Educational initiatives related with the CEABOT contest

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Abstract

Off-the-shelf robotic kits are found in almost all retail stores. Most share common elements like motors, sensors, and a computer processor that permits the robots to be programmed to move autonomously in their environment. In addition, the wide scale availability and relatively low cost have made the robotic kits increasingly popular among students and teachers. Robotics competitions that are held annually in most countries are especially popular. The experience presented here is about the efforts of a group of students to teach each other in a peer-to-peer fashion and to manage several contest-related projects.

Keywords: Arduino, CEABOT, Teaching with robotics, Didactic approaches, Humanoid robots.

1 Introduction

Over the last decade, the amount of students interested in completing University degrees and, moreover, engineering related ones is continuously increasing. The ability of robotics to captivate students is so apparent that nearly every University offers at least one course. There are many growing initiatives of educational courses in robotics, workshops, and other less formal initiatives [1][2]. All of these activities have in common that they are frequently used to generate interest in engineering careers, and develop teamwork and communication skills. However, frequently they teach very little in the way of robotics-specific pedagogy. At the risk of over-generalizing, these courses tend to focus on designing and programming mobile robots, and rely less on advanced treatment of legged or serial-chain articulated robots, such as humanoids. CEABOT was originally targeted at senior-level undergraduates or first year master's students, to overcome this deficiency [3].

In this paper we propose a new paradigm of education in robotics. Under the framework of CEABOT and other international contests, a group of students have prepared a small humanoid robot to compete in this kind of competitions. Based on this experience, these students have found a new interest in learning robotics, electronics and computer science. They also have applied, in a practical way, some of the concepts learned at University.

2 Educational Proposal

2.1 Background and Motivation

The first steps of this initiative emerged as an alternative to theoretical classes at the Universidad Carlos III de Madrid (UC3M), centering the attention in practical issues regarding robotics. As robotics is a very attractive and interesting subject, it is easy to gain students willing to develop and collaborate in projects related with this matter.

In 2006 the CEABOT contest was born as a national competition of small humanoid robots as an initiative of Prof. Carlos Balaguer. Although at first there were few participants, CEABOT has been growing in importance, acquiring international status, and becoming one of the most important robotic contest in our country.

The participation of Universidad Carlos III in this competition has been very active since the beginning, starting with the participation of students preparing several robots as their Final Degree Project. Later, in 2009, several teachers gave a seminar of introduction to robotics to the students of the Master of Robotics and Automation, centering on a practical approach. In parallel with this, ASROB (the Robotics Student Society, "Asociación de Robótica") was created, and quickly showed interest in actively participating in contests for small humanoids.

2.2 The Robotics Student Society

ASROB (the Robotics Student Society, "Asociación de Robótica") is an official student organization of UC3M, born in 2009, that aims to promote robotics among the student members of the University. This includes giving them opportunities for hands-on experience with real robots and for interacting socially with other students and researchers with similar interests. The Society is student-run and well organized, with an elected board, president and other formal positions. At the present time the organization has more than 70 members. A central server for sharing and versioning data is available, as well as a public Wiki-based webpage: http://asrob.uc3m.es.

The activity of ASROB is centered on three projects, although other activities like tutorials and teaching are also performed by the members of the Society. The first project, "Robot Civil de Aire", is developing small Unmanned Aerial Vehicles (UAV) for civilian purposes. A second project, "Robot Civil de Tierra", aims to develop land mobile robots for the same purpose. The last project, "Robot Mini-Humanoide", was created to participate in national and international competitions for small humanoids. All these projects are currently active and have their own Wiki page and email list. They involve undergraduates as well as students from the Master and Doctoral level, and have been funded by the University for the past two years.

The current work in the "Robot Mini-Humanoide" project is centered on an 18 Degree Of Freedom (DOF) Bioloid mini-humanoid platform. The robot is being improved with additional computational resources, a large number of infrared distance sensors and an omni-directional camera system, based on the Surveyor SRV-1 Blackfin Camera. The latter is being investigated for use in both sumo fighting and in navigation with unknown obstacles; e.g., in detecting movements of the opponent and for an optical-flow based centering behavior when walking between obstacles. One of the current goals of the project is to participate in the CEABOT competition in September 2011.

