Biomimetic control architecture for robotic cooperative tasks

Nicu George Bizdoaca*, Hani Hamdan**, Daniela Coman*, Anca Petrisor*, Elvira Bizdoaca*

*University of Craiova, Mechatronics Department, Romania
**SUPELEC, Dept. Traitement du Signal et Systèmes Électroniques, France
(Tel : +0402514396999; Fax : +040251438488)
(nicu@robotics.ucv.ro, Hani.Hamdan@supelec.fr ,)

Abstract: The paper proposes control algorithms applied to MIROSOT robot league architecture. The MIROSOT league soccer game concept is fairly simple: two teams of robots, with tree/five robots per side which play football completely autonomously. The ball that the teams play with is an orange golf ball. Above the pitch is a machine vision camera running at 60 frames per second. This camera is linked back to a server which then calculates the positions and velocities of each of the robots and ball, from which it determines what each robot should be doing. These instructions are then communicated to the robots over a wireless link. In order to develop an efficient control strategy and architecture it has to use the strategy from the real human soccer game. Using software Simi Scout a suitable tactics analysis can be extract from the games. Analyzing the soccer game, a number of attributes are specified and are embedded at different levels. The specified levels are interconnected and the game analysis is processed for optimization. Using this information the robot program is adapted and the tests/games are experimented. The soccer robots software is composed by three parts; FindObjects () that determines the position of the robots and the target, My_Strategy () that defines the strategy to solve the player role and Send_Command () that sends out the commands for controlling the robot. Among these functions, FindObjects () is the function dealing with the vision program. The upper level is team strategy level witch distribute the players role. The results are commented and improved control architecture, based on practical results, is proposed.

Keywords: robotics, biomimetic approach, cooperative tasks**.**

I. INTRODUCTION

The nature's inventions have inspired researchers in developing effective algorithms, methods, materials, processes, structures, tools, mechanisms, and systems. Biomimetics is a new multidisciplinary domain that includes not only the uses of animal-like robots – biomimetic robots as tools for biologists studying animal behavior and as research frame for the study and evaluation of biological algorithms and applications of these algorithms in civil engineering, robotics, aeronautics. Multi-agent system has emerged as a subfield of AI and helps to understand and provide with theory and principles for constructing complex systems with multiple agents and their coordination/competition in dynamical environments. The robot soccer game is an interesting benchmark problem for the multi-agent systems.

Generally spoken in robot soccer regarding the division of labor between the components of a soccer team, namely between the host computer system and the autonomous mobile robots, three system configurations are defined: 1. Remote brainless system; 2. Robot-based system; 3. Vision-based system.

The vision-based system can be described as the step from the remote brainless to the robot based system, as some of the intelligence is transferred from the main computer to the single agents, but the control of the vision system and the strategic coordination still remain tasks of the host unit.

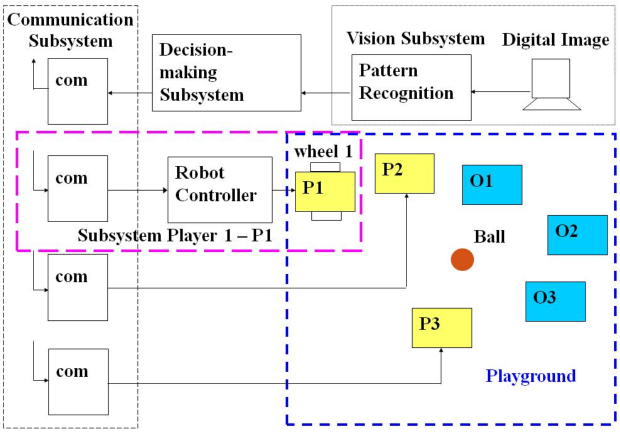

Fig. 1. Soccer robot architecture.

The Micro-Robot' World Cup Soccer Tournament (MiroSot) is the brainchild of Jong-Hwan Kim [1] of KAIST, Korea and was initiated in 1995. A mobile robot soccer team consists of up to three micro mobile robots. Two teams play soccer according to the rules similar in nature to the real soccer game. The Federation of International Robot Soccer Association (FIRA) has established these rules.

Above the field (at the height of approximately 2 m) an industrial camera is mounted.

The mechanical construction of the micro mobile robot is based on a duralumin frame, on which two DC motors with gear boxes and a controller board are mounted.

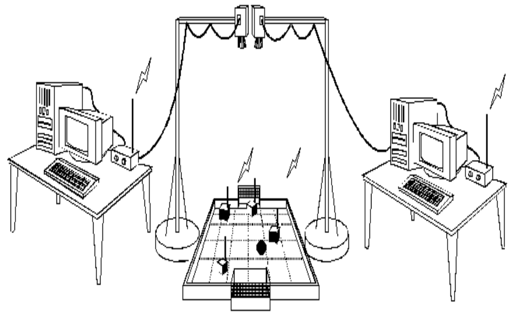

Fig. 2. Soccer robot system with the vision system, host computer and RF communication system.

