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Multi-Agent Fuzzy Control of the Robotic Soccer

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Abstract: Design and implementation of multi-agent system with usage of expert systems and fuzzy logic for robotic soccer control is shown. This approach is capable of effective recognition of the game situation and deducing of demanded speed vector for every possible case. Low conceptual distance ensures easy transfer of expert knowledge to the inference system.

Keywords: multi-agent system, expert system, fuzzy logic, robotic soccer

1 Introduction

Area of robotics is one of the most rapidly developing research and industrial field. There is a big ongoing effort on multiple levels from governments to individuals to bring usable robotic devices in use. We can see that performance of the hardware is advancing very much. This means, that the way will be more open to approaches demanding more computing power and with more 'intelligent' capabilities like the one we have shown.

Robot while executing tasks can enter many unexpected situations. Perception of its environment through its sensors and building corresponding model of the situation is suitable for deducing decision about resulting action is very complex task. The situation can be highly unpredictable, uncertain and radically changed during the time. This case requires use of specialized tools that allows covering these issues.

Target of this work is to design and to implement multi-agent fuzzy expert system for robotic soccer control. On this implementation we have accomplished several simulation experiments that aim to approve correctness of proposed concept. Our goal is to provide a proof that connection of multiple methods of artificial intelligence is valid approach to develop a system capable of easy transfer of expert human knowledge and effective recognition of complex game situation.

Developing complex robotic soccer control system means to provide satisfactory mechanism of control on all levels, from wheel speed and shearing reduction through correction of the image recognition errors to the highest levels of control as reasoning and social interaction between player individuals. We have focused on problem of wheel speed inference and group behavior without taking any side factors as characteristics of robot's engine in mind.

2 Robotic Soccer

Traditionally, we think of robot as mostly independent individual capable of interacting with its environment. On the other hand part of robot's surroundings can be another robot and when there is some kind of communication between them, robotic social interaction takes place. In this case we must see the robotic system as group of individuals and take care of emergence of their individual behaviors.

Good tool for development and testing of individual and social behavior of robots is robotic soccer [7]. It allows easy generation of various situations and comparison of effects of their control mechanism by playing against each other.

Robotic soccer is a game between two teams of robotic soccer players. Object of the control is a robotic soccer team with 5 members. A robot has two wheels as a transportation device, radio-transmitter for communication and 16 bit control unit used for basic control of electric micro engines (Image 2). The robot itself does not have any input detecting element, the only input to the robotic system is camera with image recognition (Image 1). Part of the system is also main PC machine with higher levels of the control and with image recognition [1].

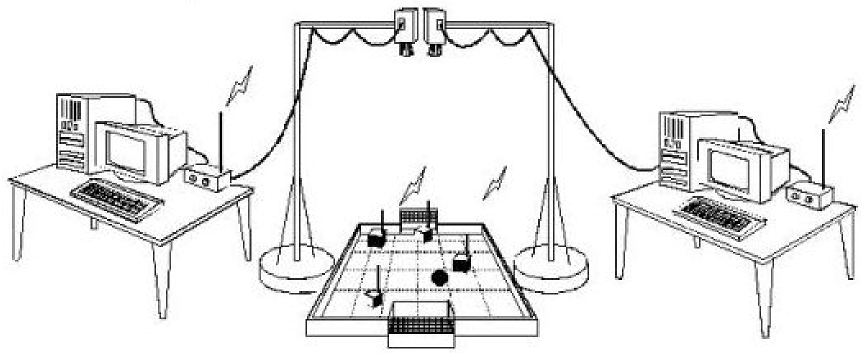

Image 1
Robotic Soccer Control

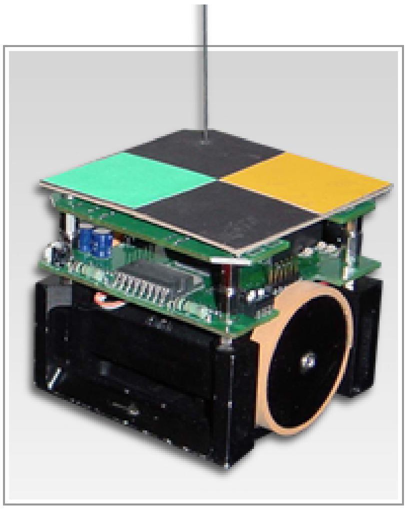

Image 2
Soccer Robot

3 Multi-Agent Fuzzy Expert System

The fuzzy reasoning approach is motivated by following advantages:

