Appealing Robots as a Means to Increase Enrollment Rates: a Case Study

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Abstract—**As teachers of an elective robotics course in a computer science degree, we have frequently faced the lack of interest of students to enroll, thus stimulating us to introduce attractive robot platforms in the classroom, and to promote robot competitions among students. As a result, course enrollment rates have significantly grown up, even in a context of decreasing number of people undertaking computer science studies. This paper summarizes our experiences during the last 20 years, and some ideas for the near future, aiming to keep those appealing elements, while balancing the load for course preparation and teaching. The use of realistic simulations for virtual robot competitions is expected to provide the same appeal and learning possibilities of robotic hardware platforms, yet minimize the amount of technical work for setting up the course.**

Index Terms—**Robot programming, competitions, simulation.**

I. INTRODUCTION

This paper presents our experiences during two decades of teaching an introductory robotics course in a B.Sc. in Computer Science at Jaume-I University (Castelló, Spain). Since its very beginning, robotics teaching was closely tightened to the Robotic Intelligence Laboratory[1].

The course consisted on an introduction to robotics, focused on industrial manipulators, covering the basic concepts of robot arms, and its direct and inverse kinematics. Influenced by our particular research interest in manipulation, only minor contents about mobile robots were included in the first editions of the course. Besides that, real robot arms being costly at that time, most laboratory work was done on simulators.

The idea of using small mobile robots in teaching was mostly influenced by two initiatives which became extraordinarily popular: the 6.270 M.I.T. course [1] and the Trinity College Fire-Fighting Home Robot Contest (TCFFHRC) [2].

The LEGO Robot Design Competition (M.I.T. course number "6.270") began in 1987 as a student-organized programming contest, inspired a course on industrial design developed by Professor W. Flowers [3]. In this course, students were given a kit of identical parts at the beginning of the term, and the specifications of a competitive task. Their goal was to build a remote-controlled machine that would solve that task faster and better than the other students' machines. This pedagogical approach had roots in the constructionist theories of learning developed by Seymour Papert [4].

The TCFFHRC aimed to increase awareness of robotic fire fighting while encouraging use of robotics as a theme for teaching engineering design. Many students found that development of a successful autonomous fire-fighting mobile robot was the most engaging and challenging project encountered in their undergraduate years.

With the advent of cheap robot kits, teaching with robots has become increasingly popular not only in universities but in high schools, and it has raised a large interest among the educational community to assess its benefits and drawbacks. Robots have been used to ease the learning process of introductory programming courses [5]. Inexpensive robot kits are claimed as a cost- and time-effective means of reinforcing behavioral robotics principles to students of different disciplines (computer science, engineering, psychology) with limited programming skills [6].

With robotic design contests becoming increasingly common, it is claimed [7] that competitions can be an important tool for fostering intellectual maturity, as defined by the Perry Model [8]. A competition involves a clearly defined yet open-ended problem, with many possible solutions. Students are encouraged to work collaboratively in teams, and the goals provide the contextual aspect of applying knowledge.

Using robots in the introductory computer science curriculum has attracted lots of attention in recent years [9]. This approach is meaning to challenge the Computer Science teaching community to move from the premise that computation is calculation to the idea that computation is interaction. Robots provide entry level programming students with a physical model to visually demonstrate concepts or ideas traditionally taught using abstractions.

Robots may add another benefit, since they could become an attractor to Computer Science studies. Number of undergraduates declaring a computer science major is dropping steadily in the last years [10]. Women, always a minority in the field, have become even scarcer than before. Use of robots in introductory computer science has been proposed as a means to fight the enrollment decline [11]. Some experiences report that student enrollment has grown over 2 fold since the introduction of robots [9].

Videogames are a serious alternative to using real robots, since their playability and realism may enhance the experience of simulation. This reduces significantly the cost of preparing the course, while maintaining the motivation of students [12].

The rest of the paper is organized as follows: in Section II we describe the progressive introduction of small mobile

[1]http://www.robot.uji.es

robots in our teaching. Section III presents our recent years of teaching with small humanoids, and the associated trends in student enrollment. Our motivation for turning back to virtual robots is explained in Section IV, together with a description of the environment for next editions of our robotics course. Finally, we summarize in Section V our feelings after two decades of teaching practical robotics.

II. Mobile Robots are so Cool (1993-2002)

Robotics was created as an elective course in the degree in Computer Science. These studies started in 1991 with the creation of Jaume-I University, and the first edition of the course was held in 1993. Since then, a small number of students chose the course, roughly 10%, with a maximum of 15% of the enrolled students in 1996. It should be taken into account that the degree in Computer Science was mostly oriented to programming and software engineering.

Laboratory work consisted on simulation of manipulators, in order to learn the kinematics of a robot arm, by using Corke's Robotics Toolbox.

