Cyberlords RoboCup 2009 Humanoid KidSize Team Description Paper

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Abstract. We describe the RoboCup KidSize humanoid robots to be used by team Cyberlords in the RoboCup 2009 competition to be held in Graz, Austria. Our humanoids are based on the Robonova-1 architecture, so this description focuses on the mechanical and electronics adaptations as well as the perception and control software developed and adapted by us for the purpose of transforming these robots into autonomous football players. We also introduce the concepts of *shot filter* and *dynamic turning*.

1 Introduction

Team *Cyberlords*, which is part of the *Mobile Robotics and Automated Systems Laboratory* at *Universidad La Salle* México, started working on our RoboCup Humanoid KidSize project in july 2008. The starting point of the project was a pair of Robonova-1 humanoids, which we had to adapt mechanically, interface to several sensors and program to give them the ability to play football autonomously. By september 2008, we had the first functional version of our football-playing humanoids and debuted them in official competition during the *1st Mexican RoboCup Open* where we faced team *Bogobots* and *Pumas UNAM*. Both, *Bogobots* and *Pumas UNAM* played with *two* outfield players and a goalkeeper, while we played with *one* outfield player and a goalkeeper. Our robots became mexican champions by winning the semifinal and final games by a narrow margin of 1:0 in penalty kicks. In addition, our robots made more goal attempts during regular game time than any of the other teams. Figure 1 depicts a practice shot between our striker *Roboldinho* and our goalie *Robo Ochoa*.

Fig. 1. Practice shot during the *1st Mexican RoboCup Open*

Our team is making two main contributions to the RoboCup community this year. In this TDP we introduce the concepts of *dynamic turning* which gives our humanoids a precise orientation control in preparation for kicking, and *shot filter* which allows the goalie to make timely decisions about when to dive in response to a shot towards the goal line. We believe these two techniques might have been the distinguishing factor that ultimately led our team to the championship since they were crucial for our robots' ability to score goals and to block our rivals' shots.

2 General Architecture

Out-of-the-box, the Robonova-1 humanoids from Hitec come with 16 degrees-of-freedom (DOF) (five on each leg and three on each arm). Each of those 16DOF is actuated by a HSR-8498HB digital servomotor from the same company. They also come with a MR-C3024 computing unit, which can control up to 24 servomotors and is based on an Atmel ATmega128 microcontroller. The computing unit is preloaded with a firmware that interprets commands written in a programming language called RoboBASIC. Both, the MR-C3024 computing unit and the RoboBASIC language were tailormade for the purpose of controlling the Robonova-1 unit by the Korean company MiniRobot.

A few structural adaptations were needed to make these robots more apt to the task of playing football (including meeting official RoboCup Humanoid KidSize League restrictions). Most notably, the front and back torso plastic caps as well as the feet plastic caps were removed. The aluminum feet toes and heels were bent upwards in order to meet the feet proportion restriction. A 2DOF pan-and-tilt mechanism was added to the head for the purpose of installing the vision system. This mechanism is actuated by two Hobbico CS-12MG micro servomotors with metal gears. An aluminum platform was added to the the back of the left shoulder in order to install a digital compass away from the magnetic field coming from the servomotors. This platform gives the computing unit located at the robot's back some limited protection against backwards falls. Finally, a wire forming a protective arch was installed on the robot chest. This reduces the potential for damage to the vision sensor during a frontal fall.

Figure 2.a shows a general view of our Robonova-1 based humanoids after all the structural adaptations were applied, while Fig. 2.b gives a close-up view of the pan-and-tilt mechanism, the digital compass platform and the frontal protective wire.

One particular shortcoming of the Robonova-1 architecture is the lack of a rotation DOF around the vertical axis either on the legs or the hip. There was an internal discussion within our team about whether it would make sense to add this DOF to the legs. We ultimately decided against that option because it would require a significant design and testing effort to get it right while, on the other hand, that problem has some simpler solutions that we discuss at the end of the next section.

