Mixed Reality Competition:
FC Portugal Team Description Paper

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Abstract. . This paper introduces both the Eco–Be robotic platform and the RoboCup Mixed Reality Competition and the research under development on the FC Portugal team in the context of this league. The Eco-Bes and the Mixed reality competition present an immediate, simple application for developing complete teams for cooperative robotic applications. The Eco-Be is a very small mobile vehicle, also known as Citizen Micro robot, remotely controlled by infrared commands. This platform provides interesting possibilities like changing the robot's firmware and using complex external agents to control it. This robotic platform is used by all teams participating in the new soccer RoboCup league, which integrates in a single setup the real (robots) and the virtual (ball). In a practical way, soccer simulation merges with real robots creating a new appealing league. This paper describes the individual algorithms developed, as well as the functional setup built to validate these algorithms. The robots were evaluated through controlled experiments and competition experiments, proving their sufficient reliability. Despite the very short development time, the results achieved in RoboCup 2007 were promising; our team won the soccer competition and achieved a final second place at the global rank in the Physical Visualization League.

Keywords: Agents, Robotic Soccer, Eco-Be, Augmented Reality, RoboCup.

1 Introduction

The Physical Visualization (PV) Soccer League, now renamed as Mixed Reality Competition, is a new RoboCup league that started in RoboCup 2007. In this competition small, real, robots called Eco-Bes, play soccer on top of a virtual field with a virtual ball, thus using the concept of augmented reality [1, 2].

Augmented Reality is an environment that includes both virtual reality and real-world elements [3]. Most augmented reality research uses a processed video which is augmented with virtual elements. The Augmented Reality at Physical Visualization League can improve the simulation, adding virtual elements that surround the real player. An example applied in that soccer league is a virtual leg with the ability to kick and to dribble the virtual ball [4].

The Physical Visualization League and the Augmented Reality environment offer a very interesting challenge for our team. All of our main research interests are included in this setup (Vision Based Self Localization, Data Fusion, Real-Time Control, Decision and Cooperation) [5]. The simplicity of this setup compared with the small-size league, where we have a huge experience, makes it very interesting for educational and demonstration purposes.

After this introduction, the next section presents the FC Portugal team and respective research topics. The third section presents the developments and the research program of the team integrated in the Mixed Reality league. Section 4 describes the educational activities in the Mixed Reality environment at the two universities integrating FC Portugal. Section 5 presents FC Portugal's 2007 Physical Visualization Team, winner of the soccer tournament competition. Finally, section 6 presents the most relevant conclusions from our participation in RoboCup 2007 and discusses future approaches to the Physical Visualization / Mixed Reality League.

2 FC Portugal Team

2.1 Overview

FC Portugal research's main focus is on new coordination mechanisms for performing teamwork and on the creation of a general coordination model [6]. For the past years we have been researching several coordination mechanisms like: coordination by structural organization including a-priori common knowledge, role definition and exchange, partially hierarchical control, spatial positioning using formations and situation based reasoning; coordination by contracting; coordination by multi-agent planning including task decomposition and allocation; coordination by negotiation; coordination by communication; coordination without communication by mutual modelling and intelligent perception [7,8].

This research has been mainly applied on RoboCup with the development of new simulated/robotic platforms and robotic teams for performing complex tasks in dynamic open environments like the 2D simulation, 3D simulation, small-size, middle-size, Sony legged leagues and Physical Visualization. We have been aiming at developing a general framework for cooperative robotics and to apply the coordination, communication, strategic reasoning and tactical modelling methodologies developed for simulated environments (like RoboCup simulation league) in real environments and real robotic teams, trying to bridge the gap between simulation and robotics.

Our initial short-term main goals on this project were to build a fully functional team, able to competitively participate in the first PV League championship, integrating some previously developed coordination methodologies. Our long-term goals include the development of a common framework for cooperative robotics with transversal application in RoboCup, including small-size, middle-size and Physical Visualization leagues, and validating simulation models in mixed-reality settings. This setup will also allow conducting research on swarms of real robots.

