Bulletin of the *Transilvania* University of Braşov
Series I: Engineering Sciences • Vol. 5 (54) No. 1 - 2012

ROBOTIC VISION SYSTEM BASED ON INTELLIGENT AGENTS

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Abstract: *This paper presents a robotic vision mechanism based on a multiagent robotic system for controlling the behaviour of the agents. In this approach, we used the fuzzy technology which is very adequate in this study case. The combined mechanisms offer surveillance of the entire set of robots and contribute to an appropriate behaviour for them.*

Key words: *intelligent agents, robotic vision system, fuzzy logic.*

1. Introduction

In the last years the multiagent technology was develop and many implementations of the multiagent systems were published. Autonomous agents and multiagent systems represent a new way of analysing, designing, and implementing complex software systems. The agent-based approach offers a powerful set of tools, techniques, and paradigms that have the potential to considerably improve the way in which people conceptualize and implement many types of software. Agents are being used in an increasingly wide variety of applications - from comparatively small systems such as personalized email filters to large, complex, mission critical systems such as air-traffic control. At first sight, it may appear that such extremely different types of system can have little in common [7].

Recent implementations of different systems with action selection dynamics (SASD) having learning capabilities increased the potential for more timely, dynamic, and vigorous interactions between the autonomous agent and its environment. These recent implementations of SASD are an attempt to create a framework in which the Urge Theory of M. Toda can be investigated [2]. It produced improvements in implementation efficiency and theoretical accuracy of SASD. The SASD network gets inputs from several different sensors (including vision), and supports learning to change inter-agent network relationships. Emotional states such as fear, curiosity, affection-seeking, hunger, joy, irritation, and anger are supported as emergent phenomena. The robot's on-board voice synthesis unit announces its internal states [4].

Vision systems have become popular for remote vision sensing in geographically distributed environments due to vast amount of information they provide. However, remote vision sensors are generally plagued with power and communication bandwidth constraints.

Mobile agent technology is a salient solution to geographically distributed and dynamic domains that require subsystems to interact with each other. Mobile agent technology increases power efficiency by

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reducing communication requirements and increases fusion processing by allowing in-site integration of on-demand visual processing and analysis algorithms. A mobile agent can dynamically migrate from one vision sensor to another and combine all necessary sensor data in a desired manner specific to the system requesting the data [10]. This paper presents a multiagent robotic system with remote vision architecture, based on mobile agent technology that provides a flexible vision fusion solution based on fuzzy methods. The architecture uses the Matlab Simulink as a basis for the fuzzy algorithms and the JADE Leap for mobile agents.

The paper is structured as it follows: in section 2 we present the multiagent robotic system with his particularities; in section 3 we focus about engineering model of knowledge, emotion and intentions and in section 4 we implement the fuzzy model. Further we present the conclusions and the references.

2. The Multiagent Robotic System

In the field of power control the validity of multiagent technology has been proved [9]. The robot's autonomy depends by intelligent elements which must be taken in consideration [8].

Research on types of vision for use in agent robots has focused on digital image processing (image conversion) in the 1970s, computer vision (conversion from two-dimensional images to three-dimensional images) in the 1980s and active vision (integration of vision and action) and image media (image recognition and generation of integration) in the 1990s [11].

Nowadays, the vision needs more emotional elements for given the society ability to the multiagent robotic systems and for use of intelligent actions.

The robot receives two types of directions that enable it to perform its tasks: explicit and implicit directions. The firsts are those of which the human is conscious of and which are given to the agent robots. The others are those that allow the robot (agentified robot) to perform spontaneously and independently even if the human is not conscious of the actions (see Figure 1).

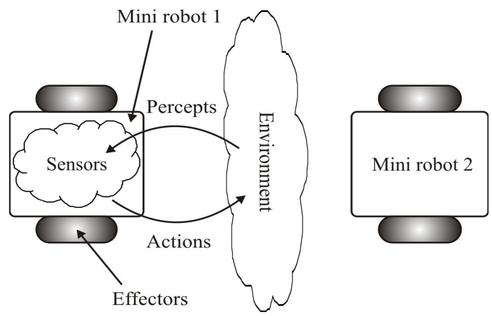

Fig. 1. *Agentified robots interactions*

For the man-machine interface, in this situation, Hashimoto and others proposed the engineering model of knowledge, emotion and intention [11].

