Fig. 2. shows a block scheme of a distributed system. User communicates with the system via interface agent. There are n processes that are active at the same time. In each process there are communication agent and agents that are needed for that specific process.

Practical examples on which we intend to test our ideas are monitoring and control of dislocated greenhouse. Three basic tasks could be defined:

- monitoring temperature and moisture value
- automatic control of temperature and moisture
- video-surveillance of greenhouse

Fig. 3. shows our example in more details. There are four agents, three of them shown on Fig. 3:

- *manipulating agent* responsible for A/D and D/A card. Its task is to collect process variables values and to send control values through D/A back to process,
- *control agent* responsible for control algorithm which includes certain self-protecting actions,
- *communication agent* responsible for communication with other dislocated devices, and
- *video agents* (not shown on Fig. 3.) responsible for video-surveillance.

The main emphasize in developing agent based system is connected with agents communication. Two approaches could be encountered:

- direct communication approach, and
- indirect communication approach (usually called federated system).

In *direct communication*, the agents handle their own coordination. Information are shared between agents directly, and there are no separate programs or agents required for communication and coordination. Disadvantages of direct communication are complexity of agents, which have to know how to communicate with any other agent in the system and large flow of communication, expanding with growth of agents' quantity (number). In *indirect (federated)* agent based systems agents communicate using so cooled "facilitator" as Fig. 4. shows.

Agents in federal system do not need to maintain information about other agents and do not need to directly communicate to any other agents. This reduces the complexity and size of agents and improves performance and mobility of the agents.

For our example federated system was more appropriate. Using facilitators communication with central unit is asynchronous in both directions. Also monitoring and control agents are in such a system dedicated only to their main tasks. They don't loose time in communication, which can be in progress independently of their actual jobs. Fig. 3. shows the communication system between agents in more details.

Facilitator has three independent agents access it regularly to check are there any new information important for their work. For example, new set-up (reference) value for control agent, or new demand to measure particular process variable for manipulating agent. These instructions are given by the user through his interface and communication agents.

Communication agents also have the ability of preprocessing user demands in order to send them to the right address. For example if the user want to rise temperature to 30°C communication agent will first check the actual temperature. If it is yet 30°C then he will do nothing except send information back to the user that the temperature is 30°C. If the user want to rise temperature to 70°C the communication agent will send that information to the control agent. The control agent has appropriate knowledge about allowed values of process variables and he will discard that demand because 70°C is surely to high temperature for the greenhouse.

The experimental setup is shown in Fig.5.

Fig. 2 shows the experimental setup photo.

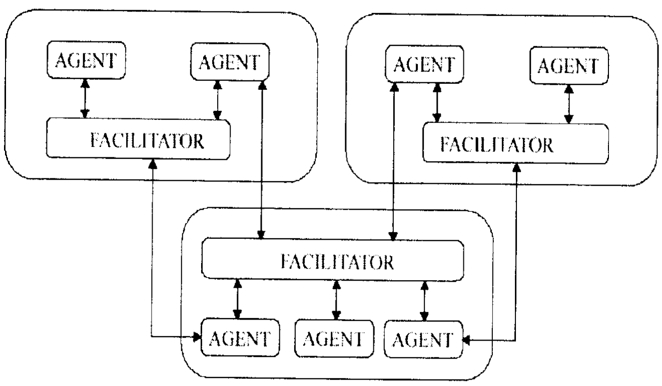

Fig. 4. Federated system

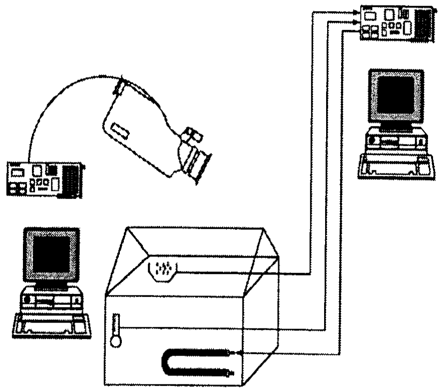

Fig. 4. The experimental setup: laboratory greenhouse, PC with ADDA boards, PC with frame grabber and analog video camera