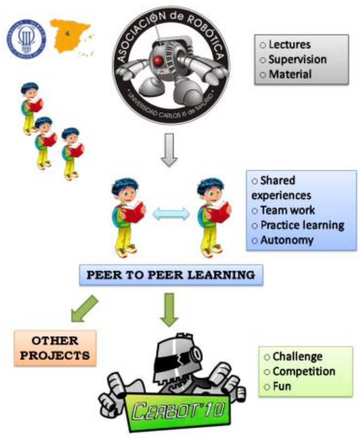

Fig. 1. Peer to peer learning

2.3 Peer to peer learning

CEABOT and ASROB are currently combining efforts to create a **new paradigm of education**, where students, initially supervised by teachers, can develop new capabilities. This includes contributing with new ideas and experiences, working as a team with other students, and becoming more independent. The ultimate goal is to improve the students' abilities to face the challenges and difficulties in his/her professional life. The vision of our learning methodology can be seen in Fig. 1.

At the meta-level, perhaps **it is time to rethink not just what we teach, but how we teach it**. We have set up an interesting experiment in peer-to-peer learning. Members of the class collectively set up a complex robotic system that is continuously evolving and that needs to be documented. So they have to maintain a community Wiki and source code repository. They are also motivated to co-author and contribute to papers with their experiences (e.g., this one). From a curricular perspective, at most Universities, entering the first course is typically selective. However, Robotics Lab and ASROB are open to teach and introduce any student of any year and specialty (if any specialty). The ASROB board actually wrestles with the challenge of creating introductory seminars at the beginning of the courses that allow easier understanding and initialization in any of the Society's projects.

3 Preparation of a Small Humanoid Robot for Robotic Competitions

A small humanoid robot has been modified to perform a set of tasks for competitions. It is a clear example of the practical application of the proposed educational paradigm, as it was performed by students of the Society with the supervision of their advisors and collaboration from their peers.

3.1 Robot Platform

The tasks the participating robots must accomplish are stated in the CEABOT contest rules [4]. They must be small-size anthropomorphic humanoid robots; that is, their body must be composed by a trunk, two legs, and at least two arms. The robot height must be less than 50 cm from the ground to the highest part of the totally upright robot. Another important feature is the robot foot dimension, as it highly affects robot stability. The maximum foot dimension is determined by the maximum distance between the two most distant points of the foot polygon (see Fig. 2). The maximum weight allowed is 3kg.

Taking these rules into account, the selected platform to compete by the ASROB team for UC3M was the ROBONOVA-I humanoid robot, by HITEC (see Fig. 3). This fully articulated, 30 cm high humanoid robot is controlled by sixteen HSR-8498HB digital servos with over-voltage current protection, Karbonite gear trains and "feedback" technology. The control board is a MR-3024 Board which is provided with the kit. The control board can operate up to 24 servos and 16 accessory modules. Powering the ROBONOVA-I is a 5 cell, environmentally friendly NiMH rechargeable battery that delivers approximately 1 hour of operational time. The robot has a lightweight metallic exoskeleton and a plastic body case that protects the control board, servo motors and battery from damage. Programming is performed with the supplied RoboScript and RoboBasic software via the included PC interface cable.

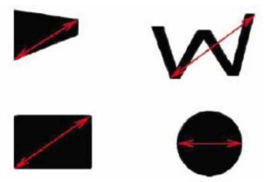

Fig. 2. How to measure robot foot dimensions

Fig. 3. The ROBONOVA-I platform

During the different editions of the CEABOT and other contests, the ASROB team has modified the ROBONOVA-I platform several times in order to improve its performance. Additional devices were included, such as gyroscopes, acceleration sensors, and infrared sensors. However, one main problem was continuously present during the robot programming stage. The RoboBasic language was not powerful nor flexible enough to properly manage the newly integrated devices. Due to this, the old controller board was replaced by a new one, the Arduino.

3.2 Arduino

Arduino (Fig. 4, left) is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software [5]. This platform is based on Atmega168, Atmega328, Atmega1280, ATmega8 and similar microcontrollers. As it is open-source, its design and distribution is free, that is, its use is free for any development without the necessity of any license. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Another interesting feature is its expansion possibility. By means of boards called 'shields', other capabilities can be added: Bluetooth, Canbus, Xbee… (Fig. 4, right).