The agentified robot will follow these concepts. Also, the agents could be deliberative [3]. Under this paradigm, agents reason and make decisions based on the symbolic representations (model) they have of the external world. Deliberative agents, which have precise goals to be achieved by their actions, need a lot of effort to symbolically represent the complex entities of the external world. On the other hand, the amount of computation these models require in order to make appropriate decisions can be enormous. The vast work on, for instance, knowledge representation, reasoning, and planning from the Artificial Intelligence (AI) area has its origins in this need to represent the world and reasoning about it. One of the well-known architectures associated with deliberative agents are the Belief-Desire-Intention (BDI) architecture. The BDI architecture has its grounds in the idea that to handle complex problems it is better to create agents whose reasoning is analogous to human practical reasoning. BDI combines philosophy, software architecture, and logic, and is based on the assumption that agents maintain and reason about internal representations of their world (cognition). Rational action is the philosophical theory that supports BDI, which is specifically focused on the role that intentions play when deciding which action should be performed. Beliefs represent the knowledge about the agent and the external world; desires represent the objectives to be accomplished or preferences over future world states or course of actions. A desire might be regarded as objectives without a plan, i.e. a long term goal that the agent does not know yet how to achieve. Intentions represent the currently chosen course of action. Intentions are chosen from the set of desires and represent committed goals. An intention might be regarded as objectives with a plan, i.e. a short-term goal that the agent knows how to reach it. It is quite common in BDI agents to find beliefs represented using the Prolog language facts. Since desires and intentions are end states, they can also be represented by variables, record structures, or symbolic expressions. In the way to achieve an intention new desires are created and, consequently, new intentions. This might be disadvantageous if the agent does not guarantee that each intention persists until it is achieved. In this case the agent can just be jumping from intention to intention without focusing (see Figure 2).

This architecture could be also implemented using the emotions, intentions and knowledge melt together with the fuzzy logic algorithms as will be described in IV.

In a robotic multiagent system, cooperation between the agent robot who receive support and the fuzzy logic algorithm that provides the support relies on two factors: the role can be changed dynamically and the

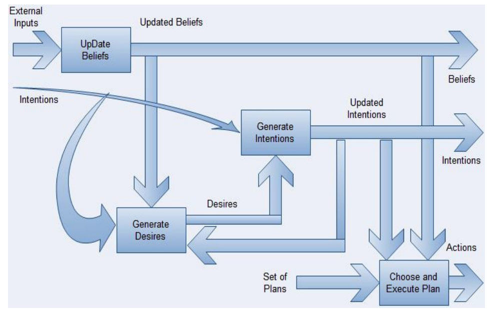

Fig. 2. *The BDI Architecture*

robot is observed spontaneously. The system needs these two functions in order to provide effective support. The agent robot needs to be able to determine its role autonomously using environmental information and to cooperate with the other agents and with the fuzzy algorithm. Conventional vision is passive vision and is used to determine one's action from the obtained information. For example, the robot first recognizes the directions given by the system, and performs its task. Active vision is the type of vision in which action are performed in order to obtain required information. For example, in order to understand directions given by the system, the agent robot first moves to a position which tends to recognize the other robots actions, and moves to the position which tends to recognize form of another robot action. However, passive or active vision are both considered to be insufficient for an agent robot in a surveillance system That is, the robot is required to observe the other robots spontaneously, while it acts. Thus, through focusing on the cooperative works between agent robots it is possible to construct a better robotic multiagent system through the realization of second function.

Tracking is a standard task of computer vision with numerous applications in navigation, motion understanding, robot control, surveillance and scene monitoring. In an image sequence, moving objects are represented by their feature points detected prior to tracking or during tracking. Feature points may have local image properties assigned to them. In many applications (including surveillance and scene monitoring), objects may temporarily disappear, enter or leave the view field. The character of motion and the merit of tracking quality also vary from task to task. Two main classes of tracking methods are distinguished: the optical flow based (see Figure 3) and the local feature based techniques [5]. In this paper, the multiagent robotic system is supervised by tracking the agent robots moves using the second method.