Robot has two parallel wheels and in addition is suspended by two slipper elements mounted at the front and back part of the frame.

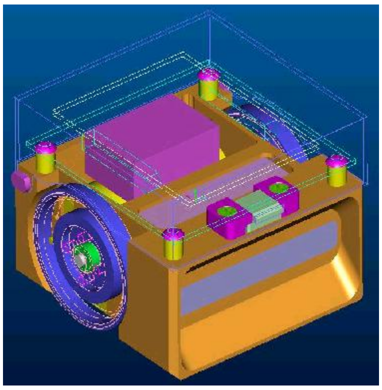

Fig. 3. The soccer robot CAD– Yujin Company

The basic features of the micro mobile robot are:

- dimensions: 7.5×7.5×7.5cm,
- weight with batteries: 0.43kg,
- maximum velocity: 1m/s,
- maximum acceleration: 0.75m/s

II. POLLING ROBOT SOCCER STRATEGY FROM THE REAL SOCCER GAME

The soccer robot game structure has 6 steps:

Step 1: Image acquisition and primary calculation (distance, velocity, relative angle calculation etc.)

Step 2: Decide which posture is suitable for player offensive or defensive.

Step 3: Determination of team strategy and player profile assignment.

Step 4: Determination of the target position.

Step 5: Path planning.

Step 6: Calculation of the wheels' moving direction, velocity and displacement.

In order to have a successful team the secret are: good player's profile, good team strategy.

The player profiles are:

- Attack
- Midfield
- Defender
- Goalkeeper

Using Simi Scout a real game is analyzed and the player profile is extracted (for this example is used Romania Columbia, 1994, soccer game, and for players profile, is used Romanian player profiles)

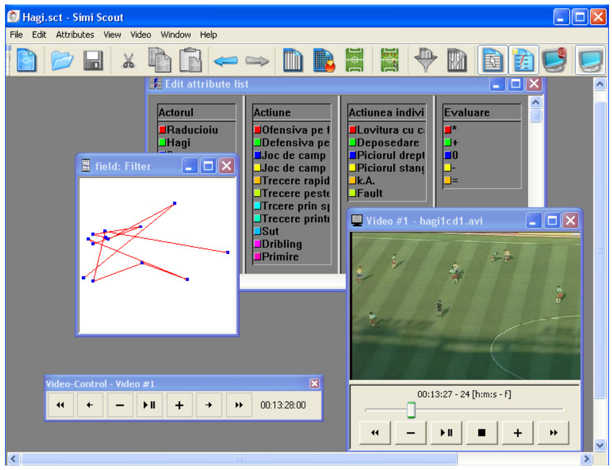

Fig. 4. SimiScout analise for soccer game Romania-Columbia

Using the real game information, the player situations can be extracted. Let's analyse , in detail, the strategy for **Attack player** [2]**.**

Assuming that the left half of the playground is the opponent side, it is reasonable that the attacking player must move to the right side of the ball as soon as possible.

The Petri net model [3] for the attacking soccer robot modeling the real situation, has been designed so that the topology to contain the following situations in which the attacking robot can be, as follows:

a) the attacking robot is behind the ball;
b) the attacking robot kicks the ball;
c) the attacking robot is in offside position;
d) the attacking robot is in contact with ball and the ball is situated behind the robot.

In state (a) the attacking robot is in a probable position to kick, in state (b) it is kicking the ball, in state (c) it is in front of ball, so should be careful to avoid the offside position, and in state (d) it is in contact with ball.

With these four states, the Petri-net for the attacking robot controller is formed. "Angle" is used to refer to the angle between the heading direction of the attacking robot and ball. "Distance" is used to refer to the distance between the attacking robot and ball in pixels. In state (a), the attacking robot is ordered to move to ball and kick it. In state (b), if "Angle" is above 45° , or "Distance" is more than 20 pixels, the attacking defense robot goes to state (a). In state (a), if the ball is on the right side of attacking robot (offside position), it should go to state (c). In state (b), if the attacking robot fails to kick the ball, the robot goes to state (c). In state (c), the attacking controller orders the robot to move sideways and it comes behind the ball without touching it and goes to state (a). In state (c), if "Distance" is below 10 pixels, the robot goes to state (d), so it should move away from the ball till "Distance" is above 20 pixels and then can get into state (c).

Analyzing the situations for Goalkeeper player, for Defender and for Midfield we can generalize the situations as:

p_1) the robot is behind the ball;

p_2) the robot kicks the ball in the opponent direction;

p_3) the robot is in unwanted position;

p_4) the robot is in contact with ball and the ball is situated behind the robot.