- Providing an efficient way to cope with imperfect information [2].
- Offering flexibility in decision making process and it gives interesting human - machine interface by simplifying rule extraction from human expert [2].
- Knowledge base of expert system contains explicit expression of the domain expert knowledge [3].
- Connection of principles of expert systems and fuzzy logic brings capability to work with explicit knowledge in form of rules and also handle uncertain terms that often emerge in the domain of robotic soccer. Example of such rule is: *If ball is far away and opponents are close, then run fast.*

Expert knowledge often has to deal with uncertain knowledge. This especially applies to knowledge in robotic soccer domain, where we woks with terms like ‘close’, ‘left’ and similar. Fuzzy logic allows us to work with this kind of information.

Soccer game contains more entities by its definition. In robotic soccer there are more robotic players and each has its own task and requires different approach and knowledge base. It is clear that we cannot think of soccer team as one single object. Multi-agent theory allows us to dissolve problem into several entities and think of every part of relevant knowledge separately.

Design of the multi-agent system is composed from more type of agents [4]. Each one has its role in decision process. Their independence allows good decomposition of the problem and on the other hand their cooperation allows back emergence of their contributions to complete control system. In the multi-agent system for robotic soccer control we need more types of reasoning agents and some kind of broker agents that should provide communication, synchronization and caching information.

Definition in [5] states that 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 .In our case, autonomous agent is agent containing fuzzy expert system for reasoning.

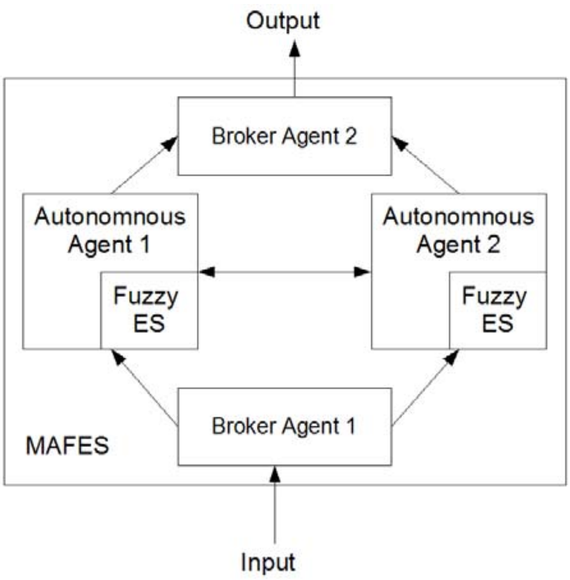

Image 3
Multi-Agent Fuzzy Expert System

General information about broker agents can be found in [6]. However, in this work we use term 'broker agent' more intuitively. Purpose of broker agent in our apprehension is to collect data from other sources and provide them for other agents. They do not perform any reasoning by themselves.

We have stated following definition: System using multi-agent distributed architecture, expert system and fuzzy inference mechanism we call multi-agent fuzzy expert system (MAFES).

Example structure of MAFES is presented on Image 3.

4 Components of the System

When we were looking for role models for multi agent system for robotic soccer control, ideal place for that was real soccer match with real people which created the soccer match together. The game is not crated only of players on the field but also coaches, referees, audience even people that work on television transmission allowing us to see the match at home are included in whole process. Taking in mind these facts, our system of control contains following entities: Player Agent, Coach Agent, Television Agent and Postman Agent.

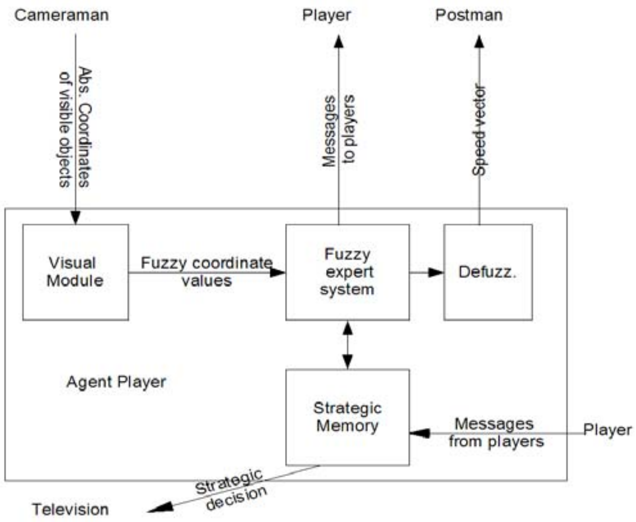

Image 4
Player Agent Structure

Player Agent represents a person that has contact with the ball. It emulates human abilities to get to the best position, acquire ball, pass to other player or shoot to the goal. Player can play role of goalie, attack or defense.

