The RoboCup Domain as Foundation for Practice Based, Research Integrated Studies in Electrical and Computer Engineering

Reinaldo A. C. Bianchi

***Abstract* — The RoboCup Soccer Domain, which was proposed in order to provide a new long-term challenge for Artificial Intelligence research, constitutes real experimentation and testing activities for the development of intelligent, autonomous robots. At the Faculdade de Engenharia Industrial we are developing a project in this domain aiming the integration of undergraduate students with research in an active and cooperative learning environment. There are several students working part time on the project, designing the robots and implementing control and computational vision software. We conclude that undergraduate students have great interest in research projects and should be involved in real research agendas.**

***Index Terms* — Active & Cooperative Learning, Practice–Based Engineering & Computer Education, Undergraduate Research Experiences, Artificial Intelligence, Autonomous Robots.**

I. Introduction

Modern Artificial Intelligence textbooks such as Russell & Norvig [1] started to present this course from an unifying point of view, allowing the typical problems of the field to be approached by multiple techniques. This is the result of the belief that AI must not be seen as a segmented domain.

According to this tendency, the application domains that are being probed are also changing. In the games sub-field, a traditional AI domain, the creation of a chess player program that is better than a human champion is not a distant goal but a reality: new domains became a necessity.

The RoboCup – Robotic Soccer Cup – domain was proposed by several researchers [2, 3] in order to provide a new long-term challenge for Artificial Intelligence research. Soccer games between robots constitute real experimentation and testing activities for the development of intelligent, autonomous robots, which cooperate among each one to achieve a goal.

Some of the reasons why the RoboCup Domain must be considered as a Foundation for Practice Based, Research Integrated Studies in Electrical and Computer Engineering are presented by Verner [4]. They are:

- the majority of team members are graduate or undergraduate students;
- RoboCup offers the students the possibility of working with a wide range of modern technologies, and;
- Most of all, RoboCup provides an exciting learning environment in which new educational approaches may be developed and examined [4, pg. 47].

The purpose of this paper is to present a project in this domain that is under development at the Faculdade de Engenharia Industrial - FEI - with the aim of integrating undergraduate students with research and providing an active and cooperative learning environment. It started in 1999, with a selection that attracted more than 40 students only from the computer engineering course 4th year.

This paper, which describes the initial results of this project is organized as follows: section 2 describes the RoboCup Robotic Soccer domain; section 3 presents related work in the use of RoboCup in education. Section 4 describes current Scientific Initiation projects at FEI and section 5 presents the use of RoboCup related material in the computer engineering course. Finally, section 6 presents the conclusions of this work.

2 The RoboCup Robot Soccer Domain

Soccer games between robots are a way to foster a scientific and technological spirit in the younger generations. The development of soccer teams includes more than the simple integration of AI techniques. According to Kraetzchmar [5], "Mechatronic devices, specialized hardware for controlling sensors and actuators, control theory, sensor interpretation and fusion, neural networks, evolutionary computation, vision, multiagent cooperation are examples for fields strongly involved with the RoboCup challenge".

Annual competitions already exist, being held in conjunction with important events of the Artificial Intelligence and Robotic areas, where the developments in this type of application are most observed. Every 4 years the RoboCup World Cup is being held together with the real Soccer World Cup, in the same country. Thus, in 1998, the

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RoboCup was held together with the FIFA Soccer World Cup, in France, sponsored, among others, by FIFA. The First Brazilian Robotic Soccer Cup was held from March 23 to 25, 1998, at the Escola Politécnica da Universidade de São Paulo. Six teams from Brazilian Research Institutes and Universities took part of the tournament. The second Brazilian Robotic Soccer Cup was held last year in Porto Alegre.

The RoboCup have several competition Leagues that differs among each other due to the size of the robots and the presence or not of a central computer. The physical platform of the RoboCup *Small League* is constituted by a field for the game, plan, with the dimensions of 150x90 cm (similar to a table tennis). For each team there is a video camera and respective image acquisition system, one computer, data-communication system and up to 5 robots. The maximum robot dimensions depends on the league and ranges from 7.5x7.5x7.5 centimeters (in the Micro Robot League) to an area of 2025 cm^2 in the X-Y plane, with a maximum height of 80 cm and maximum weight of 80 kg (in the Middle Size League). The robots in the Micro and Small Size League are usually composed by 2 electrical motors controlled by a microprocessor, battery and wireless communication system. Robots in the Middle Size League are usually autonomous, with cameras and computers on board. Figure 1 presents the basic sketch of the system and figure 2 presents the winning team of the 1997 Cup, the CMUnited. The used ball in the games is an orange golf ball.

