Robofoot ÉPM Team Description – RoboCup2004 MiddleSize League

Julien Beaudry, Sylvain Marleau, Pierre-Yves Mailhot
julien.beaudry@polymtl.ca, sylvain.marleau@polymtl.ca, pierre-yves.mailhot@polymtl.ca
École Polytechnique de Montréal, Laboratoire de mécatronique, Montréal, Québec, Canada
http://www.polymtl.ca/robofoot

Abstract. This paper is the description of the Robofoot team of autonomous soccer playing robots developed in order to participate in the RoboCup2004. Various aspects of the team of robots are presented: mechanical, electrical and software architectures, dynamic player behavior and simulation platform. Since Robofoot is a newcomer in RoboCup for 2004, simplicity is the key to success for the team. By using simple but efficient solutions for every important problems to solve, the robots manage to respond efficiently, with robustness and predictivity.

Introduction

Robofoot is a newcomer in the RoboCup MiddleSize League. Besides the research projects of the Mechatronics Laboratory at École Polytechnique, the main goals of the Robofoot team, as a newcomer, is to achieve good tournament results with a low-cost but quite efficient team of robots. Since the technical developments involved in building a team of autonomous soccer playing robots are various and quite challenging, a promising approach is to develop, in the first, technical solutions that are simple while offering performances satisfactory enough to reach the team goals. By designing solutions that must be simple in every part of the design, the overall design can promise to be efficient, robust and could also help to reach a low-cost overall solution. The next paragraphs presents some of the technical elements developed by the team using this guideline. The mechanical, electrical and software platforms are presented and some interesting features of the project like the omni-directional vision system, the simulation platform and the layered behaviors of the play algorithms. For a specific technical development, once a simple solution is developed and well tuned, a second approach, more optimal but with longer development time, can then be studied. In the future work of the project, some second approach solutions are currently studied.

The team of robots, differential drive platform

The Robofoot soccer player playing robots are based on a robust differential drive platform developed by a team of students and technicians from École Polytechnique de Montréal. This platform uses two 30W DC motors drive and two free wheel for stability. The platform offers lateral and longitudinal symmetry, which allows the robot to complete the same operations, with appropriate programming, forward and backward. The gravity center of the robot is kept very low so that good accelerations can be reached. The weight of the platform itself is only 4.5kg, but the overall weight of the robots, including all electronics and pneumatic devices is 21kg. The maximum velocities of this platform are 2.5m/s longitudinal speed and 17.5rad/s rotational speed. Longitudinal acceleration can reach up to 4m/s². This platform is powered with a 24V 7,2Ah battery pack. The next figure shows the Robofoot team of robots. 6 robots have been built and 4 of them will be used during a RoboCup MiddleSize League, allowing two robots to act as substitutes in case of technical problems.
Fig. 1. The Robofoot team is a group of 6 mobile robots, 4 of them will be used in a MiddleSize League match-up.

Ball handling and kicking device

This device is mainly constituted of a passive handling device and a pneumatic kicker. The more interesting feature of this device is that it is compact enough to fit two devices in the robot, one in the front and one in the back of each robot. With the mechanical symmetry on the longitudinal direction along with the benefits of the omni-directional vision, the robots are able to dribble the ball forward and backward.

The handling device is made of appropriately located 5 foam rolls that allows the robots to move the ball forward and allow a certain rotational speed while dribbling with the ball. Each roll has been precisely located to give sufficient motion resistance for dribbling while not stopping the ball from rolling on the ground. By keeping only one third of the ball inside of this device, the robots stay in respect of the tournament rules. Moreover, the spongious material of the foam gives a good shock absorbing characteristic to allow an easier ball catching.

As a kicking device, a pneumatic system has been designed in order to obtain high kickoff speeds and low electrical consumption. A 3000 PSI cylinder is used to feed a system that works in the 0-150 PSI pressure range. The pressure of the kicks can be manually adjusted and the valve opening period can be controlled by the robots software. This way the kicking power can be precisely adjusted. By using a high pressure cylinder made of aluminium and carbon fiber, the kicking device has a reasonable total weight with an autonomy of approximately 400 kicks with a filled cylinder.
a) CAD of the device in CATIA

b) Device kicking the ball during tests

Fig. 2. Picture of the ball handling/kicking device of the Robofoot soccer playing robots.

**Omni-directional vision**

As the main perception device, the robots use a high quality webcam with a hyperbolic mirror in order to achieve low-cost and efficient omni-directional vision. Since the objects of the RoboCup field use predefined colors, color is the most useful information used for object detection. To achieve precise and robust color segmentation, the HSI color space is used. To obtain a visual representation that is more representative of the human interpretation, a panoramic image is used to detect the objects.