Player's ability to see in Player Agent is implemented as *Visual Module*. Purpose of the Visual Module is to receive absolute coordinates from agent Cameraman, transform them into radial form and insert fuzzified information into inference system.

Every object, visible to the Player is transformed into radial coordinates which are more close to human perception. In common thinking we see object 'close', 'far', 'forward' or 'left'. Each of these terms can be expressed as fuzzy set.

Capability to receive messages from other Player agents and agent Coach can be compared to real men's ability to hear. This kind of agent's input can be used to take in mind intentions and states of other agents. For example, when robot gets the ball, it can be announced and rest of the team can remember his announcement and focus on obtaining better positions in playground received from agent Coach.

Strategic memory stores states of the game. We can use it for remembering data that does not change every round of decision cycle like intentions of the robot, its strategic target or relevant announcements from other agents. Unlike expert system's data base, contents of strategic memory are preserved during the game to precisely mirror strategic situation.

Contents of the strategic memory are changed by receiving messages from other players (someone from the team have received the ball) or when change of the game situation is detected in the reasoning process (e.g. ball suddenly appeared in front of player). State diagram is shown on Image 5.

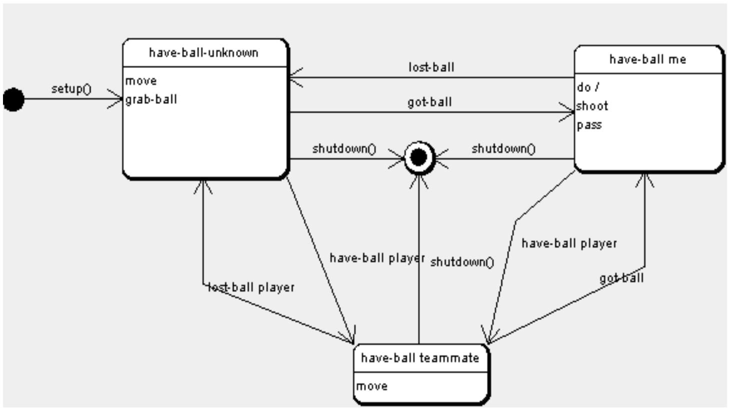

Image 5
States of the Player Agent

Player's skill to play soccer is apprehended as ability to process visual information and resolve it into action. When we take visual and hearing input, reasoning using player knowledge should lead into deducing desired player's action.

This action is then executed by the inference system and speed vector is produced. This vector then can be sent to other agents for further processing.

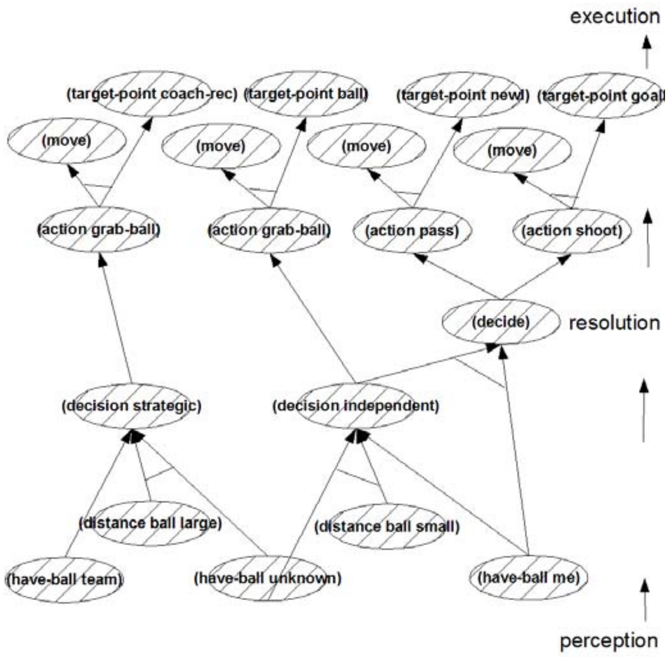

Image 6
Player Agent Resolution Process

First part of *inference process* is that, visual information and recommended position information from coach is processed and inserted into inference system. Every Player has also strategic memory that contains data about current play situation and action from last round. Contents of strategic memory are inserted into inference engine too. This step is called *perception*.