2.2 Affiliations and people involved

FC Portugal is the result of a cooperation project between the University of Aveiro and the University of Oporto. Research is conducted in associated research institutes, IEETA in Aveiro and LIACC in Porto. The development of the FC Portugal Physical Visualization team that participated in the 2007 exhibition was performed by 3 undergraduates, 2 PhD students and 2 Faculty Staff members. Currently we have a total of 8 people that will be involved in the development of the FC Portugal Mixed Reality team for 2008. These 8 people include: 1 PhD student, 3 undergraduate students and 4 faculty staff.

2.3 Participation and results in past robotic competitions

Our team (FC Portugal) participates in several RoboCup competitions (2D, 3D, coach, rescue, legged) and has strong connections with Portuguese teams that participate in small-size and middle-size leagues (CAMBADA and 5DPO). FC Portugal always had very good competition results. The team won 3 World and 5 European championships together with several other awards.

2.4 Organization of robotic related events

We have also been involved in the organization of several and Competitions related with Cooperative Robotics and RoboCup including tutorials on RoboCup at the national AI conference, organization of national Robotic Competitions (Robótica 2004, 2008, a national micro-mouse competition (2001, 2002, 2003, 2004, 2005, 2006, 2007) and a cyber-mouse competition (2006, 2007) [9,10,11].

The organization of conferences and workshops has also been an important issue, namely the organization the Workshop on Multi-Agent Systems Theory and Applications (MASTA 2001, 2005 2007) and the International Workshop on Intelligent Robotics (IROBOT' 2005, 2007) [12, 13].

2.5 Past and ongoing funded research projects

We are and have been involved in several research projects concerning cooperative robotics and multi-agent simulation, including, among others: ABSES - Agent Based Simulation of Ecological Systems, FC Portugal: New Coordination Methodologies in the Simulation League, Portus Project: A Common Framework for Cooperative Robotics, Lemas Project: Learning in MAS using RoboCup Sony Legged League, CAMBADA - Cooperative and Autonomous Robots with Advanced Distributed Architecture, FC Portugal: Coordination of Heterogeneous Teams in Search and Rescue Scenarios, Micro-Mouse Contest: Mobile Robotics Promotion Activities and ACORD: Adaptive Coordination of Robotics Teams. More information regarding this research projects may be consulted in our websites [14, 15, 16].

3 Developments and Research Program

Citizen's research and educational platform will be used for research and educational purposes on our two laboratories and universities. Our strong experience in developing robotic simulators, robotic visualization and debugging tools and robotic teams makes our team a very good partner for helping developing the Mixed Reality league. We plan to help improving the platform so it may be a standard multi-agent research and education tool and to explore real world applications with this setup.

Specifically we plan to develop a generic coordination layer for the specification of strategy for a Mixed Reality soccer game. This coordination layer will be more and more important as the number of team elements is increased, as we hope will be the case in the 2008 soccer tournament. In this context, the objective of the ACORD (Adaptive Coordination of Robotic Teams) project, starting in January 2008, is to develop a common agent-based framework for controlling cooperative teams of mobile robots and coordination mechanisms to enable teams of heterogeneous robots to accomplish complex tasks in dynamic environments. Specific objectives are, to develop:

- Knowledge representation structures for cooperative knowledge in all RoboCup leagues;
- Communication languages between the common framework and specific action and perception modules;
- High-level communication and supervision languages for robotic teams performing complex tasks;
- Cooperative decision-making mechanisms both at individual and team level;
- Agents capable of supervising different teams to fulfill different cooperative tasks.

ACORD main contributions will be twofold: (i) a configurable framework flexible enough to deal with perception, decision-making and action for different (both real and virtual) cooperative teams of robots; (ii) Coordination and communication mechanism enabling heterogeneous robots built and programmed by different entities to work together as a team. The Mixed Reality environment is, by its characteristics, a very interesting platform for the developments within the ACORD project.

4 Educational activities that use the Mixed Reality environment

Several different educational activities are ongoing or being finished in our universities, using the Mixed Reality environment with the 2007 robots.

