ROBOTIC SOCCER: THE GATEWAY FOR POWERFUL ROBOTIC APPLICATIONS

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Abstract: From the RoboCup goal of having a fully autonomous humanoid soccer team, it is possible to see many applications of the research in the Humanoid Soccer, such as the development of mechanical legs and arms and exoskeletons. The onboard vision algorithms for multi target tracking and the cooperative decision making of some Soccer Leagues can be used in squadrons of autonomous vehicles in a variety of missions. The algorithms for image processing of the Small Size League can be used in aerial or satellite images to track vehicles. The Simulation League allows the development of many intelligent agents applications. The formations and team play positioning of the Simulation League can be used to optimize the positioning of a squadron of autonomous vehicles. The research of Robotic Soccer fosters and strengthens the research in Robotics, allowing and contributing to the development of many powerful applications which can great benefit the mankind.

1 INTRODUCTION

The RoboCup initiative is an attempt to foster AI and intelligent robotics research by providing a standard problem where a wide range of technologies can be integrated and examined. RoboCup chose to use soccer game as a central topic of research, aiming at innovations to be applied for socially significant problems and industries. The ultimate goal of the RoboCup project is by 2050, develop a team of fully autonomous humanoid robots that can win against the human world champion team in soccer (The RoboCup Federation, 2007).

Although clearly stated by RoboCup that in order for a robot team to actually perform a soccer game, various technologies must be incorporated including: design principles of autonomous agents, multi-agent collaboration, strategy acquisition, real-time reasoning, robotics, and sensor-fusion (RoboCup, 2007), some people do not understand why RoboCup choose the soccer and not another robotic application with real and direct benefits to the mankind as its central topic of research. Some robotics researches even do not recognize the Robotic Soccer research as a serious one. And even among RoboCup researches there is some which are so concentrated in developing competitive Soccer Teams that do not really realize the real potential of their research in Robotic Soccer.

With the introduction of the RoboCup Rescue and RoboCup Leagues, part of the research for RoboCup Competitions can be direct and immediately applied to some robotic applications, but the research in Robotic Soccer may also foster the research in more advanced and specific topics which lead to great advances in Robotics, both in hardware and software.

The objective of this work is to show some of the many relevant and important applications which can be derived directly or indirectly from the research in Robot Soccer.

Starting from the main RoboCup goal of having a fully autonomous humanoid soccer team, it is possible to see many direct applications of the research in the Humanoid Soccer League, such as the development of mechanical robotic legs and arms for the cripple and exoskeletons for paralytic. The onboard computer vision algorithms for multi target tracking and the cooperative decision making of Humanoid, Middle Size and Four Legged Soccer Leagues can be used by squadrons of sea, ground or aerial unmanned vehicles in search-and-rescue, surveillance, recognition or even attack missions. The algorithms applied in the image processing of the Small Size League for image segmentation and multiple targeting of fast moving objects can be used in aerial or satellite images to track vehicles or boats and even aircrafts and isolate each target and its velocity and attitude. Finally even the Simulation League research is very important and besides helping the development of algorithms for the other Leagues, can allow many intelligent agents applications to be developed in many areas. In conjunction with the multi target algorithms and cooperative decision making algorithms developed in other RoboCup Leagues the defensive and offensive formations and team play positioning of the Simulation League can be used to optimize the group positioning and area coverage of a squadron of unmanned autonomous vehicles.

Some research topics of the RoboCup Soccer Leagues are presented in the next section and in section 3 the relations among the research in the RoboCup Soccer Leagues and powerful real world applications are explained in detail, leading to the conclusion that the research of Robotic Soccer in the various RoboCup Soccer Leagues foster and strengthen the research in Robotics, allowing and contributing to the development of many powerful hardware and software which can great benefit the mankind.

2 ROBOCUP SOCCER LEAGUES AND SUB LEAGUES

The RoboCup Soccer Competition has a total of five senior Leagues, some with Sub Leagues, but for our purpose we should consider only four different approaches for Robotic Soccer Research. The first of these four approaches to be considered is the Humanoid Soccer League, were anthropomorphic autonomous robots must be developed to play soccer, perform penalty kicks and accomplish some technical challenges related with soccer playing skills. The second embodies the Four Legged and the Middle Size Soccer Leagues were autonomous robots must coordinate their actions to play a soccer game. The third approach is the Small Size Soccer League, where a unique program controls an entire team of robots using the information provided by a camera that has a satellite like view of the entire field of play, including all robots, field marks and the ball. The fourth and last approach is the Simulation League where team play algorithms must be developed to autonomous intelligent agents play soccer coordinating their efforts.