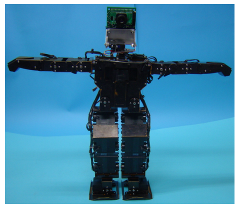
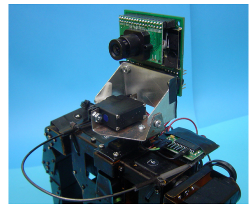
(a)  (b) 

Fig. 2. Structural adaptations for the Robonova-1 based robots of team *Cyberlords*

3 Perception and Low-Level Motion Control Systems

For the purpose of giving our humanoids some degree of autonomy four kinds of exteroceptive sensors were interfaced to them:

- A CMUcam3 vision system.
- A CMPS03 digital compass module by Devantech.
- A pair of PK3 piezoelectric gyroscopes by Multiplex.
- An ADXL330 3-axis accelerometer by Analog Devices.

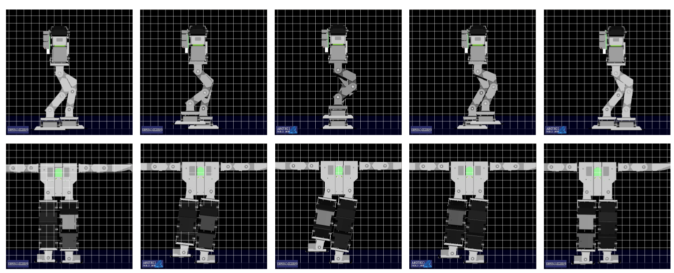
The 2008 version of our humanoid robots used its vision system mainly to locate color blobs (ball and goals) with respect to itself, aided by the information obtained from the digital compass. However, it did not implement any kind of self-localization within the field. For the 2009 version, we will provide our humanoids with self-localization capabilities that will in turn enable them to make a more informed decision about whether its better to dribble the ball or kick it towards the goal.

Low-level motion control for our robots is implemented on the MR-C3024 control board. In addition to controlling the servomotors, this computing unit is directly interfaced to all of the sensors, except for the camera in the CMUcam3 vision system which includes its own additional computing unit.

Our humanoid robot design obtains proprioceptive feedback from the pan-and-tilt head servomotors in order to aid in the localization of the goals and ball relative to its own position. In fact, this proprioceptive information is crucial in the algorithm that ultimately triggers the goalie's diving reaction when the ball is approaching the goal line. This will be discussed in the following section.

Although in the steady state any servomotor implicitly gives proprioceptive feedback, that is actually not the case before reaching the steady state. That is why the HSR-8498HB digital servomotors used in the Robonova-1 architecture were such an attractive choice. The fact that they are *digital* means that, by using Hitec's HMI serial protocol [1], one can obtain proprioceptive angular position feedback at any time, even before reaching the steady state. In addition, that same serial protocol allows for interoceptive feedback since it can also return information about the actual voltage being applied at the H-bridge of the motor. Although the 2008 version of our humanoid robots did not make use of this interoceptive and proprioceptive information available from the HSR-8498HB digital servomotors, for the 2009 version we will make use of this feature to enhance stability and motion control. This means that we will replace RoboBASIC with our own firmware. One initial difficulty for the implementation of this firmware was the lack of documentation for the HMI protocol and the inner workings of Hitec's digital servos. Thanks to the detailed and comprehensive technical report by Rafael Cisneros [1] it is now just a relatively simple task to implement the new enhanced low-level control firmware. We plan to release this firmware to the public domain after our participation in the RoboCup competition in Graz 2009.

The walking and running routines for our humanoids will be redesigned using the Robonova-1 inverse kinematic model and 3D simulator ARMS (Advanced Robot Motion Simulator) developed by our collaborator Rafael Cisneros [2]. This will allow us to obtain faster and more stable gaits. Figure 3 shows a sample gait generated using ARMS.



Arms are intentionally extended to allow for a better view of the motion of the Robonova-1 legs. The body looks gray instead of black due to shininess. For the sake of simplicity, the head is not shown in this 3D model, so the real humanoid robot is actually taller. Images were flipped horizontally to show the motion from left to right.