In the course of the Robotics discipline of the Doctoral Programme in Computer Science/Informatics Engineering [17] and of the Masters in Computer Science/Informatics Engineering [18], of the University of Porto, a small project was developed to use the Eco-be platform for a box-pushing application.

We have an undergraduate student, of the University of Aveiro, using the Mixed Reality environment for the development of a new platform where this environment is used for the development of maze-solving robots with rules that are similar to ciber-mouse contest [10, 19]. In this platform, robots will be real while the maze is virtual.

The Mixed Reality environment is also planned to be used as one the platforms of the small projects to be developed in the context of the Intelligent Robotics discipline of the MAP-I Doctoral Programme in Computer Science [20], a joint venture of University of Minho, University of Aveiro and University of Porto (MAP). The first edition of this discipline will be in the 2nd semester of 2008.

There are plans to use the Mixed Reality environment as the basis of one of the interactive experiments to be included in a Mobile Robotics Exhibition that is being planned in the context of the "Micro-Mouse Contest: Mobile Robotics Promotion Activities" funded project.

5 FC Portugal 2007 Physical Visualization Team

Considering the late time the robots arrived, less than one month before the competition, we had to adapt the team to focus on the robots' low-level algorithms.

5.1 Basic Players' Movement

A world state class was implemented to synchronize the data received from the server and to compute higher level information from this data. The server provides the relative positions of the following elements: team poles, opponent's poles, the four field flags, ball, teammate and two opponents (real elements) as shown on Figure 1.

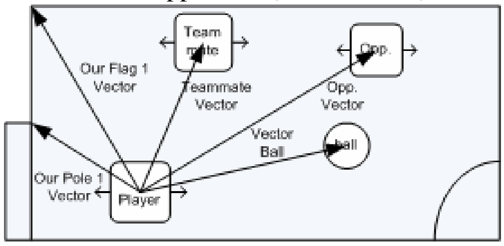

Fig. 1. Kick Forward Direction from the Goalie

In the world state a conversion of relative position provided from the server to absolute co-ordinates is made. That conversion allowed a more precise decision algorithm for the players enabling quick decisions, without vector arithmetic.

The server accepts kicks from every side of the player. With respect to the players' movement, an important improvement at the original movement procedure was to allow the robot to go forward and backward in function of its destination. Some opponents had the limitation to move just forward and they lost a precious time rotating 180 degrees to start the movement. Another important improvement about the movements was the in-place rotation of the robot if it was displaced approximately 90 degrees in relation to the destination (usually the ball). That offers a flexible solution for both attacker and goalie and allows the use of the fastest forward movement.

The team chose thus to focus on particular skills and behaviors. This development was twofold: a goalie and an attacker progressed separately.

5.2 The Goalie Algorithm

The goalie was chosen to have a straightforward behavior as the goal was relatively narrow. This choice implied that the goalie had a fixed strategy: it would position itself on a half-circle centered in our own goal center, and move radially as the ball approached and changed its' position with respect to the goal. During the competition this behavior was successful: our team did not lose any game, and, in 6 matches, only conceded 4 goals. During the penalties with goalie in Final Match, we did not concede any goal in all five tries.

5.3 The Attacker Algorithm

The attacker had a more complex task, since it had to both help defending the own goal, and also try to score goals against the opposite team. This was attained through the development of the following skills and behaviors.

A "do not disturb strategy". When the ball was near our goalie, the attacker would stay away from the ball, in order to avoid disturbing the goalie and to be a in a good position for reception when the latter kicked the ball away, generating good counter attacks, from which most of our goals were scored.

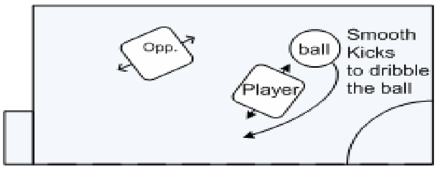

Fig. 2. Soft kicks to dribble the ball

A dribbling skill was developed, aiming at different directions depending on the position of the ball and the opponents on the field (fig. 2).