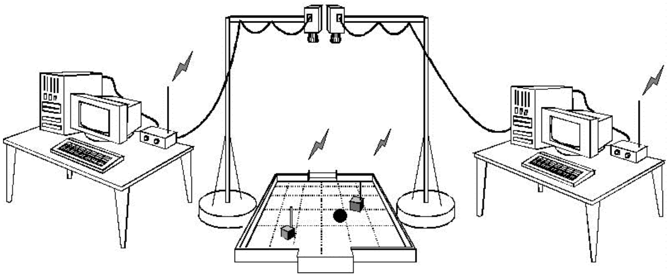

Fig. 1. Basic game setup presented in [6].

The operation of each teams follows one same basic formula: each team carries a image acquisition through its camera and then processes the picture using Computational Vision techniques to discover the position and velocity of all the robots and the ball. With this information, a decision system defines the best strategy to apply and the movements of each robot at a defined moment. In the Micro Robot and the Small League, all this processing is carried through in a central computer. With the decision of the robot movements, a radio based communication system sends for the robots a message describing the movements that must be done.

Among the challenges and problems that can be addresses in this domain, Shen affirms that “robot players in a soccer game must perform real-time visual recognition, navigate in a dynamic field, track moving objects, collaborate with teammates, and hit the ball in the correct direction.” [7, p.251]. To reach this goal the robots must be autonomous, efficient, cooperative, with of planning, reasoning and learning capabilities, and able to act under real time restrictions.

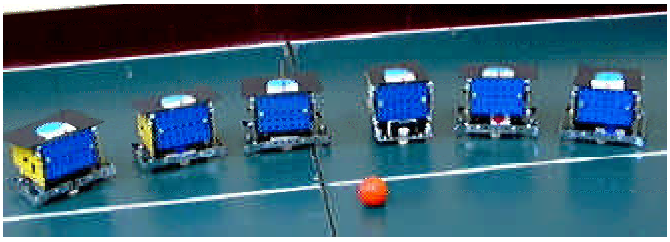

Fig. 2. The CMUnited'97 Small Size Team. [8]

Veloso et al. [8] affirms that “Robotic soccer is a challenging research domain which involves multiple agents that need to collaborate in an adversarial environment to achieve specific objectives. The fast-paced nature of the domain necessitates real-time sensing coupled with quick behaving and decision making. The behaviors and decision making processes can range from the most simple reactive behaviors, such as moving directly towards the ball, to arbitrarily complex reasoning procedures that take into account the actions and perceived strategies of teammates and opponents”.

This allows the competition among teams with diverse approaches and the measurement of their results, which can be done in an objective way: score and final position in the championship. In this domain the real time nature of the restrictions of is obvious: a system must be fast enough. If it take some seconds between the perception and the action the team will lose the game.

Finally, the Robot Soccer domain have been acquiring more importance each time in the area of Artificial Intelligence because possesses all the features found in other real complex problems, such as automation robotic systems, that can be seen as a group of robots carrying through an assembly task, or even space missions with multiple robots [9].

3. RoboCup in Education: Related Work

The development of an integrated robot team can be used as basis for Electrical and Computer Engineering and Computer Science practice based education as it is a multidisciplinary domain, which includes a variety of fields. Also, it motivates a large number of students due to its challenging nature and arousing public interest.

Work on the use of RoboCup for education has been done in two fronts: as an introductory research program for undergraduate students or as subject to be taken on AI courses.

The first is analyzed by Verner [4], who made a survey about the participants in 1997. According to this work, several features characterize the RoboCup Domain as a unique environment:

1. The learning subject comprises knowledge in hi-tech electrical, mechanical and computer engineering.
2. The learning method concentrates on practice in design, constructing and operating intelligent robot systems.
3. The training practice is a form of students’ participation in research and development of projects

that aim the implementation of a soccer game robot team.
4. The robot systems developed are discussed at RoboCup forums.
5. The domain reflects the state of the art in robotics and Artificial Intelligence.
6. It attracts wide professional and public interest. [4, p. 52]

The use of RoboCup in AI classes is analyzed by Coradeschi & Malec [10]. They present an AI Programming course organized around the RoboCup SoccerServer simulation system, aiming the study of knowledge based software systems, multi-agent theory, and other AI techniques. As results, the students found stimulating to implement a real system and were enthusiastic until the end. Finally, one of the teams created during this year course has won vice-championship of Sweden for year 2000, loosing only to a professional team. Two other teams have taken the 4th and the 5th place.

4. Scientific Initiation Projects

At the moment there are several students working part time on the project - four of them receiving science initiation scholarships - designing the robot and implementing control and computational vision software. At the same time, they are learning research techniques and how to work in a research group.