Next, in *resolution* step inference system takes inserted data from data base and decides action that player has to execute. Decision can be deterministic, when certain action must happen every time or stochastic, when player can choose from several possible actions. Stochastic decision can be influenced by control parameters, when we can set preference to certain actions. These parameters can express player's individual characteristics (team play, agility...). Part of Player's knowledge base related to resolution step is displayed as decision tree on the image.

Last step is called *execution*. In this step resulting action and its target point (ball or recommended position) is taken and by using Mandani's fuzzy inference we obtain speed vector. This vector is result of the whole inference process.

Thanks to fuzzy inference system fuzzy knowledge can be included in every part of the inference. For example, target point's coordinates are expressed in fuzzy manner.

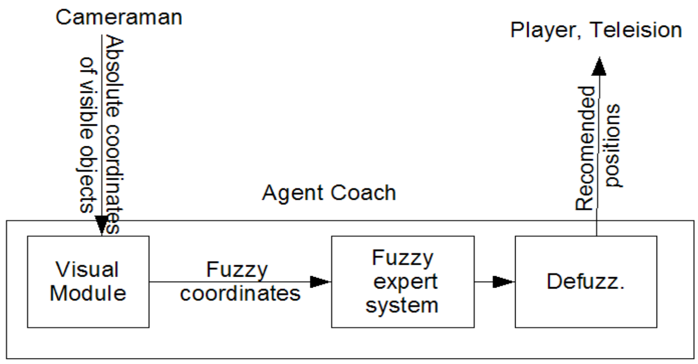

Image 7
Agent Coach Structure

Agent Coach stands as director of the team. Coach does not play by himself and this allows him to see the whole playground and focus on strategy of the team. Coach agent represents ‘team play’ or strategic knowledge of the team. He evaluates current play situation and shouts to the players what they should do.

Agent Coach, unlike Player, can see the playground from bird's eye. This approach brings better focus on strategic parts of soccer knowledge. Coach works with terms like ‘penalty area’,’center of the field', ‘left side’ etc. These terms are used to construct Coach's linguistic variables. Agent's visual module takes absolute coordinates, fuzzifies using linguistic terms stated above them and inserts in the inference engine. Result of Coach's inference is the set of recommended positions for agents of type Player.

Agent Cameraman sends message containing coordinates of all visible objects to all agents that contain some kind of perception of visual information, Cameraman's messages can also serves as synchronization signal for the whole system. Every time when autonomous agent receives new visual information, it can run a new round in its reasoning.

Regular cameraman has electronic device for scanning the playground and sending the image for the further processing to TV. Purpose of Agent Cameraman is to deliver visual information of the playground to agents that need it. He does not have any decision abilities; his purpose is just caching and delivering visual information.

Agent Postman does not have its role model in soccer match. Postman just serves as a buffer for gathering information about results of decision from the players. He can send processed and synchronized outputs to the outside world from the system.

He was arranged more likely from implementation reason rather than conceptual. But this agent is very simple and does not contain almost any logic.

5 Implementation

When we put all entities together and watch their operation, general view on the flow of the signal in the designed MAFES is showed on the image and can be described in following way.

Every agent in the system has his own name. We have more Player Agents and they have been named according to first five alphabet letters: Adam, Brano, Cyril, Daniel, Emil.

Signal from image recognition goes to the agent Cameraman. This agent translates it to the understandable form and sends it to Agent Coach and agents Player. Agent Coach resolves and deduces recommended positions for Players. Agent Player takes in mind recommended position from agent Coach and positions of other objects and infers its speed vector. Speed vector goes into Agent Television and agent Postman. Agent Television displays current positions of visible objects and results of inference of autonomous agents Agent Postman then collects speed vectors form agents of type Player and each one transforms into a pair of speed values, which is output of the control system.

