An experience for teaching humanoid robotics in computer engineering studies

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***Abstract*—In this paper, the author presents his personal experience on teaching robotics, and more specifically on teaching humanoid robotics, within the studies for the Computer Engineering degree in the Escuela Técnica Superior de Ingeniería Informática of the Universidad Politécnica de Valencia, Spain. In the paper, first of all there is an introduction to the topic and how is the situation of robotics courses within computer engineering degrees in the more significant centres in Europe and Spain. Then, the paper progresses to explain how is the situation in Valencia, where there is a Robotics Course and a Robot Laboratory Project, explaining their main characteristics, contents and progress plan. The theoretical content for the unit on humanoid robotics is explained. The paper goes in details on the available equipment and the content of the laboratory sessions, the knowledge acquired by students and the exercises they have to do in order to pass this part of the course. Main issues covered on the Robot Laboratory Project are development of walking procedures for humanoid robots, the sensor control and the robot navigation in mazes. A student contest is organized so that the different student groups can show their abilities to program specific robot tasks, such as races and going up and down stairs and ramps. Last but not least, the paper will show the conclusions on this teaching experience on robot humanoids.**

Keywords- robotics; humanoid robots; teaching robotics; robotics in education

I. Introduction

In the last years and currently, humanoid robotics is one of the most difficult but popular topics in robotic research. Last advances on this field have produced promising results such as the Honda Assimo, the Sony Qrio and the AIST's HRP-2 and HRP-4. Every year there are more international conferences which include this topic, and specific conference for this topic, such as the IEEE-RAS International Conference on Humanoid Robotss [1], which shows the late advances on this field.

In opposition to this recent interest on research and diffusion on humanoid robotics, it seems that teaching on this field is not progressing according to the repercussion of efforts done in researching. The teaching in humanoid robotics is mainly focused for post-grade programs such as master and doctor courses and/or degrees. An example can be found in the 6th International UJI Robotics School IURS-2006 "Humanoid Robots" [2]. There are some other research courses on humanoid robotics, such as [3] in Carnegie Mellon University and [4] in University of Southern California.

Robot contests, such as RoboCup [5], are growing all around the world. During this year, the most significant robot competition at the European level has been the RoboCup Mediterranean Open, RomeCup [6], with different contests. One of the most significant one is the Football (Soccer) competition with standard platform league (then Nao robot of Aldebaran [7]) which has been won in 2010 [8] by the Spanish team Los Hidalgos of Instituto de Automática e Informática Industrial of Universidad Poltécnica de Valencia in cooperation with the Universidad de Murcia.

II. The Studies on Robotics in Computer Engineering Studies

A. Robotics in computer engineering studies

A review of the most representative university centres (schools and faculties) around Europe imparting the degree of Computer Engineering has been done in order to know the importance of robotics teaching in the most significant centres. The centres have been selected according to the Academic Ranking of World Universities in Computer Science – 2009 [9] to select the three most significant centres in Europe and in Spain.

For Europe, none of the best three centres according to this ranking (in Oxford [10], Zurich [11] and Cambridge [12]) has any course related to robotics in the studies of Computer Science BA degree.

Related to the robotics courses in Spain, the analysis has been done considering the three most representative Spanish schools and faculties imparting the degree of Computer Engineering, which are, together with the ETSInf that will be commented next section:

- Facultat D'Informàtica de Barcelona, Universitat Poltiècnica de Catalunya [13]. In the new studies, there is a robotics course of 75hours including industrial robots and mobile robots [14].
- Facultad de Informática, Universidad Politécnica de Madrid [15]. There is no course on robotics in the studies for the degree in Computer Engineering. It will be included a course on autonomous robots in the Master Program.

In centres as in Escuela Politécnica Superior, Universidad Carlos III of Madrid [16] or Escuela Politécnica Superior,

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Universidad de Almería [17] there are robotics courses now, but in both cases, these courses will disappear in future years for the new degrees adjusted to European Education Space. In Universitat Pompeu Fabra [18] there will be a course on robotics in the future when there is no one now.

From this study, it can be stated that, even considering that it is clear the important rule of computer engineers in the development of humanoid robotics in the future, there is a lack of formation in this field.

B. *Sudies on Robotics in the ETSInf, the school of computer engineering in the Universidad Politécnica de Valencia*

The School of Computer Engineering (Escuela Técnica Superior de Ingeniería Informática, ETSInf) is the result of the integration into one single institution of the Higher Technical School of Applied Computing and the Faculty of Computer Science due to the Bologna process. The ETSInf was officially created on February 27th 2009. This School inherits a long tradition of teaching and research in Computing that goes back to 1982.