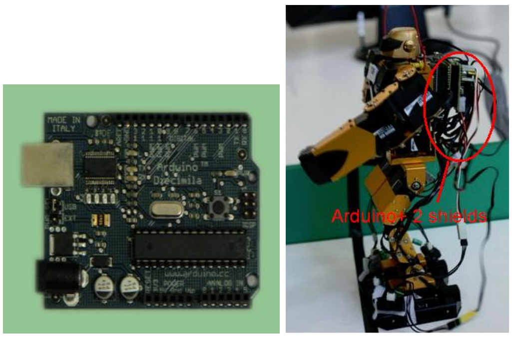

Fig. 4: The Arduino board (left) and the board with two 'shield boards' integrated in a ROBONOVA robot (right)

Regarding programming capabilities, Arduino/ArduClema accepts a large set of programming languages. The C/C++ language has been used to develop the applications for the contests.

3.3 Implementation of Arduino in Robonova

As ROBONOVA has 16 servos and Arduino has only 6 PWM outputs, a 'shield' board has been designed to obtain all the outputs needed to control the robot. This shield is set over the Arduino board. To control all PWM servos, a TLC5940 controller (demultiplexer of PWM signals) has been used. The source code to manage the TLC5940 with Arduino has been released and can be found on-line [5]. The libraries have been modified to control all 16 ROBONOVA servos.

ROBONOVA servos operate with signals between 600µs and 2400µs, which correspond to positions between -95º and 95º (see Fig. 5).

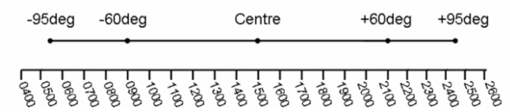

Fig. 5: Relation between servo position and PWM signal

Servo positions, θ, can be calculated with the simple equation 1, where p is the pulse width in µs.

$$\theta = (p - 1500) / 10 \quad (1)$$

To make the robot programming easier, a group of functions to control every limb of the robot have been developed. The application developer only needs to introduce the servo angle, and it is directly transformed into a PWM signal. A sample function definition, extracted from the application programmer interface is the following:

```
void MOVE_RIGHT_LEG(int s0,int s1,int s2,int s3,int s4)
```

3.4 Sensing

To give more autonomy to the robot, four infrared sensors have been added (Sharp GP12D12). One sensor has been attached to each one of the two arms, to detect lateral walls in running test competitions. Two sensors have been set in the feet, one in the front of the robot and one in the back, to detect the opposite robot in combat trials. These last sensors are also used in running trials to detect the front wall. The sensor type used can detect distances between 10 and 80 cm (see detection curve in Fig. 6).

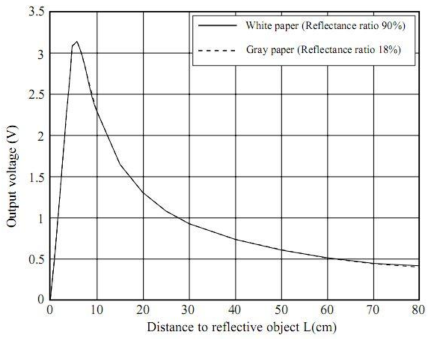

Fig. 6: Relation between Output Voltage and Distance for the Sharp IR sensor

3.5 Control Logic

The robot is prepared to participate in two contests: a running contest, and a combat contest.

3.5.1 Running Contest Algorithm

In Fig. 7, the control diagram of the program for the running contest is shown. The robot starts walking 8 steps forward, then stops and reads the IR sensors. If the left IR sensor marks detection, it means that the robot is near the left wall, so it turns right 4 steps. If it detects a wall to the right, it turns left. If the robot detects a front wall, it turns around and moves forward 8 steps. While the counter is smaller than 10 and the IR does not detect anything, the robot moves forward 8 steps. If the counter is greater than 10, it moves only 4 steps. The counter is used to make the robot go slower when it is near the front wall.