Fig. 3. Lateral and frontal views of a parametric gait generated using ARMS

In the previous section we made reference to the lack of a DOF that would allow the Robonova-1 robots to rotate around the vertical axis. Hitec provides a solution to this problem, which consists of using one foot as a pivot while the other one steps forward and then pulls the body around the pivot foot. While this solution may prove to be useful in some situations it has the inconvenience of being slow, highly sensitive to the friction between the floor and the feet, and it gives a rotation step too long to achieve precise positioning in front of the ball. Our teammate, Pablo Monroy, devised an ingenious solution to this problem. We now call his solution *dyanmic turning*. This technique consists of a sequence of fast movements that start with a micro-jump and is followed by a coordinated arm-swinging action that transfers a vertical angular momentum to the rest of the body. The micro-jump reduces sensitivity with respect to the friction between the feet and the floor, while the range and speed of the arm-swinging action controls the length of the turning step thus allowing for very precise positioning in front of the ball. We believe that *dynamic turning* might be useful even in the case of a humanoid architecture that includes a vertical rotation DOF on the legs. Once we have a complete and accurate dynamic model for our humanoid robots we will take on the task of publishing the details about *dynamic turning*.

4 Robot Behavior Control

The behavior control architecture for our robots is based on a hierarchical finite state machine (FSM). There is a high-level FSM which implements one state for each high-level action to be performed by the robot, such as GetUp, Walk, FindBall, AdjustOrientation, and so on. Each of these high-level states may in turn execute a lower-level FSM. For example, the high-level FindBall state is implemented by a low-level FSM that moves the head in a predefined sequence testing for the presence of the ball at each step.

The FSM transitions from one state to another triggered by a set of crisp conditions that depend on sensory information. These include AccelFallen, BallFound, ShotFilter, CompassDisoriented, BallFar, BallFoot, and so on. More than one condition may be triggered at any one time, so a conflict-resolution strategy is needed. Our approach is to give priorities to each condition so, for example, AccelFallen would have a higher priority than BallNotFound (or any other state for that matter) and BallNotFound would in turn have a higher priority than CompassDisoriented. Within each state, conditions are tested in the order of their priority, so whenever more than one condition applies only the highest-priority condition is taken care of, while the rest are not even tested. This makes sense since, for example, whenever the robot falls over it doesn't matter whether it knows where the ball is or not, the only thing that matters at that point is getting up.

Another special contribution from our team is the implementation of the ShotFilter condition inside the goalie's FSM. This condition is responsible for detecting a shot towards the goal, which in turn triggers the goalie's diving action in the appropriate direction (left or right). The ShotFilter condition uses the proprioceptive information from the pan-and-tilt head servos that is generated while the vision system tracks the ball. Whether the ShotFilter will be triggered or not depends both on the speed and location of the ball relative to the goal line. However, the relationship between these two ball-motion state variables and the head-servos angular positions is non-linear and it is not immediately obvious what set of conditions should trigger the diving action taking into account that there is a delay between the start of the reaction and the moment the goalie's arm actually reaches the goal line. Our solution to this problem is based on a parametric non-linear filter that we adaptively fine-tune by using experimental data. The details of our technique will be the subject of a forthcoming publication.

5 Conclusion and Future Work

We have described the details of the structural and sensory adaptations applied by team Cyberlords to the Robonova-1 humanoid robots for the purpose of playing football autonomously. We have introduced the concepts of *dynamic turning* which gives our humanoids a precise orientation control in preparation for kicking, and *shot filter* which allows the goalie to make timely decisions about when to dive towards the goal line in order to block a rival's shot. Both concepts will be properly contributed to the scientific community in due time.

With regard to our plans for future versions of our humanoids, we are in the process of developing an FPGA-based board with a PC104 format. The presence of the PC104 bus on this board will allow us to use it either as a stand-alone board or in conjunction with a PC104 motherboard. This FPGA-based board will be the basis for interfacing all sensors and actuators into the processing unit in a much more efficient way than is possible to achieve using a single processor. We are also studying ways to implement *dynamic walking*. Our current version does not implement any kind of collaboration among our robots since that would require communication among them, which is an issue we have not addressed yet. We plan to start tackling this communication/collaboration problem in the very near future.

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Team Members

Team Cyberlords for 2009 will be integrated by at least the following people:

- Team leader: Prof. Luis F. Lupián.
- Student members: Alberto Romay, Pablo Monroy, Andrés Espínola, Karla de la Loza, Daniel Gutiérrez, Fernando Aguirre, Otto Carrillo, Josué Rabadán.
- External collaborators: Prof. Juan M. Ibarra Zannatha, Rafael Cisneros.

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