The webcam used by the system gives a refresh rate of 15fps with 640x480 pixel images. These characteristics make it difficult to obtain a precise vision system when the field dimensions of the MSL are considered (8x12m). On the other hand, the vision system developed for the Robofoot soccer playing robots uses many additional features to help find the specific objects of the field. To be able to work in various lighting environments, the HSI color space is used and the acceptable regions of hue and saturation can be dynamically adjusted in order to be adaptative. Moreover, with an appropriate abstract description of the static and dynamic objects of the field, the system is able to track objects with predefined colors, dimensions and forms. With a knowledge of the current position of the vehicle, predefined location of static objects and current trajectory of dynamic objects, the system is able to track the desired objects by scanning only small regions of the image and give global estimates of positions. This high level representation of objects allows this omni-directional system to work in any partially known environment.
Software architecture

The software developed to control the team of autonomous robots uses the C/C++ language and is built on a high level representation of the robot perception, cognition and motion systems. One important feature of the architecture is that it is working under most of the popular operating systems (Linux, Windows, Unix, QNX). This feature enables the different software modules to interact with each other, with the benefits of TCP/IP communication, on a set of machines that can be heterogeneous. To achieve this multi-OS capabilities, the software uses MICROB (Integrated Robot Control Modules), an open-source C++ library that offers many useful modules to model and/or control different types of robots and to develop real-time robot control software. The OSDL module (Operating System Dependent Library) is the part of the library that helps compiling the code appropriately for a given operating system. The robots use the Linux operating systems with some minor kernel modifications to achieve real-time capabilities. To allow a fast periodic response while offering robust communication interfaces with other modules, many modules of the architecture are multi-threaded.

In order to efficiently use the wireless LAN present on the robots and to enable communication between all the modules present in the architecture, the Client/Server classes of the MICROB library are used to allow a very flexible architecture. This TCP/IP communication is used for interplayer communication (for team behaviors and global estimates) and remote connection for game control and telemetry. This communication will also allow the robots to connect to the MSL referee box. Other modules can be easily added to the architecture, for example a joystick interface to allow remote control for debugging purposes. To easily control the whole system and have a very useful debugging tool, a system interface have been developed. This interface uses the wxWindow library in order to stay portable. The next figure gives a block diagram of the software architecture.
Simulation platform

The simulation platform developed to simulate the Robofoot soccer playing robots is basically made of a VRML viewer, a ball dynamics simulator and of a virtual model of the robot Controller class. By using a VRML viewer with Client/Server communication, it is easy to obtain a flexible and portable virtual scene to show the dynamic elements on the field. The ball dynamics simulator simply simulates the movement of the ball on the field by considering rebounds on mobile robots and an approximate deceleration.

Fig. 4. Software architecture with Client/Server modules.

The Controller class of the robot software is intended to send desired velocities to digital PID filters and to read the values of odometry sensors. In order to simulate the movements of the mobile robot platform, it is possible to simulate the feedback of the odometry sensors by including the kinematics and dynamics models of the robot in a virtual version of the Controller class. This simulation platform allows to use all of the modules normally used to interface the team of robots. This way it is possible to develop and test most of the parts of the robot software in simulation and to embed them on the robots once they are validated.

Fig. 5. VRML viewer of the Robofoot simulation platform.
Layered player behaviors

In order to appropriately let each robot present good individual skills while offering higher level behaviors and team cooperation possibilities, it is necessary to use a layered behavioral structure. The following figure shows the layered structure used in the players software (except for the goalie which is different and more simple).

![Layered Player Behaviors Diagram]

**Fig. 6.** Layered player behaviors with individual skills used by higher level layers.

The higher layer of behaviors is the dynamic cooperative behaviors which decides whether to use defensive or offensive behaviors and then individual skills can be selected. Each behavior can have its own definition of states and the switching must be predefined. In the case of cooperative behaviors, it is important that every player uses the same predefined switching scheme in order to allow correct synchronization. Every behavior also has access to the actual world state to affect its behavioral process. The lowest layer, individual skills of the robot, is the one that has access to robot actuators.

Future work

Many interesting new avenues are currently studied to allow the team of robots to benefit from the most recent technologies and concepts in mobile robotics and artificial intelligence. For now, an important project is the development of an omni-directional robot platform that must be smaller and lighter than the actual one and must offer accurate proprioceptive sensing. The omni-directional vision system may also be completed with additional sensing devices especially to allow a better response for ball handling. Finally, the distributed cooperative layer of player behaviors may be revised to allow a global decision scheme to decide of individual behaviors. The decision process for cooperative behaviors is currently studied to offer robust synchronization of behaviors. As the solutions developed in this project attain a mature stage, new approaches to technical challenges continually arise.

References