Using Simi Scout a set of attributes are assured. Statistically, after analyzing the all attributes proposed, only 7 are retained and become transition for our algorithm:

t_1 : tries to kick the ball, though it is not in a good position to kick,

t_2 : in front of the ball and at the following instant it is in a good position to kick,

t_3 : in front of the ball, and moving to an unwanted position,

t_4: in unwanted position and escaping from that,

t_5 : misses the ball, and is in front of the ball,

t_6 : in unwanted position, and then in contact with the ball and behind, and

t_7 : away from the ball and behind, but still in an unwanted position.

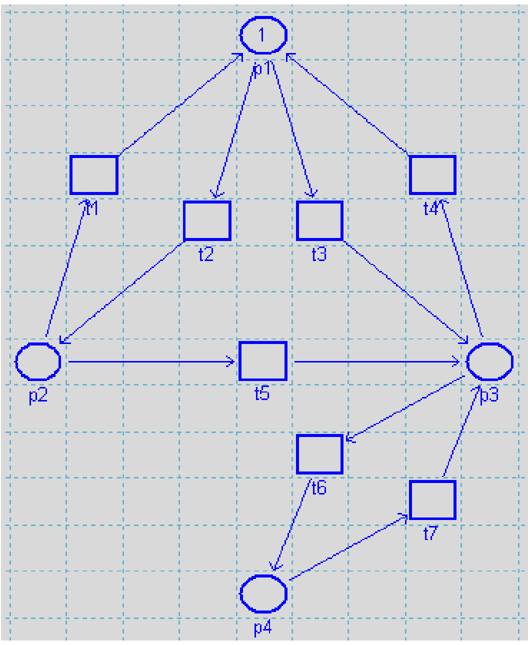

Fig. 5. Petri net model for the soccer robot

As every robot has the same strategy, the role for attack, defender, midfield or attack can be easily switched between the robots. The roll will be assigned dynamically, be image analyze.

A role assigned it is means that the intervention area of the robot is in:

- Attack Area
- Midfield Area
- Defense Area
- Goalkeeper Area

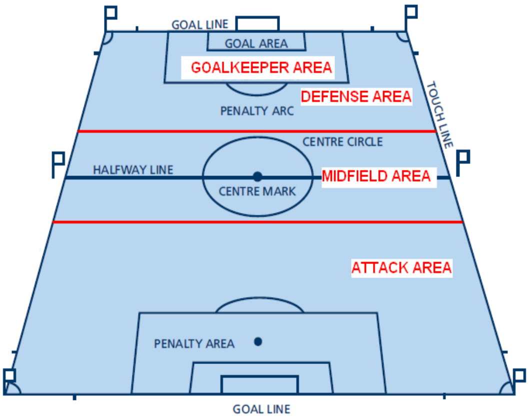

Fig. 6. Playfield division areas

The ball position will switch the team strategy.

The team strategy extracted (from Romania – Columbia 1994 - soccer game - using Simi Scout software) is:

- If the ball is in attack area then 2 player are attack player, and the nearest player to midfield area is midfield
- If the ball is in the midfield area, then 2 player are midfield player, and the nearest player to defense area is defender
- If the ball is in defense area, then 2 players are defense player, and the nearest player to goal area is goalkeeper.

III. NUMERICAL SIMULATION AND EXPERIMENTS

The results from the mathematical method of checking through the invariants method associated transitions and the corresponding positions after calculating the incidence matrix of the net have been validated through the simulations using Petri Net Toolbox in Mat lab environment.

It was validated in this way that the net topology, the evolution of (their dynamics), as well as structural and behavioral properties. The following two tables (Table 1- Global Statistics Places and Table 2 - Global Statistics Transitions) present the complete lists of global indices associated with the places and the transitions considered in the architecture of Petri net that modeling the controller for attacking robot.

Table 1. Global Statistics Places

Place Name	Arrival Sum	Arrival Rate	Arrival Dist.	Throughput Sum	Throughput Rate	Throughput Dist.	Waiting Time	Queue Length
p1	100	1	1	101	1.01	0.9901	0.9901	1
p2	51	0.51	1.9608	50	0.5	2	0	0
p3	149	1.49	0.67114	149	1.49	0.67114	0	0
p4	74	0.74	1.3514	74	0.74	1.3514	0	0

Also, the special options of Petri Net Toolbox, which confers a high capacity of analysis, has made possible a synthesis of this Petri net model which allows exploring the dependences of global performance indicators associated with the net positions/transitions on two "Design Parameters" (being considered places p_1 and p_4) for the various parameters of the simulation.