The degree programmes taught at the School of Computer Science are:

- Computer Engineering (5-years programme).
- Computer Technical Engineering (3-year programmes).
- Library and Information Management (2-year programme as second stage).
- Bachelor degree in Computer Engineering (4-year programme).

The Computer Engineer undergoes extensive training in all computer-related areas. This solid training allows graduates to fit easily into different professional careers and to efficiently manage the ever-changing technological advances in the field.

In the last year of the degree course students can choose between some specialist pathways. One of them, Industrial Computing offers a complementary teaching in the application of computer engineering to the industrial systems and processes, including aspects such as real-time systems in industries, robotics, computer aided design and manufacture, automation and control of industrial processes, industrial instrumentation and computer networks, computer vision and digital image processing.

This general objective is implemented through the courses offered in the context of the pathway, which are distributed so that the student must be enrolled according to the scheme shown in Fig. 1.

From this structure it can be noted that there are two courses related to robotics, Robotics Course and Robot Laboratory Project, which will be introduced in the next section.

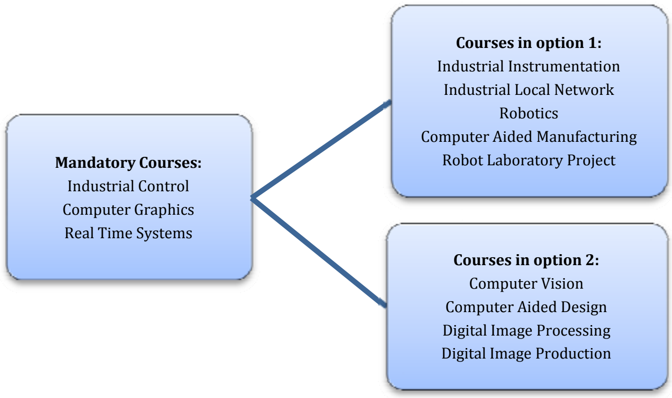

Figure 1. Structure of the Industrial Computing pathway

III. ROBOTICS COURSE AND ROBOT LABORATORY PROJECT

A. *Robotics Course*

The objectives of the robotics course are:

- To introduce the basic concepts of robotic systems in the platforms: industrial robot manipulators, mobile robots and humanoids.
- To learn the basic programming of each of the different types of robots.

The content of the course is according to the following program defined in parts and units:

- Part 1. Introduction to robotics
  - Unit 1. Basic principles of robotics
  - Unit 2. Spatial relations in robotics
- Part 2. Articulated robots
  - Unit 3. Industrial robot manipulators
  - Unit 4. Robot programming
- Part 3. Mobile robots and humanoids
  - Unit 5. Mobile robots
  - Unit 6. Humanoid robots

To fulfil the objectives, laboratory work is organized according to:

- Introduction to robotics:
  - Use of a robot simulation software
  - Spatial relations in robotics
- Industrial robot manipulators:
  - Programming simulation of robots
  - Industrial robot programming
- Mobile robots and humanoids:
  - Applications on mobile robots
  - Applications on humanoid robots

The robotics course has a total of 4.5 Spanish credits[1] meaning a total of 45 attending hours. The distribution of these hours is shown in Table 1.

TABLE I. HOUR DISTRIBUTION OF ROBOTICS COURSE

Didactic Part	Attending Hours	External Hours*
Introduction to robotics	13	5
Industrial robot manipulators	20	20
Mobile robots and humanoids	12	5
Total hours	**45**	**30**

* Estimated

The course evaluation is made using the following methods:

- Course project. It is a teaching strategy in which students develop a new and unique product by progressing with a series of tasks looking for effective use of resources.
- Online written test with open answer. Time trial, via web, in which the student builds his/her response. Students can use any material support.
- Laboratory tests. A short practical exercise that students must fill at the end of a laboratory session.

The final mark is obtained with a weight addition: 70% with the project coursework and 30% in continuous evaluation (on-line tests and laboratory tests).

All the Robotics Course teaching material is available in an OpenCourseWare website [19]. OpenCourseWare (OCW) is a web-based publication of course contents. OCW is open and available to the world and is a permanent activity. Its origin came from MIT [20] but nowadays is spreading through the world. In Spain, OCW is managed by Universia [21].

B. *Robot Laboratory Project*

The objective of the Robot Laboratory Project is to develop computer projects in the field of the material studied in the Robotics Course with the integration of concepts acquired in other courses studied, mainly within the Industrial Computing pathway.

With this objective, there is only one learning unit dedicated to the development of practical computer projects in the field of robotics.

Different projects are offered to the students, as for example:

- An automation project with the use of the industrial robot and auxiliary devices (conveyor tracking, rotation table, …).
- A project for mobile robots, in order to generate a program to solve a maze or to generate sweeping trajectories on a small room
- A project for humanoid robots, as will be explained in the next section.