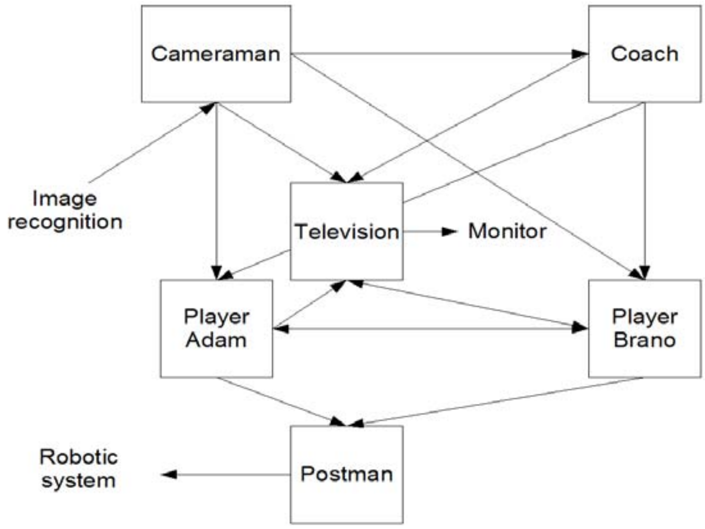

Image 8
Soccer Agent Team

Image 8 shows simplified structure of the whole designed control system. For the sake of simplicity, some agents of type Player have been excluded. More general view to the structure provides Image 3.

Implementation of the system was made by using Java programming language, JADE agent platform, Jess expert system and FuzzyJ – fuzzy Jess extension.

Graphical output of the agent Television is shown on image. It is called SAT – Soccer Agent Team. Its purpose is to serve as tool for validating proposed concept and serve as basis for further research.

In its current form, SAT is not focused for the control of real robotic soccer, but it works as pure simulation. Instead of acquiring data from OCR, they are directly generated by agent Cameraman. Output of the system is sent form agent Postman to agent Television to be displayed. Knowledge for the Jess expert system is written in the CLIPS language. Each autonomous agent can have its own rule base, but in this implementation knowledge base is common for every Player agent.

6 Experiments

Experiments were done in the implementation of designed control structure called SAT. In performed experiments we have observed following values:

- Optimal sample time of the control system
- Accuracy of deduced speed vector
- Group behavior of agents

We have prepared these simulated game situations:

Test	**Situation**
Direct	Ball goes from our half through whole playground
Across	Ball goes from opponent's right corner to the our team's left corner
Sine	Ball goes to opponent's half following sine trajectory

Every robot has prescribed constant speed and infinite acceleration. Opponents were not taken into account. Reference platform is PC Intel Celeron 2000MHz, 512MB RAM.

First experiment was focused on obtaining optimal sample time. Optimal sample time means time, when the system is usable for control of the robotic system. We have run SAT simulation with various sample times on all simulated situations and observed system behavior.

We have discovered that value of the sample time for the control system critical stability on this hardware is 170ms. Under these conditions agents incline to gain oscillations in their trajectories (Image 10). Higher values are acceptable for control; lower values of sample times are unacceptable.

When the sample time was too small, insufficiency of the computing power causes loss of messages in the multi-agent system container. Delay in reasoning is then too large; agent starts to lag in its function.

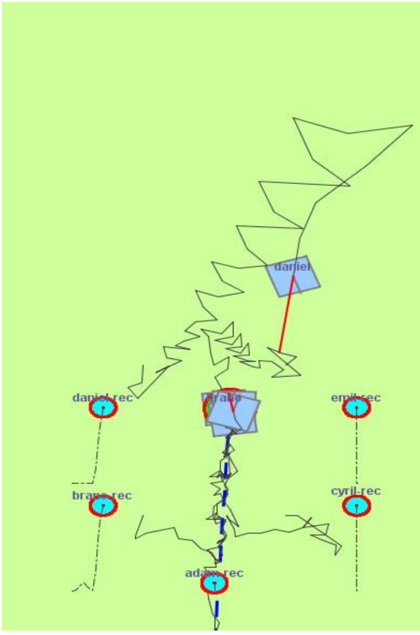

Image 9
Unstable system behavior

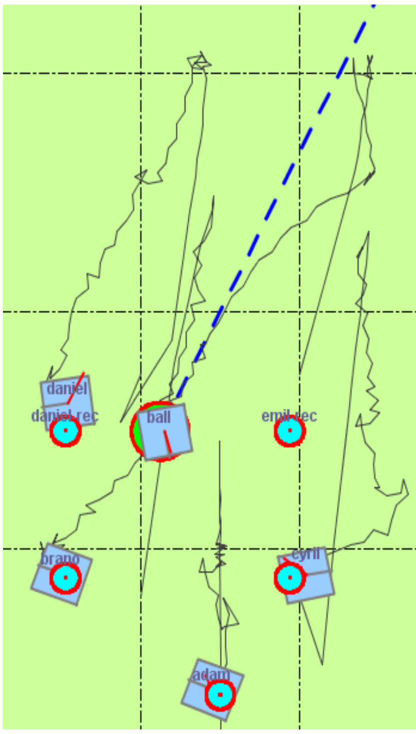

Image 10
Group cooperation in SAT, system stable

We have observing optimal sample times on various platforms. Results are shown on table:

Hardware	Critical Sample Time
AMD 800, 256MB RAM	300ms
Intel Celeron 2000, 512MB RAM	170ms
Intel Centrino Duo 1600MHz, 1GB RAM	70ms

Next experiments were run with sample times 100, 170 and 500 ms and were focused on observing angle of speed vector accuracy. On low message loss obtained accuracy is substantial for robotic soccer control and varies from 5 to 10 degrees. Results are displayed on Image 11 and 12.

Then we were observing group behavior and internal states of agents as it was displayed on the screen of agent Television. To get interesting situations we were running ‘Across’ and ‘Direct’ game situation. Again we have noticed that relevance of internal states and delay in reasoning according to actual game situation depends on message loss. On low message loss we have achieved group cooperation o conflict.

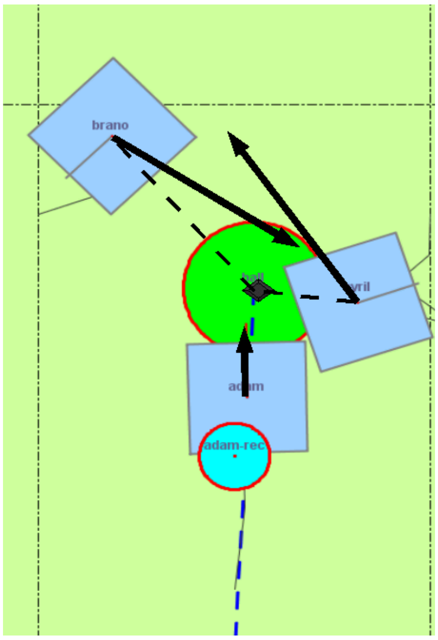

Image 11
Accuracy on the ball target

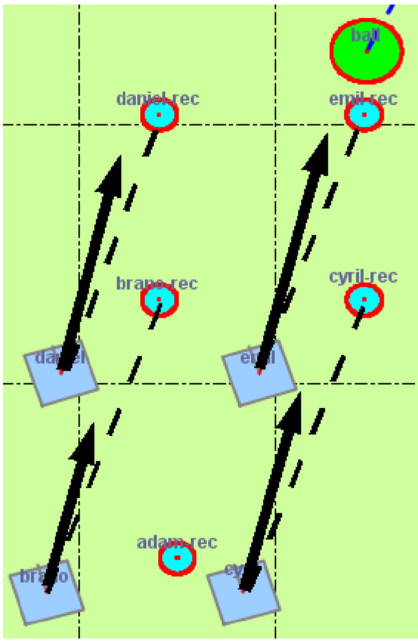

Image 12
Accuracy on recomended position

1) *Cooperation:* The ball was followed by only one agent, Rest of the team heading to their recommended positions from agent Coach. When the ball was faster that Player agent, after reaching critical distance it returned to its recommended position. We have obtained this behavior in the most cases. (Image 9)
2) *Conflict:* The ball was followed by two or more agents. After some time one of the agents decided to leave the ball and returned to its recommended position. Agents were more liable on conflict when message loss was bigger and internal states were delayed.

Experiments have shown that the weakest point of this implementation and approach is in synchronization. Message loss on lack of computing performance causes pauses in reasoning and agents are forced to wait for each other.

Results on reference hardware platform are compiled in the table:

Sample Time	Message Loss	Behavior	Accuracy	Delay
150 ms	High	Confused	Low	High
170 ms	Low	Confused	Varies	Low
500 ms	None	Regular	Sufficient	None

Conclusion

We have proved, as the results of performed experiments show, that this approach is usable in area of robotic soccer control. Major enhancements consist of good group cooperation, conflict resolution and intelligent behavior of robots in the robotic soccer game. Expert knowledge can be easily transferred into rule base of the control system.

However, experimental implementation in this form is still not capable of control of the real robotic soccer match. Reason is, as shown in experiments, performance of the system s still not good enough. Necessary areas of improvement are in synchronization of agents and knowledge base.

We hope that our approach would be useful not only in the field of robotic soccer but also for research of multi agent technologies, expert systems and fuzzy logic. This methodology could be used as a starting point in development of arbitrary multi-agent system for group coordination, decision support or cooperation of multiple entities on common task.

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