Table 2. Global Statistics Transitions

Transition Name	Service Sum	Service Rate	Service Dist.
t1	25	0.25	4
t2	51	0.51	1.9608
t3	50	0.5	2
t4	75	0.75	1.3333
t5	25	0.25	4
t6	74	0.74	1.3514
t7	74	0.74	1.3514

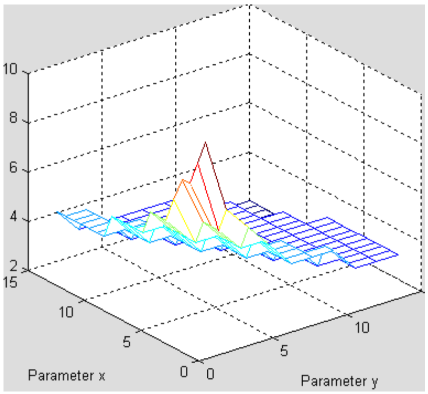

Fig. 7. Dependency of the Service Sum index associated t_2 transition

IV EXPERIMENTAL RESULTS

The experimental results obtained by applying the proposed method for the attacking robot are presented in snapshots Fig.8 and Fig.9. It is used three robots having the yellow team color, the ball having the orange color and the playing field with the color black.

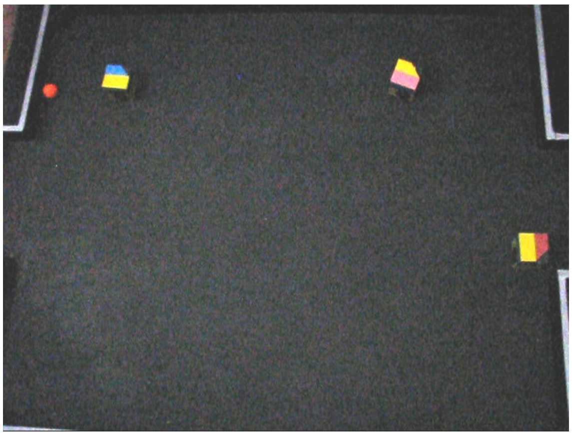

Fig. 8. The midfield robot become attack robot and goes to t_1 transition

The blue robot color is assigned as attacking robot and moves to the ball and then shoots it into the goal successfully.

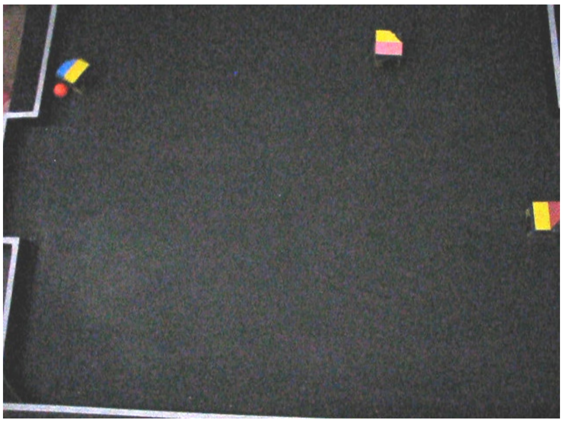

Fig. 9. The attack robot goes to t_2 transition

V CONCLUSION

The research proposes a biomimetic algorithm based on analyzing the real situation [4]. In this paper, a Petri net model is used for designing a low level controller for the soccer robots. The presented controller did not use the information of opponent team. A future development of this research will add the opponent predicted strategy and a more dynamical switching strategy. Using a single model robot controller offer advantages in terms of implementation, but the team strategy can be easily indentified by the opponent and annihilated. The Petri net model presented is implemented in MATLAB environment. The simulations studies was validated that the net topology, the evolution of (their dynamics), as well as structural and behavioral properties and was provided the global performance indices associated with the places and the transitions and also the whole set of global indices associated with all the nodes of the net. Finally, the feasibility of the proposed architecture is demonstrated by the experimental results.

ACKNOWLEDGMENTS

This report is part of the ROMANIAN NATIONAL UNIVERSITY RESEARCH COUNCIL (CNCSIS) contribution to the project PNCDI – II - 289/2008.

REFERENCES

[1] Kim J. H., Kim D.H., KimY.J., Seow K.T., Soccer Robotics, Springer-Verlag, 2004.
[2] Coman D., Using Petri Nets in the Soccer Robot Control Architecture, Annals of DAAAM for, 2008, pp. 295 – 296.
[3] Peterson J. L., Petri net theory and modelling of systems, Prentice-Hall Inc., 1981.
[4] Bîzdoacă N.G., Degertu S., Diaconu I. – Behavior based control for robotics demining – International Symposium on System Theory, SINTES 12, 20-22 octombrie 2005, ISBN 973-742-148-5, 973-742-152-3, pp. 249-254.