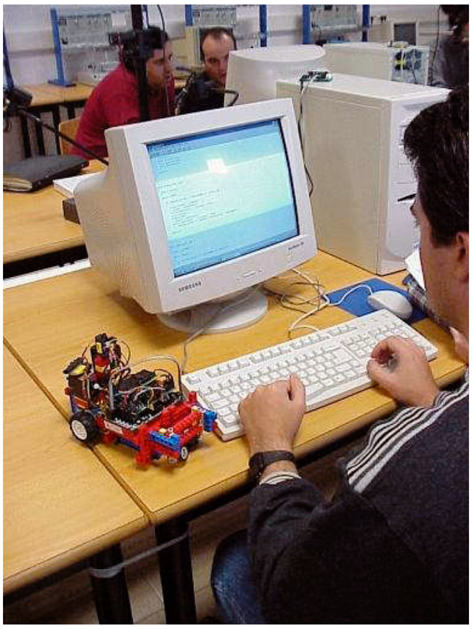

Fig. 1. Student programming a small mobile robot at the laboratory.

With the advent of cheap mobile robot kits [13] [14], it became feasible to use real robots in the classroom. Thus in 1999, we introduced laboratory works with small mobile robots (Fig. 1), and promoted a sumo competition among the students [15]. Needless to say, the competition tremendously boosted the interest of the students in the work. Since it was the first event of this type in the university, it raised a large interest not only among the students in Computer Science, but in the whole community, as seen in Fig. 2. This interest was also widespread in the media, with several references in local newspapers.

Fig. 2. Robotics sumo competition at UJI, academic year 1999/2000.

We believe that both the use of robots and the competition were the reasons for the sudden yet sustained increase in the ratio of enrollment in the robotics course. As depicted in Fig. 3, the percentage of students who chose this course was nearly doubled starting from year 2000, and it kept increasing up to a previously unseen 26% by year 2002. Such numbers roughly represent a 2-fold increase over the mean value of the editions prior to the use of small mobile robots in the classroom.

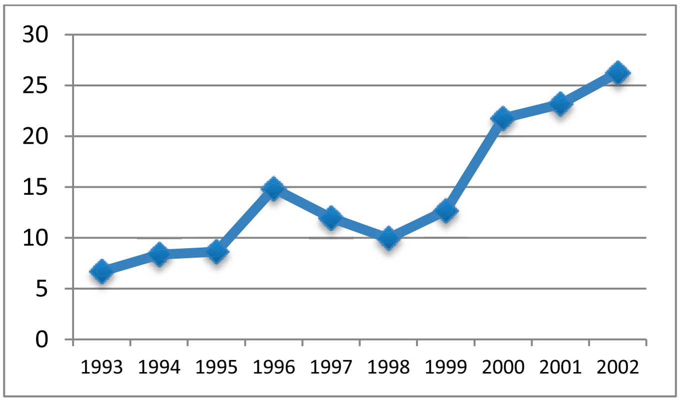

Fig. 3. Percentage of students enrolled in the elective robotics course between years 1993 and 2002.

III. Humanoids Rule! (2003-2011)

In 2001, a major change in the organization of the degree in Computer Science was taken. Two three-year degrees were created, oriented to software and hardware respectively, and the five-year degree was re-organized in three itineraries, one of them being devoted to industrial informatics.

The reorganization did not represent any increase in robotics credits, though. Despite its popularity, the academic commission kept robotics as an elective course, which was offered only in two of the three degrees. Possibly due to incomplete information about the changes, the enrollment in the course decreased significantly in its first edition in 2003. By that time, we used small mobile robots in the classroom, and the numbers were slightly recovering in the following years, but the next major breakthrough was produced after the introduction of a new robot platform.

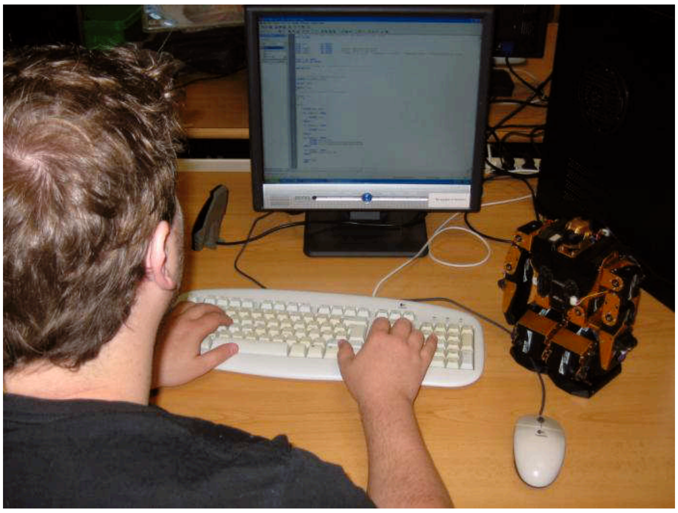

Fig. 4. Student programming a small humanoid robot at the laboratory.