[1] Conversion: 1 ECTS credit = 1.25 Spanish credits; 1 Spanish credit = 0.8 ECTS

The students choose one project and work on it during the semester. All hours in Robot Laboratory Project are dedicated to the practical development of the projects, with 60 attending hours and 20 external hours (estimated).

The evaluation of Robot Laboratory Project is made using a team project, developed during the semester.

C. *Robotics teaching resources*

Resources available for the laboratory sessions of the Robotics Course and for the project work on the Robot Laboratory Project are:

- Robotics Laboratory, with an industrial robot (ABB IRB 140), two mobile minirobots (Khepera-II) and 11 humanoid robots (Robonova-1).
- Software for the laboratory sessions: MS Visual Studio 2008 for C++ programming, VirtualRobot software for robot simulation and programming, EditRapid for ABB robot programming using Rapid language and RoboBasic v2.5 for Robonova-1 programming.

IV. TEACHING HUMANOIDS

A. *Teaching Theoretical Concepts on Humanoids*

As it was seen in the contents of the Robotics Course, there is a unit for humanoid robots. The objectives of this unit are:

- To understand the basic characteristics of humanoid robots and their possible applications
- To learn the basic methods for humanoid motion control and its problems
- To understand the possibilities of humanoid minirobots
- To understand the development of a specific case of humanoid minirobot

The contents of this unit are:

- Introduction. This part covers the definition humanoid robots, their evolution compared to human evolution, differences between humanoid & other robots, social aspects to be considered, current problems and working fields, …
- Applications, detailing possible service applications but also including industrial ones
- Motion control. In this part, the problem of stability in humanoid robots is introduced, and possible kinematics models are basically introduced with some examples. Walking strategies for stride execution and methods to capture human motion and their possible applications to humanoid robots are also explained in this point
- Humanoid minirobots. Within this part, it is explained the following issues: the origin of minirobots, several commercial humanoid minirobots, the robocup competition and an example product developed at our university, microbiro, with its hardware and software architecture and main feasibilities.

B. Humanoid equipment for laboratory session

For laboratory sessions we have available a total of 11 Robonova-1 humanoid minirobots (Fig. 2). Hitec's Robonova-1 is a fully articulated, 12" high humanoid robot, which includes a HSR-8498HB digital servomotor in every joint.

Robonova-1 kinematics has 5 joints for each leg and 3 joints for each arm, giving a total of 16 joints moved via servos. These servos can be programmed developing users' programs in RoboBasic language with the development tool RoboBasic. Programs are downloaded into the robot controller Micom board MR-C3024 through a RS232 cable.

Servos can be modified in a range of degrees (from 10º to 190º), although some joints have a smaller range (for example, the ankle or the knee) because of physical constrains.

The position of joints can be defined with program sentences, and changing angles of motors in a certain way, the robot can make several movements like walking, running, dancing, etc.

Figure 2. Some of the 11 Robonova-1 robots used in the laboratory work.

In addition, the robot controller can manage some sensors (proximity, inclination…) and the data obtained with these sensors can be evaluated within RoboBasic programs running on the controller. For example, we can write a program with an 'if then else' sentence that depends on a variable whose value is the inclination of the robot. Depending on the position of the robot, we could execute the correct series of sentences to stand up the robot (if it is face up or face down).

Every Robonova-1 used in the course includes the following sensors:

- An infrared proximity sensor on its chest
- An infrared proximity sensor on each of its arms
- A tilt (inclination sensor) in its back
- An IR LED on its head to receive remote control orders.

Robonova-1 kits come with a remote control. Robot programs can get information from the remote control (for example, which button has been pressed) and use this data in the code as if it was another sensor. In this way, different programs can be run or robot motions and actions can be modified according to user's actions in remote control.

Robonova-1 is powered with a 5-cell NiMH rechargeable battery. In this course, for every Robonova-1 there are two batteries in order to be able to use the robot with a battery while the other one is recharging. Notice that for a full charge of the battery, it has to be plugged almost two hours, and then it gives about one hour of working time with the robot. Obviously, these times are approximated and depend on robot motions. Hence, battery save is very important, mainly considering that when battery is not fully charged, the robot can work in a wrong way.

RoboBasic is an exclusive BASIC extended programming language designed for controlling humanoid robots. With RoboBasic, commands that are needed to control a robot have been added to the general BASIC programming language. Because the grammar of RoboBasic is based on the general BASIC programming language, most of RoboBasic is similar to or the same as BASIC. In order to develop programs and download them on the robot, a development program, also called RoboBasic (v2.5) is provided with Robonova-1.