2.1 Humanoid Soccer

In the RoboCup Humanoid Soccer League, autonomous robots with a human-like body plan and human-like senses play soccer against each other. In addition to soccer games, penalty kick competitions and technical challenges take place. Dynamic walking, running, and kicking the ball while maintaining balance, visual perception of the ball, other players, and the field, self-localization and team play are among the many research issues investigated in the Humanoid League (RoboCup Humanoid League, 2007). Figure 1 shows some of the Humanoid Robots which participated in the RoboCup 2006 at Bremen.

Figure 1: Robots of the Humanoid Soccer League at the RoboCup Championship - Bremen2006.

To ensure that the humanoid robots perform well all these activities a wide range of technology must be researched and adapted. Some of the research topics in the RoboCup Humanoid League are:

- The design and assembly of anthropomorphic robots;
- The development of optimal and robust control algorithms that optimize the speed of the movements keeping a robust stability of the robots;
- The development of real time image processing algorithms, capable of tracking moving objects and even anticipates actions of adversary robots;
- The development of team play algorithms that allow the coordination of the robots actions according with the state of the game.

Some RoboCup teams fully design and assembly their robots (Santos et al, 2006), (Behnke, S. et al, 2006), while other augment some commercial robots and there is even Robotic Companies which adapt their robots to test their capabilities in the Humanoid League (Faconti, 2006).

2.2 Autonomous Multi-Agent Soccer

For our purpose of establish the relations of the research in the RoboCup Soccer Leagues and real world applications the Four-Legged and the Middle Size RoboCup Leagues can be explored together. In the Four-Legged League teams consisting of four Sony Aibo robots each play on a field of 6 m x 4 m. The robots operate fully autonomously, i.e. there is no external control, neither by humans nor by computers (Four-Leegged, 2006). In the Middle Size League two teams of mid-sized robots with all sensors on-board play soccer on a field; relevant objects are distinguished by colors; communication among robots (if any) is supported on wireless communications and no external intervention by humans is allowed, except to insert or remove robots in/from the field (RoboCup2004 Middle Size League, 2007).

The great difference among these two leagues is the hardware. In the Four-Legged League, all teams are limited to the Sony Aibo robot, while in the Middle Size the teams have the freedom to design and build their robots according to some dimensions and weight limitations. But both leagues have some research challenges in common, which are also Humanoid Soccer challenges:

- The development of real time image processing algorithms, capable of tracking moving objects and even anticipates actions of adversary robots;
- The development of team play algorithms that allow the coordination of the robots actions according with the state of the game.

But as the concern about stable biped walking doesn't exist and the design of the robots is easier or also nonexistent in these leagues and usually the processor power of the Aibos and mainly of the Middle Size Robots are far better than the humanoid ones, more advanced and complex techniques can be developed and applied in these two leagues. Such techniques can latter be used by the humanoid robots when their processor power reach better standards.

2.3 Small Size League

The Small Size Soccer League focuses on the problem of intelligent multi-agent cooperation and control in a highly dynamic environment with a hybrid centralized/distributed system. A Small Size robot soccer game takes place between two teams of five robots each.

Although local on-board vision sensors are permitted, most teams use a global vision system, where an overhead camera and an off-field PC are used to identify and track the robots. The off-field PC also performs most of the processing required for coordination and control of the robots (Small Size Robot League, 2007). Figure 2 shows the structure of the control loop for the robots using the global vision system and Figure 3 shows a typical image acquired by the overhead camera.

Fast moving multi-target tracking and multi-robot coordination are some of the big research challenges in the Small Size Soccer League.

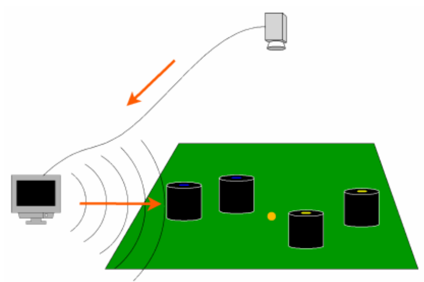

Figure 2: Control Loop Structure for the Global Vision System.