After some months of previous testing, we introduced in 2006 a small humanoid robot in the classroom (Fig. 4). It consisted on a kit with all the parts and servos to build a highly autonomous robot, and the students were challenged not only to program simple behaviors but to participate in a sumo competition with their partners.

In addition, the winner of this local competition would qualify for a national competition against other Spanish universities (see Fig. 5). This time, the news spread not only on newspapers but also in television and radios. As a result, the enrollment rate grew significantly in 2007 and beyond, achieving an unprecedented 46% in 2009, and keeping over 40% in successive years, which represents roughly three times the ratio of the former editions (excluding the first year). Another major factor of this increase could be that our university team won the national competition during three consecutive editions.

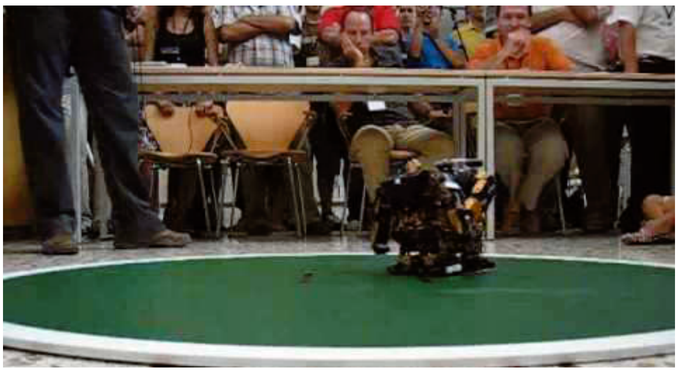

Fig. 5. Humanoid sumo combat at CEABOT'08 competition between UJI and UHU teams.

With the advent of Internet video and social networks (Youtube, Facebook), there are many opportunities to disseminate the experiences on robot teaching and competitions, and to stimulate present and future students in the discipline[2,3] thus contributing to increase the enrollment rates.

Fig. 6 depicts such undeniable growing trend, which is even more impressive when compared with the absolute global number of students enrolled in the degrees in Computer Science. This number has been decreasing steadily since 2005, not only in our university, or in Spain, but worldwide. Though some claim [10] that robotics could attract more students to computer science disciplines, we have not experienced such effect. Nevertheless, the visibility in the media, and the activities promoted in primary and high schools could bring some fruits in the future.

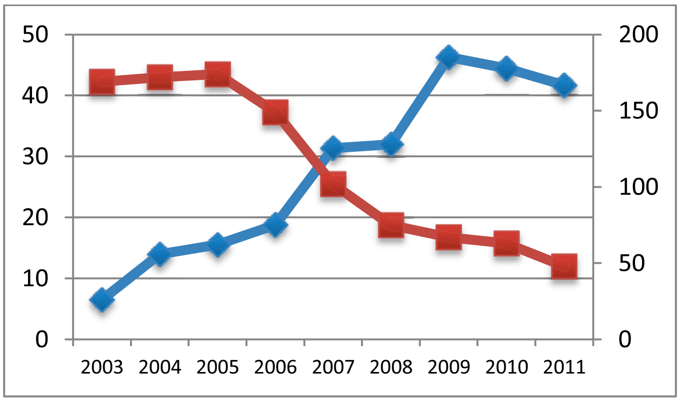

Fig. 6. Percentage of students enrolled in the elective robotics course (blue line, left scale), and absolute global number of students in the degrees of computer science (red line, right scale).

IV. Virtual Robot Competitions (2012-?)

A. *New Academic Context*

Ten years after the first reform, we are now facing a major change in order to adapt to the European Higher Education Area[4] (EHEA). The EHEA was meant to ensure more comparable, compatible and coherent systems of higher education in Europe, and it was finally launched in March 2010. In Spanish degrees, the process was implemented by extending the bachelor level to 4 years, while keeping 1 or 2 years for the master level. As a result, in the field of computer science, a single 4-year B.Sc. replaced the former 3- and 5-year degrees. A specialized M.Sc. in Intelligent Systems has also been introduced as an intermediate step towards PhD. The master students can choose between two majors on service robotics and interactive systems respectively. In the new B.Sc. the former robotics course has been merged with another course on Artificial Intelligence to become a single compulsory course on Intelligent Systems. This course will be started on Autumn 2012.