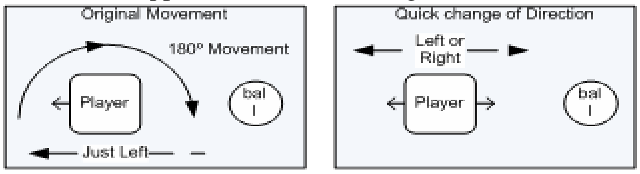

Fig. 3. Eco-Be with movement in both directions

A new moving skill was developed, running faster and avoiding unnecessary turns, when compared to the similar skill available on the standard player included in the server code (fig. 3 and 4).

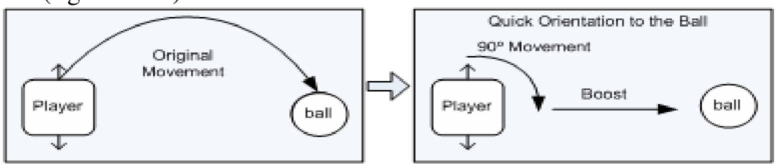

Fig. 4. 90º movement to go straight to the destination (ball)

A shooting skill at the goal was fine-tuned, aiming the shoot to an empty part of the opponent's goal, and with an enhanced kick power (fig. 5). The dribble skill had to change during the final penalties. Since there was no goalie in the last penalty sequence, the player just had to kick the ball directly in the center of the goal.

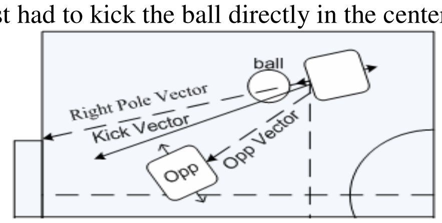

Fig. 5. Looking for the empty part of the opposite goal

5.4 Results and Discussion

Due to the short development time, it was decided to develop the low-level skills and actions first. It should be remembered that, in this first year of competition, the games were played with only two robots per team, which inhibits the use of high-level communication or coordination strategies.

The developed skills from our goalie and attacker were empirically combined through a simple decision algorithm which based the decisions on the world state. The result was a fast attacker that behaved well when approaching and recovering balls, and which scored goals in every game. Other teams applied more sophisticated decision processes, including, e.g., position exchange between the players. The state of development of the server, and the scarce development time available showed that our approach was appropriate, well developed and thoroughly tested. The low-level skills proved decisive for the results attained.

Such results emphasize the flexible nature of these robots, and their broad field of application. They allow a relatively easy setup of a real situation, while keeping costs low. They allow teams that have no hardware or electronics expertise to have a grasp at real robots and at a good approximation of reality. Moreover, due to their low cost and size, these robots allow an easy access at experiences with a high number (20-30 is foreseeable) of robots.

6 Conclusions and Future Work

The team achieved very good results in spite of the timeframe, robot late availability and limitations of the initial resources. In spite of these limitations, the team's demonstrations and presentations positively contributed to the Physical Visualization League development and the team's performance in the soccer competition achieved excellent results winning five games and only drawing one during the competition.

Developing new low level skills for physical robots in virtual environments proved to be a very challenging task. The new dribble, passing shooting and goalie positioning mechanisms developed during this project performed very effectively and, together with the flexibility of the teams' previous research in coordination, positioning and role development, resulted in a winning combination.

New future applications have been encouraged at our lab, ranging from integrated simulation of rescue environments to evaluate multi-agent systems to Sokoban cooperative solving using Eco-Bes in an augmented reality setup. In the rescue application, the augmented reality with the Eco-Bes can simulate a fraction of a city in a way that each robot is a rescue vehicle or even a specialized rescue robot in a building after an earthquake. In the future, it is our intention to develop a simple Rescue Simulation League in such a relative small setup with a considerable amount of Eco-Bes. Increasing the number of Eco-Bes used in the application allows the use of concepts like Situation Based Strategic Positioning and Dynamic Positioning and Role Exchange that use flexible agent roles with protocols for switching among them.

Overall, this initial experiment with the Eco-Bes robots allowed concluding that this new competition was clearly both viable and successful, the hardware platform can have a bright future, where multi-robot research can be directed to new and diverse scientific goals, and finally that the league is very attractive to a wider audience.

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