Figure 3: Typical Small Size image (Manzuri-Shalmani et al, 2006).

2.4 Soccer Simulation League

The RoboCup Soccer Simulation League have two main objectives, the first is to develop a simulation environment where it is possible to research the software aspects of RoboCup, allowing a fast development of new techniques and algorithms. The second is to present by itself a challenge multi-agent problem, for that it enables for two teams of 11 simulated autonomous robotic players to play soccer (The RoboCup Soccer Simulation, 2006) .

So, the main challenge in the Soccer Simulation League is to develop efficient team play algorithms for autonomous intelligent agents. The offensive and defensive formations of the players are one of the researches topics associated with this challenge.

3 REAL WORLD APPLICATIONS

RoboCup not only create student and media interest in the research of Robotics (Brãun, 1999) and RoboCup Soccer Competitions are not limited to just make students to work in practical solutions. The research in the Robotic soccer teams should allow a great advance in the Robotics field and besides the most obvious applications of the RoboCup research being of military or space exploration use (Kitano et al, 1998) the methods, techniques and algorithms developed to make robots play soccer can be used in many real world applications which can benefit all the mankind.

To start understand the extension and potential of the research in Robotic Soccer it is easier to imagine that the main RoboCup objective of develop a team of fully autonomous humanoid robots that can win against the human world champion team in soccer was achieved. The year is 2050 and the RoboCup humanoid team is able to win against the human soccer world champion team. What more these robots should do? What more should be done with the technology used in these robots?

From the electromechanical point of view, having such humanoid soccer players will help many cripple and paralytic people. Using the same technology and components used to assembly the soccer robots it will be possible to assembly mechanical legs and arms so or more efficient than the humans members. Also, the same algorithms used in the robots to walk, run, jump, kick and pick a ball should be used to control these robotic prosthesis. With some changes the robotics prosthesis can be turned in orthosis and even full body exoskeletons can be assembled.

The vision algorithms and the cameras should be used to help blind people and to monitor everything. The robots will be able to accurate track the ball, all the teammates and adversaries and all the field landmarks. If the image processing techniques used in the robots should do that the will also be able to guide blind people in a crowded metropolis. The vision processing will be able to tell when an obstacle is approaching, the best way to avoid a collision and even anticipate movements of other people. But we do not need to wait until 2050 to see some of the powerful applications that can be derived direct or indirect from Robotic Soccer.

3.1 Humanoid Research, Prosthesis, Orthosis and Exoskeletons

Although not all direct related with Robotic Soccer much researches are already being done and some important results are already being obtained with robotic prosthesis, orthosis and Exoskeletons.

It is true that one of the main usages of exoskeletons or lower part exoskeletons (Chu; Kazerooni; Zoss, 2005), (Low et al, 2006) is the enhancement of human soldiers, improving their endurance, speed and load carrying ability, but there are also other uses for them. Figure 4 shows the BLEEX (Berkeley Lower Extremity Exoskeleton). Exoskeletons may be used by paralytic people to perform all actions that any another people should do. Construction workers, miners, firefighters and rescue agents should also use exoskeletons to do their jobs more safely and efficiently. In the case of firefighters and rescue agents and exoskeleton may be the difference for saving an human life.

Exoskeletons or orthosis, like ankle-foot orthosis (Agrawal, 2005), (Ferris, 2005) may also be used in the rehabilitation of patients and help in physiotherapy.

Figure 4: The Berkeley Lower Extremity Exoskeleton - BLEEX.

In the research directed related with humanoid soccer robots one should cite the use of reinforcement learning for humanoid robots (Latzke; Behnke; Bennewitz, 2007) and studies of dynamic stabilization techniques for humanoid robots (Renner; Behnke, 2006). Both research topics are very important to have humanoid robots capable to adapt themselves to adverse conditions.

3.2 Image Processing, Self-Localization, Sensor Fusion

Two common problems in most Soccer Leagues are the image processing and the coordination of multi-robots. The solutions for both problems can be applied in a wide range of robotic and even just monitoring applications. Recognizing and tracking objects and using images for self-locating are general image processing research topics and are not limited to the Robotic Soccer.