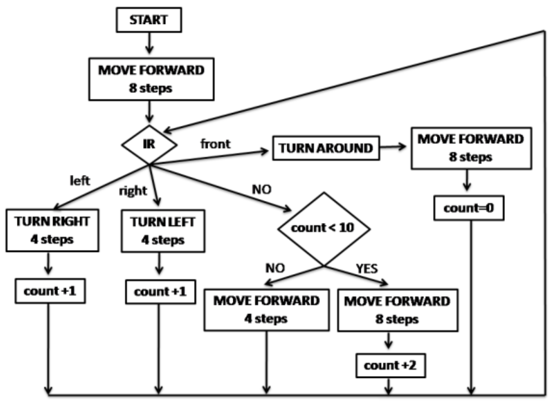

Fig. 7: Diagram of the Algorithm for the Running Contest

3.5.2 Combat Contest Algorithm

For combat trials, the robot is provided with 2 IR sensors, one located on its front and another on its back. If the robot does not detect anything, it turns 15º. If it detects an opponent which is further away than 15 cm, it turns 90º and, at the same time, it moves laterally and tries to hit the opponent with its left arm. If the opponent is nearer than 15 cm, the robot tries to hit it with both hands. If the robot detects the opponent with its back sensor, it starts to hit the opponent. A diagram of combat routine can be seen in Fig. 8.

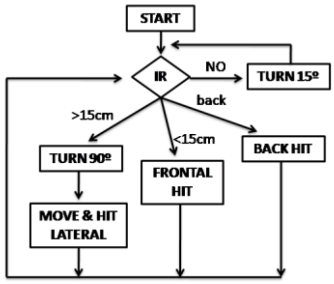

Fig. 8: Diagram of the Algorithm for the Combat Test

3.6 Participation of platform in national and international contests

The 'arduinized' ROBONOVA has taken part in several national and international competitions during 2008 and 2009. During all this time, the programming and hardware of the robot has been continuously improved with different results. It is important to point out that the participants in all these contests are mainly undergraduate students. Due to this, the improvements have different levels of success at contest time.

An example of a national contest with this kind of robot is the III CEABOT 2008 edition celebrated in Tarragona, Spain, in which the final result of the UC3M team was the third position. This was the second edition using the arduinized robot. The main improvement applied for this contest was the integration of infrared sensors to detect obstacles, and one tilt sensor to detect the inclination of the robot to be able to implement falling avoidance (Fig. 9).

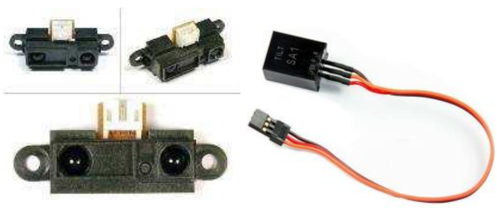

Fig. 9: Sharp GP2D12 Infrared Sensor, and SP1 (PWM Output Type) Tilt sensor

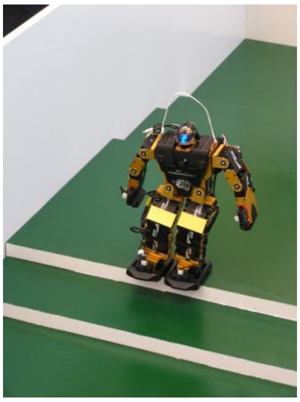

Fig. 10: Walking Across Stairs Race

The UC3M team also participated in the IV CEABOT contest, celebrated in Valladolid, Spain in 2009. This time there was three different tests. The first one was an obstacle race. The second one was a climbing stairs race with steps of different lengths (Fig. 10). Finally, there was a fight test. For these contest, several changes were performed in the robot hardware. The most important improvement was the addition of a digital compass. This allowed the robot to walk in the right direction.

In the case of international competitions, the UC3M team participated in the VI RobotChallenge 2009 European Robotics Championship, in Vienna, Austria. This event consisted of two independent contests: running and sumo fighting (Fig. 11). The final results were first position in sumo and second position in running. The main modification for this competition was the addition of a new shield with an independent servomotor controller, leaving the Arduino board only for sensor information processing.

Fig. 11: Robot Challenge Sumo Fighting

4 Conclusions and Future Work

In this paper, we propose a methodology for practical education and learning which involves using small humanoid robotic kits. It is based on the effort of students, which learn to carry out technical projects with an initial supervision, investigate new resources and ideas, collaborate in teams, and develop new capabilities and personal attitudes.

After these new experiences, some undergraduate students have been invited to participate in this project. So a new open question appears as CEABOT will be open for undergraduate student. How to manage, from a didactic point of view, non-heterogeneous levels and skills?

The issue of how newly available hardware or software can facilitate the inclusion of topics, traditionally assumed to be too difficult, is also relevant. Last year's experience was designed to explore how the availability of a new open-source board could improve an off-the-shelf robot kit. The intended achievements must facilitate the hands-on exploration of legged locomotion at the undergraduate level. The setup of new hardware has been a new challenge for ASROB undergraduate members.

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