B. *Videogames and Learning*

This context of changes has lead us to make modifications in the subjects, in an attempt to reverse the declining trend in

[2]http://www.youtube.com/user/RobInLabUJI
[3]http://www.facebook.com/pages/Robotic-Intelligence-Lab/55085509725
[4]http://www.ehea.info/

student enrollment. With this goal, we have taken into account some considerations.

Research over many years indicates that the use of digital videogames for learning leads to improved general learning, increased motivation, and higher performance. It has been found that students provided with computer-based or console-based videogames to facilitate learning score significantly higher on tests. Although experts differ greatly in other aspects, they share similar opinions on which are considered the key gaming features necessary for learning and engaging: *fantasy, representation, sensor stimuli, challenge, mystery, assessment* and *control*. Videogames overcome the rules of reality in order to use their own rules, whereas simulators attempt to model a system in a manner that is consistent with reality. Nevertheless, despite the differences between videogames and simulators, they contain many common elements. Furthermore, key gaming attributes are important to increase the "game-like" feel of simulators. Also, fidelity in simulators is rather variable: low-fidelity simulators simplify systems in order to highlight only its key components, whereas high-fidelity ones try to model systems as realistic as possible and tend to be more game-like [12].

Experiences of the National Institute of Standards and Technology (NIST) demonstrate that competitions are an effective means of stimulating interest and participation among students. So, we can find many worldwide virtual robotics competitions such as RoboCup Rescue[5], or Virtual Manufacturing and Automation Competition[6]. These competitions tend to get the students engaged and encourage larger participation in the research community.

Virtual environments are needed for teaching robotics in distance learning. When teaching technologies, the need for laboratories in many courses steps back universities from offering such disciplines. Realistic simulators may replace the need for real equipment, thus allowing the enrollment of students who either work part-time or live in distant countries [16].

Last but not least, setting up a virtual environment is less time-consuming than keeping a collection of real robots in working condition.

C. *Realistic Virtual Environments for Teaching Robotics*

Consequently, we have organized a course that allows students to acquire robotics knowledge and use a realistic virtual environment, which includes a challenging robot sumo competition. The course is based on freely available (mostly open-source) off-the-shelf software components:

a) ROS[7] (Robot Operating System) is an open source framework for robot control that provides libraries and tools to help software developers create robot applications. [17].

b) UDK[8] (Unreal Development Kit) is a free edition toolset powered by Unreal Engine 3 (3D engine of Epic Games first person shooter Unreal Tournament III) that includes a world editor. Unreal Engine 3 offers graphical realism and smooth gameplay.

c) USARSim[9] (Unified System for Automation and Robot Simulation) is an open source high fidelity 3D robot simulator built on top of UDK. In addition, USARSim provides detailed models with high quality physics of interaction and let users to build their own robots and sensors [18].

So, we have combined these tools to obtain a virtual environment of simulation trying to preserve those attributes that make videogames so motivating [19].

Regarding fantasy (element in a game that represents something that is separate from real life and evokes mental images that do not exist), we have included a sumo ring surrounded by water (see Fig. 7).

Concerning representation (physical and psychological similarity between a game and the environment it represents), we have modeled the building with many details to achieve realism (see Fig. 8 and Fig. 9).

Fig. 7. Virtual environment for robot sumo competition: the ring is surrounded by water; animated flags and torches are added for enhancing visual realism.

Fig. 8. Outdoor view of virtual building.

With reference to sensory stimuli (visual, auditory, or tactile stimulations with the purpose of distorting perception and using temporary acceptance of an alternate reality), we have introduced some visual and audio effects for water, fire and wind, e.g. distortions, reflections, light flashing, moving shadows, etc.

[5]http://www.robocuprescue.org/
[6]http://www.vma-competition.com/
[7]http://www.ros.org
[8]http://www.udk.com
[9]http://usarsim.sourceforge.net

Fig. 9. Indoor view of virtual building with a mobile robot.

V. DISCUSSION

In two decades of teaching robotics, we have used many simulation environments and real robot platforms. We have witnessed the enthusiasm of students with small real robots, and their commitment to challenges posed by robot competitions.

But we have experienced ourselves the overhead in course preparation needed for setting up and keeping a fleet of small robots in working condition.

Together with the advent of powerful yet inexpensive video cards, we advocate for the use of virtual robot competitions in teaching. We believe that many benefits of robot competition can be also grasped in virtual environments, as demonstrated by the appeal of videogames.

Nowadays, virtual environments with tremendous realism are possible in a standard computer, and software tools are freely available for setting up a virtual robotics laboratory or competition. The simulation of physics makes programming in virtual robots almost as challenging as in real ones, while keeping maintenance work to a minimum.

Virtual worlds allow the introduction of enhancing fantastic elements that enrich the gaming experience, thus we expect that students will enjoy the course, making robotics attractive for them, and increasing the enrollment rates.

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