A. Genetic Programming Based Control

Genetic Programming [11] have become a widespread technique in the recent years. It is based on the implementation of programs that simulates the processes described on the evolution theory. In this approach, programs are treated as individuals, described as trees of defined functions. The fundamental process used to evolve programs can be described in the following steps:

1. Generate a random population of N processes, each one simulating an individual in a population;
2. Evaluate the fitness of each program;
3. Create a new population of individuals based on the reproduction, crossover or mutation of the best individuals of the current population and the removal of the most unfit;
4. If the current population has not reached a minimal pre-defined quality or a pre-defined number of cycles has not bean reached, return to step 2.

Genetic Programming is usually applied in a wide range of problems, such as control or search applications. Our target is the use of Genetic Programming to evolve individuals which are capable of playing soccer in the RoboCup domain.

As a first step in our study we built a wall following robot in a simulated environment, similar to the one described in [11]. Fig. 3 presents the result of this study, showing the path of a robot following the wall, where each step of the robot is marked with a higher gray level, resulting in a degrade path.

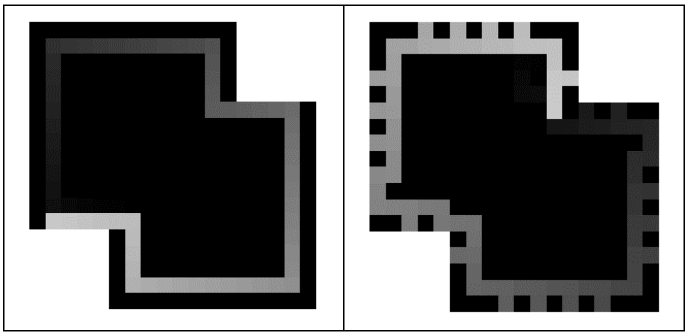

Fig. 3. Results of the wall following robot in 2 different configurations.

The next step is to develop a ball following robot and finally evolve team strategies.

B. Hardware Based Vision

The most time critical process of the Robotic Soccer is the discover of the position of the robots in the game. We are using hardware to compute the position and speed of the robots in the game, implementing Computational Vision – CV – algorithms in a FPGA circuit.

A Field Programmable Gate Arrays [12, 13] is an integrated circuit that can have its hardware designed by the user. It contains a large number of identical logic cells that can be viewed as pre-defined components, which combines a few inputs to one or two outputs according to a Boolean logic function specified by a user defined program. In its turn, individual cells are interconnected by a matrix of wires and programmable switches.

A user's design is implemented by specifying the logic function for each cell and selectively closing the switches in the interconnect matrix. This is done by means of a user program that defines the function of the circuit, usually written in VHDL (a high power Hardware Description Language).

The advantage of using a FPGA is that it gives hardware speed to user applications. As the computational power of these programmable logic devices is increasing (the maximum number of gates in an FPGA is currently around 500,000 and doubling every 18 months, while the price is dropping), complex applications are beginning to be feasible.

In this project we are translating well known Computational Vision algorithms to VHDL. The CV algorithms studied allow the definition of position of objects in an image and include Binarization of images, Limiarization, Edge Detection and Chain-Code Segmentation.

These algorithms are being tested on an ALTERA University Program Design Laboratory Package, which includes an MAX+PLUS II Development Software (Student Edition), one UP 1 Education Board and a ByteBlaster download cable.

The MAX+PLUS II software is a development system that includes design entry using graphical and hardware description languages, design compilation, design verification, and device programming. The UP 1 Education Board (Fig. 4) features two programmable and reconfigurable logic devices. Finally, the ByteBlaster allows the download of MAX+PLUS programs in the board.

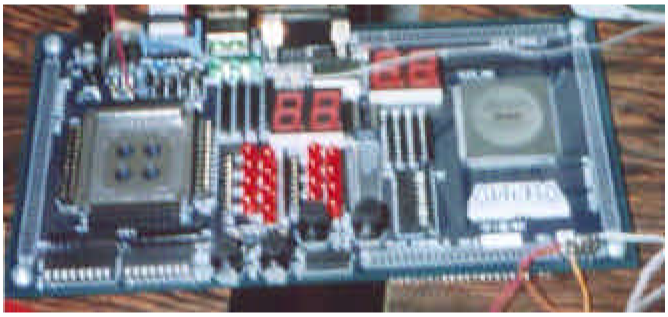

Fig. 4. The ALTERA UP 1 Education Board.

This part of the project is at the moment most active, and allows 3rd And 4th grade students to develop their skills in the design of digital circuits.

C. Step motor Controller

Finally, the construction of the physical robots is under development. We decided not to buy a market available robotic platform in order to allow the development of the students skills in digital and analogic circuits, power electronics, control theory, and even Mechatronic devices.