Algorithms used to track a moving ball and predict changes in its movements due to contact with robots (Li; Zell, 2007) can be used to track vehicles in a road or the trajectory of any moving object, anticipating possible collisions. Algorithms developed to differentiate opponent robots from teammate robots (Lange; Riedmiller, 2007) can be used in traffic cameras to easy identity a suspect or robed car and in military operations in armored vehicles and aircrafts to avoid friendly fire.

Although some tracking and localization algorithms used in the RoboCup Soccer Leagues still relays on colored artificial landmarks (Iocchi, 2007) there is already research in the Four Legged League for self localization of the robots based on field features and not in colors (Herrero-Pérez, 2007). These algorithms can be use in any kind of unmanned vehicles to detect features in the terrain around it and self locating its position. They can also be used in conjunction with terrain data bases for better localization.

In the RoboCup Soccer Leagues there are also researches in fusion the visual information of the robots for better ball and robot localization on the field (Nisticó et al, 2007). These sensor fusion algorithms and techniques can be extended to sensor fusion and movement coordination in the target tracking of a squadron of unmanned vehicles (Ludington, 2006) the target should be a fugitive, a suspicious car, an airplane or even a spaceship or rocket which must be followed with precision.

3.3 Global Image Processing, Team Coordination

The Global Vision System of the RoboCup Small Size Soccer is very similar to the satellite imaging and surveillance aircraft image systems, where the images is collected from a point high above the ground, resulting in a practically 2D image. The image processing algorithms used in the Small Size Soccer League to track multiple fast moving objects can be used in satellite tracking and with aerial video. Figure 5 shows a unmanned aircraft vehicle with its camera field of view and a sample image.

Figure 5: UAV camera field of view (left) and sample image (right) (Arrambel et al, 2004).

There are also research in RoboCup to autonomous extract relevant information from robot marks and used this information to anticipate robots actions (Umemura, 2007). The same algorithms can be used to extract relevant information from any moving target and also anticipate its movements.

Bruce and Veloso (Bruce; Veloso, 2007) extended a motion planning algorithm primary developed and used in the Small Size Soccer robot navigation to an unmanned aircraft vehicle.

The Team coordination algorithms of the Small Size League and of the Simulation League can be used for teams of ground, sea or aerial unmanned vehicles. Search and Rescue, Patrol, Surveillance, and Escort Missions among others will need team coordination. If an off-field computer has the global view of the field of interest the Small Size decision Algorithms should be used, but if each vehicle has to take its own decision on coordinating efforts the Soccer Simulation algorithms and team positioning strategies should be used.

A good example for the use of the team positioning and team coordinating algorithms are the search for missing people. A Squadron of UAVs must cover a wide forest area searching for missing tourists. A defensive positioning for covering a wide area without blanks like the one used in Soccer Simulation to block passes should be assumed by the UAVs squadron. Also, when one of the UAVs leaves the formation to see an area of interest the others UAVs should close the formation to cover the space left, like to close a defensive formation when one player is not available for the defensive action.

Multi-agent coordination techniques can also be applied in Air Traffic Management to ensure safer and more efficient operation of civilian aircrafts (Nguyen-Duc, 2003). And finally the Soccer Simulation league should be used to explore many intelligent agent cooperation techniques, which should be used in any of the Intelligent Agent applications fields, like Process Control, Manufacturing, Air Traffic Control, Information Management, Electronic Commerce, Business Process Management, Patient Monitoring, Health Care, Games or Interactive Theater and Cinema (Jennings; Wooldridge, 1998).

4 CONCLUSIONS

The RoboCup Soccer Competition is more than just an attractive for students and media and more than one place to test hardware and software outside the laboratories. The research done to create fully autonomous soccer robots can really be applied in many useful robotics applications and allow and foster the development of even more powerful and important applications to the mankind.

From prosthesis and orthosis to cripple, passing to image processing algorithms which can save lives and arriving in multi-agent cooperation algorithms and decision making which will optimize the actions of squadrons or even swarms of robots or intelligent agents, the researches in Robotic Soccer can really allow and foster the development of powerful robotic applications.

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