C. Laboratory sessions on Humanoids

The first two laboratory sessions within the Robotics Course intend to be a starting point for humanoids practical work with the use of a humanoid robot Robonova-1. There is a specific tutorial [22] prepared to introduce the robots to the students (as users and programmers) who never had a previous contact with this robot or its programming language RoboBasic. The hardware of Robonova-1 and some basic programming guides to start moving the robot are described at the tutorial.

Students are grouped in couples, so the maximum numbers of student in a session are 20 (only 10 Robonova-1 robots are used so that there is one extra for demonstrations). A very simple first exercise allows students to start working with the system, software and hardware and to try the connection of the robot to the computer and to verify their communication. The students have to program a task to control the light that is on the robot head. The students learn then how to use the RoboBasic system, including the steps to introduce a program, to compile it, to edit program errors, to download the program in the robot and to execute it.

Next step is to program movements. The students begin with the simplest way to make a sequence of movements: moving the robot manually to different positions, memorize them and play them. RoboBasic has facilities to do this and the students soon are moving the robot to different configurations.

After verifying the previous example, in the sessions some exercises related to robot motions and postures are given for the evaluation of the laboratory sessions. Possible exercises are:

- Keep in balance on one leg.
- Step forward.
- Step lateral (right or left).

- Step backward.
- Roll 45º around robot position (right or left).

During these laboratory sessions, the students have a close contact with the robots and learn mainly the stability problems that exist to get a proper motion control on humanoid robots (Fig. 3).

D. Projects on Humanoids

After the previously explained laboratory sessions, the students are ready to develop their own project on humanoids in the Robot Laboratory Project. In the academic course 2009/10, six students of 15 have chosen to develop their project on humanoid robotics.

Every pair of students is assigned a robot through the semester so that their developments are specific for this robot. They start their project with the common goal of developing walking procedures for the humanoid robot.

Then they start controlling the sensors on the robot, first with the tilt sensor. A program must be done so that the robot control its inclination angle and move its arm with opposite angle, so that the arm keeps always in vertical status. Note that in this way, the program is using a servo motion as an output indicator of a value.

The next step is to control the three infrared reflectance sensors for distance computation. From the sensor specifications, the students must compute an approximate value of the distance from the value read for the sensor. Calibration is a critical issue in this problem.

Figure 3. Two students working with the Robonova-1 miniobot.

The project is organized in a contest with the following four trials:

- A race for going up and down a stairs
- A race for going up and down ramps
- A race avoiding obstacles in a simple maze
- An open trial to demonstrate some robot programming abilities

The definition of the first three trials is shown in Fig 4. An event for the contest has been organized this year in May [23], with an attendance of more than 75 students of the degree to watch the trials. Some pictures are shown on Fig. 5 and Fig. 6.

V. CONCLUSIONS

Humanoid robotics is one of the most promising research topics in a close future for science and technology. Computer engineers have a crucial work to do in this field as robots must be programmed and controlled. Nevertheless, not many universities are including robotics in their Computer Engineering degrees. This paper shows an experience of teaching humanoid robotics in this studies, explaining in detail how is organized a course and a laboratory project.

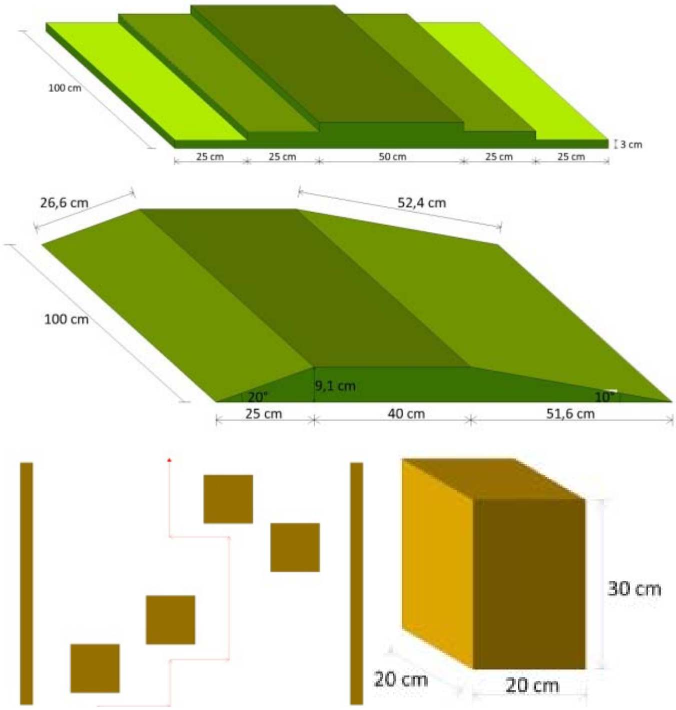

Figure 4. The definition of the stairs, ramps and maze trials.

Figure 5. A robot on the stair contest trial.

Figure 6. A robot on the ramp contest trial.

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