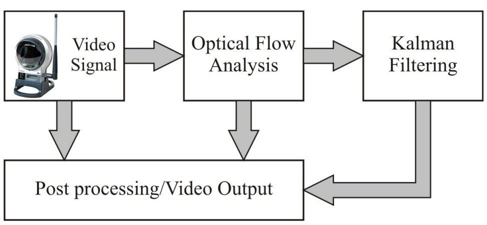

Fig. 3. *Optical Flow tracking method*

3. Engineering the Model of Knowledge, Emotion and Intentions

In this paper, a hierarchical knowledge structure in which the "emotion" layer, which expresses the emotion of the agent robot's human, and the "intention" layer, which expresses the intentions of the agent robot, was added to the Rasmussen model with three layers (macroscopic knowledge, microscopic knowledge, and the local loop) to form the engineering model of knowledge, emotion and intention for the welfare support robot (following robot) [6].

An agent robot changes environmental information, such as gesture of the human, into characteristic information using a characteristic extractor. And, the characteristic information is inputted into macro knowledge, micro knowledge, the local loop, and "emotion". The macroscopic knowledge recognizes gesture of the others agents from the characteristic information. The agent robot's emotion to human ignites from the recognition result. The agent robot's intention of ignites from the emotion. The agent robot selects concrete pattern of operation by selection mechanism of operation in macroscopic knowledge, and emotion of agent robot or recollects, finally, the agent robot performs selected operation by controlling actuator to follow the pattern of operation in microscopic knowledge. The "knowledge" of macroscopic knowledge is recognition of gesture, a guess of an intention of the gesture, and the selection mechanism of operation of the agent robot corresponding to it. And the "emotion" is emotion of the agent robot to operation of the other robot, and the "intention" means the purpose of operation of the agent robot. Spontaneously, the intellectual agent who does suitable operation to the other robot can constitute by constructing cause-effect relation between operations of the agent robot (emotion pattern) among three layers of the "knowledge", "emotion", and "intention", the pattern of operation which the agent robot can perform in microscopic knowledge and the feedback-control mechanism to realize concrete pattern of operation in the local loop, respectively.

Moreover, cause-effect relations between knowledge and emotion, emotion and intention, and intention and knowledge are implemented using Fuzzy Neural Networks (FNNs) [1]. FNNs expresses the "grade" of "there are a little relation" or "it being almost unrelated" between cause and effect by fuzzy-izing the cause-effect relation. Using this model of knowledge, emotion and intention, the agent robot is more able to positively support the other robots.

The FNNs used for the cause-effect network are presented in Figure 4 and the experiment with it is presented in section 4.

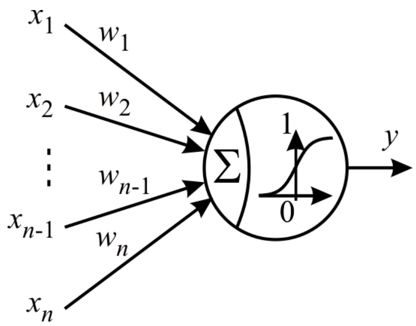

Fig. 4. *Structure of multi-input one output FNNs*

The FNNs used has a structure with multi-inputs and one output. In Figure 5, are presented one of the nodes of knowledge, emotions, and intentions. Each node expresses conception (Fuzzy set) and the conception grade (membership grade - $x_1, x_2, ..., x_n$) so that it can be said to be expressed as a numerical value between 0 and 1 (given by: $w_1, ..., w_n$). Moreover, inputs' weights are expressed by "little (0.2)", "normal (0.5)", "very (0.9)". By assigning the $w_1, ..., w_n$ values between -1 and +1 we could express cause-effect relations of excitement by positive values and relations of control by negative values.