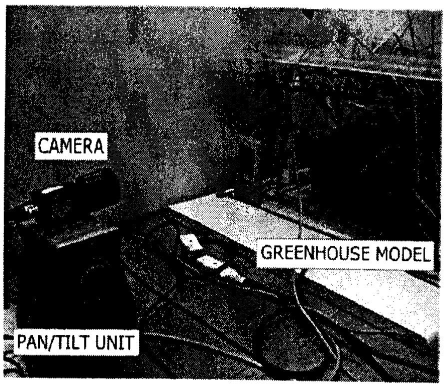

Figure 5. Laboratory greenhouse model and analog video camera mounted on pan & tilt unit

The schematic drawing of the greenhouse is shown on the Fig. 6. The laboratory greenhouse was equipped with few temperature sensors for measuring temperature in air (T_0), on the ground level and inside the ground (T_{11} – T_{23}) and with one humidity sensor (H_0).

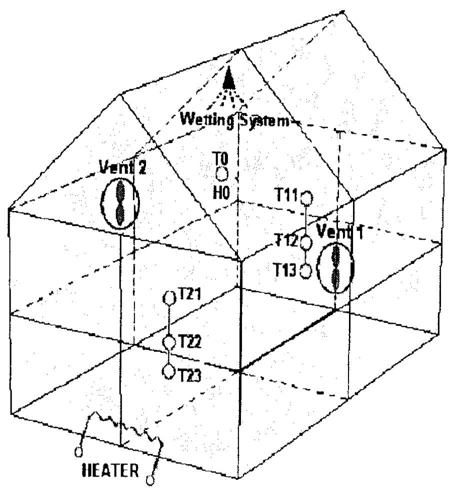

Fig. 6.Experimental laboratory greenhouse model

Heating and cooling examples are shown on Figures 7. Figure 7a) shows the situation where all openings on greenhouse roof were closed and the heater was set to 100% power. Figure 7b) shows the situation when all openings were closed, too, heater was set to 0%, and Vent1 was set to 100%. The sampling interval in both cases was 60 seconds.

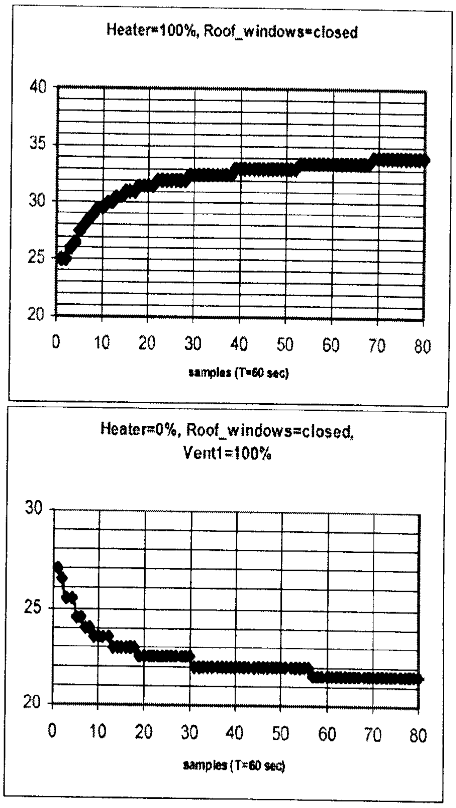

Fig. 7. a) (up) Data for heating example with closed roof windows b) (down) Data for cooling example with ventilator 1 switched on

At the end we would like to explain once again the main agent features. They are autonomous, they can respond to demands of other agents or user, but only if their demands are not opposite to main system goals. Agents work continually and they can control the process without any intervention from central unit. This means that if the distributed system lose connection it will continue to work lead by its autonomous agents, maintaining some average state of process variables.

4. CONCLUSION

The application of agents for monitoring and control of complex, distributed systems could improve characteristics of such systems and help solving encountered problems. The agent characteristic "autonomy" is particularly suitable to improve system robustness and decrease system centralization. Also the system becomes more open and easily expandable by simply adding new agents. Existing facilities or software processes can be integrated fast. We should emphasize that this system is still in process of development. Benefits from using agents and possibilities of such systems on basic of our premises have jet to be investigated. So comparative analyze with similar systems will be object of future researches.

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