The first result is a step motor control hardware that gives high torque and high-speed results (Fig. 5).

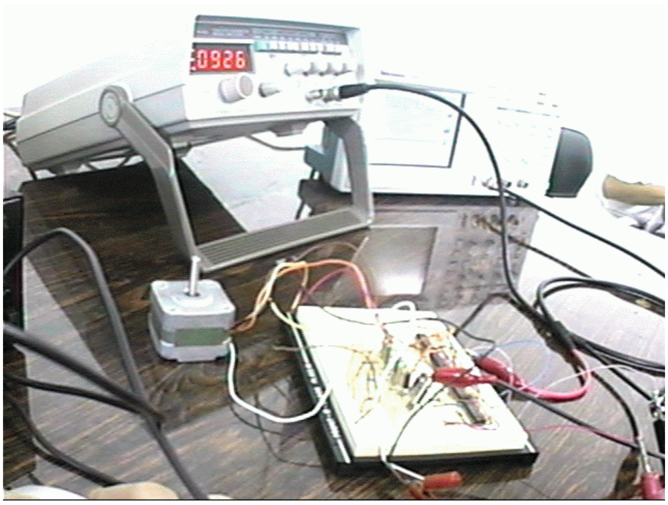

Fig. 5. The step motor controller.

5. RoboCup in the Classroom

Two courses (Artificial Intelligence and Computer Graphics) are using project results as classes topics.

In the first course we are testing the use of the RoboCup Soccer Server [14] as a study platform. This simulator (Fig. 6) is a system that enables autonomous agents programs to play a match of soccer against each other. A match is carried out in a client/server style: A server, SoccerServer, provides a virtual field and calculates movements of players and a ball. Each client is an autonomous agent that controls movements of one player. Communication between the server and each client is done via TCP/IP sockets. Therefore the clients can be written in any kind of programming systems that have TCP/IP facilities, such as UNIX (SunOS, Solaris 2, DEC OSF/1, IRIX, Linux) or Microsoft Windows.

The SoccerServer consists of 2 programs: a server program that simulates movements of players and a ball, communicates with clients, and controls a game according to rules and; a monitor program that displays the virtual field from the server on the monitor using the X window system.

The use of this server is still under evaluation: last term it was a suggested activity - not a compulsory task - due to difficulties in installing and executing the server. Because of these difficulties we are studying the use of other kinds of robotic simulators.

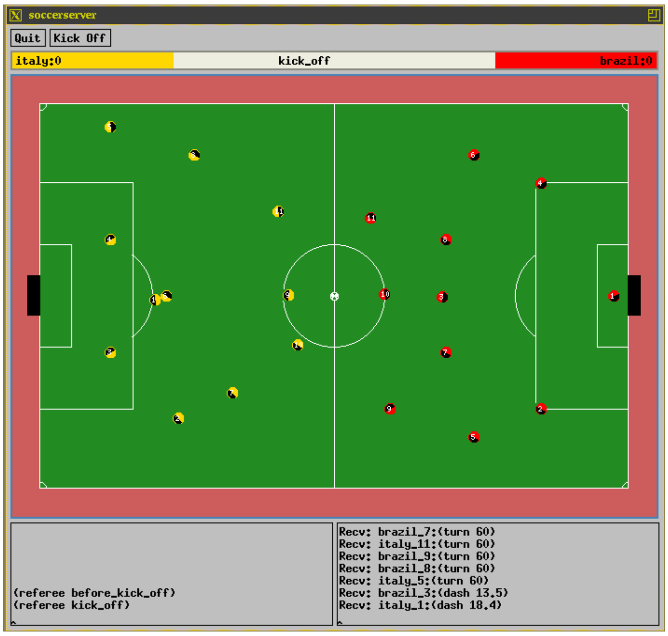

Fig. 6. The RoboCup Soccer Server - Screenshot [14]

Computer Vision and Genetic Algorithms used in the RoboCup domain are also being presented as AI classes examples.

In the Computer Graphics course the development of graphical simulations of the RoboCup domain by the students is being stimulated. Also, RoboCup is used as a example of Object Modeling.

6. Conclusion

We conclude that undergraduate students have great interest in research projects and are capable of defining and following real research agendas, as well as project the needed systems.

Among the methodologies and technologies the students have learned are: FPGA, VHDL, EDA, Digital Circuits, Step Motor Control, Artificial Intelligence, Computer Vision, Genetic Programming, Neural Networks, UNIX/Linux, C and

C++ Programming Languages, TCP/IP Network programming and Wireless Data Communication.

Finally, that the RoboCup Domain is a motivating practice based group activity that greatly improves students' skills.

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