4. Experiments and Simulations

The setup for experiments consist in two wheeled mini robots which cooperate in order to make a multiagent system by agentified them. Obviously the number of the robots may be higher (until 256 in our architecture) but to demonstrate the concepts is enough. The robots are flexible mini robots, which take advantage of a layered design approach. Each level may also involve multiple closely related functionalities. The sub-modules are designed and manufactured at Automation Laboratory. Locomotion module has a mechanical base, and locomotion module hardware (sub-module). The base of the robot consists of an aluminium frame, two stepper motors, some gearing, two wheels and associated ball bearings, and the batteries. The base is designed by CAD tools and machined with high precision CNC machines. The battery selected for the mini robot is an AA form factor NiMH rechargeable cell. Four of these cells connected in series are used in the system. The cells are nominally 1.2 volts each for a system voltage of 4.8 volts.

The two wheels module is very versatile and easily directional. This mechanism allows the robot to make short turns by moving only a wheel and stopping the other. Another advantage is providing by the sensors. The time delay is not critical because, in this situation, the locomotion module has plenty of time to turn and the control module has plenty of time to make decisions. Over on this sub-module is the main controller, an ATMega8 microcontroller running at 16MHz. The 8kB flash memory is included on chip and also 512B RAM and 1kB SRAM. All other components are soldered directly to the board. With improved memory architecture, the mini robots are able to run in a flexible architecture.

At the top, the sub-module for communication layer is based on an XBee hardware board (serial version) (which is very similar to familiar ZigBee modules) [12]. This is necessary for agents interactions and for reporting to the main server unit which is hosted on a PC. Another XBee module (an USB version this time) is connected to a host PC and connects the mini robot to the control program. Also many mini robots (a maximum of 16 is recommended) equipped with XBee module can be interconnected in this manner. The control program will coordinate the messages.

These robots constitute a networked organization of mini robots that have together formed a cooperative dynamic network to reach group benefits. Practically we form a society of agents (the mini robots) and therefore their interactions are at society level. The mini robots can be considered intelligent agents because they are proactive, reactive and have social ability. They are proactive since they have goal directed behaviour that is seen when the layers involved participate in society with the best possible performance. Moreover, they can keep working even under environmental coalitions. They are reactive in the sense that they react to changes in the external environment, which are "sensed" through messages. Although agents are not purely reactive, the importance of messages in their behaviour is so relevant that their architecture is more reactive than proactive. Finally, they have social ability because they are able to negotiate and cooperate with the other mini robots.

Communication and interaction among individuals and about a domain can only take place if some conceptualization of that domain exists. To guarantee a common semantic understanding, agents must use an appropriate ontology to communicate with their partners. In this case, all the mini robots need to share some basic concepts, such as skills, requests, services and agent. Therefore all agents of the proposed architecture share a basic global ontology that models the basic referred concepts.

For our purposes, we have adopted the description of an agent as a software program with the capabilities of sensing, computing, and networking associated with the specific skills of the mini robots described above. This implementation is made in JADE because this development tools is very versatile and could be very well integrated with others development tools (like Protégé-2000 and Java). Also JADE is an open source FIPA compliant Java based software framework for the implementation of multiagent systems. It simplifies the implementation of agent communities by offering runtime and agent programming libraries, as well as tools to manage platform execution and monitoring and debugging activities.

Once the multiagent robotic system is formed, the robots have been programmed with a specific task (monitoring a building with 5 rooms and take care about collisions and intruders) and let to navigate along building. Obviously this building is in miniature because we have to surveillance the entire foreplay with one camera for vision feedback on the system. We used a wireless (WiFi compliant) IP Linksys camera for video signal. We collect all the information exchanged between the agents and the between agents and the main computer. These messages are after that computed with Matlab/Simulink program which is versatile about fuzzy logic. Also, the video signal is uploaded in Matlab/ Simulink together with messages.

The architecture of Fuzzy Neural Network used, are described in Figure 5.

As shown in Figure 6, the predicted operation was given as input data, and action suitable for the successful performance on each prediction was chosen. As shown in Figure 7, when there was no predicted operation as input data, that is to say, it the robot doing nothing, the B7 node was chosen. That is, when the robot is still, the other robot chooses simply to observe it.

In Figure 8 the simulation of the system is depicted, using only the video signal from the camera and not using the messages catches by JADE. With very minor differences it is the same behaviour (for both cases) but illustrated in different manner. This confirm that the active vision surveillance work in this situation. It is still possible that in more complicated situation this simple fuzzy network to obtain different results.

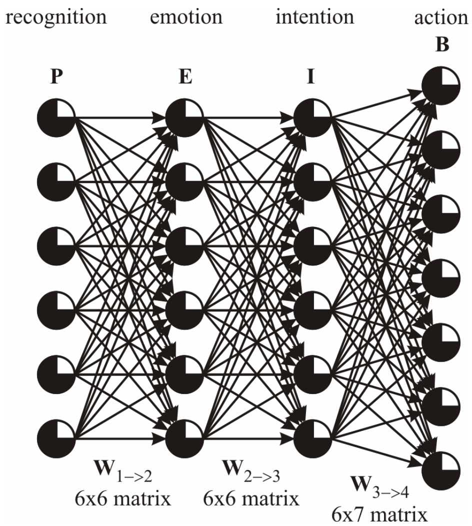

Fig. 5. *The architecture of FNNs for active vision*

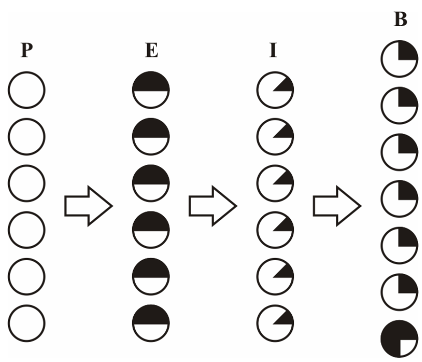

Fig. 6. *Simulation for case 1*

P6 –> E4 –> I4 –> B4

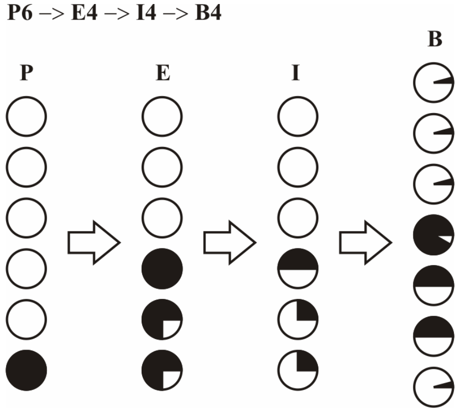

Fig. 7. *Simulation for case 2*

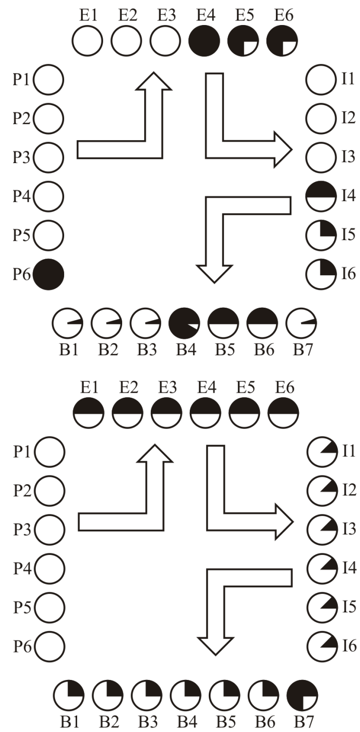

Fig. 8. *Previous simulations with active vision*

5. Conclusions

In this paper, the use of multiagent technology applied in flexible mini robotic system has been presented. Two robots were constructed and implied in multiagent robotic system, with the possibility of extending this number by adding similar robots. A surveillance system for multiagent system was built by adding a digital camera and a software program to have the feedback. The process for vision system it created. After that we create a fuzzy cognitive map for monitoring the messages and the behaviours of the agents.

The presented results confirmed the theoretical predictions made during design stage. The proper function of the robotic system is important from a practical viewpoint since it provides a detailed framework about the design of the control structure and the behaviours tasks. This confirm that multiagent technology can be successfully implemented for control the robotic systems and that the vision surveillance can be made with fuzzy logic program.

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