A Learning Approach Based on Robotics in Computer Science and Computer Engineering

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Abstract—**It is well known that the number of students that arrives to engineering studies decreases every year, due to the difficulty that these studies present, when compared to other studies, in a society that tends to be more social oriented than in the past.**

In order to increase the interest of the students this paper presents a Project Based Learning (PBL) that involves hardware and software using the robotics as the main object in computer studies. This educational project is being held in the Computer Science and Computer Engineering studies of the *Universitat Autònoma de Barcelona*.

Keywords-component: Project Based Learning (PBL), robotics in computer science/engineering.

I. State of the Art

The use of robotics for teaching purposes has motivated several generations of professors and students in computer studies. In 1994, Pattis et alt. presented *Karel the Robot* [1], a simulator to introduce programming techniques. From there up to now, several companies have introduced in the market excellent robot kits for education as Lego Mindstorms [2], Sony with Aibo [3], etc, based on robots that are programmed using specific tools. More recently, the Institute for Personal Robotics in Education and Microsoft presented the Myro robot [4] with an educational environment that has been extensively used to introduce students in engineering studies. Also, several authors [5] [6] have argued the use of robotics as a means in order to help the student in programming courses.

Until now robots have been extensively used in learning stages as a resource to improve teaching results, but rather limited to specific areas of knowledge. The robot, as a whole, is a powerful tool that can be used in transversal teaching processes. In this sense, engineering studies have a lot of transversal subjects that can be explored using the robot as a resource. Usually, the robot has only been used as a helping tool in the learning of programming techniques. The technological power that a robot presents has not been used as a whole in computer studies.

A. A PBL based in robotics in Computer Science

The paper shows a transversal experience that uses the technological power included in robots in a learning process in computer studies that includes hardware and software. Topics are introduced in a way such that students are confident with what computer studies imply despite the use of the robot. Robotics is only the "toy" for motivating the beginner students on the subject.

Of course, a PBL based in robotics in computer studies can include many topics comprising subjects from the first year to higher level courses. In the first year the robot can help to introduce basic topics taking as a basis the duality hardware/software (fundamentals of computer science, machine programming, programming techniques, programming languages, introduction to operating systems, etc.). At higher level courses, artificial vision, neural network and fuzzy programming, real time applications, human-computer interfaces, software engineering, etc. are typical subjects were robots are used as a resource. Robotics embraces all the computer engineering and computer science knowledge [7].

In this experience, the authors have used robotics in the first course as a resource to motivate the beginner students. In this sense, the robot has been used to introduce, hardware and software topics. The experience developed includes the subjects of fundamentals of computer engineering including low level programming (assembler), algorithms and high level programming and data structures.

The paper presents the experience that is being developed in our university. The explanation begins with a discussion in section two of the first course syllabus in computer studies and its adaptation to a robotic-based PBL. Section three introduces the scheduling of the reported experience. The setup and cost of the experience is discussed in section four. Section five describes the PBL application and results obtained and, in the end conclusions are presented.

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II. A SYLLABUS FOR A ROBOT-BASED PBL IN COMPUTER STUDIES

A. *Syllabus in the first course of computer studies*

The experience developed in this paper is being hold in the first course of computer studies in the Universitat Autònoma de Barcelona. The subjects of the computer studies are defined in the student guide. Table 1 resumes the topics covered in the student guide during the first year of entrance in the university. The table shows that the main involved topics are software, hardware, mathematics and an introduction to electronics. In fact, this curriculum, with little changes, corresponds to a typical first course in computer engineering / computer science studies in Spain.

A first glance to this curriculum shows that it could be a tough course for students that arrive to the university. Near the half of the topics are related with computer studies but they are not strictly computer science topics. That is, a significant part of them are mathematics and electronics. Professors are aware that these topics are not really pleasant to first year students. Many of these students are used to work with computers only to chat with friends or to play games.

Furthermore, the decrease in the number of students that arrives to computer studies (and into engineering in general) worsens still more the panorama.

In this sense, the authors are aware that it is necessary to motivate first year students. A method to improve it is introducing new educational methods that help to improve the motivation in first year students as, for example, using a robot as a motivating resource in the studies.

TABLE I. COMPUTER ENGINEERING FIRST COURSE SUBJECTS

Programming languages & Algorithms (105 hours)	Programming languages Functions and procedures Pointers Files Algorithm analysis Search and ordering algorithms Recursive algorithms
Data structures (60 hours)	Object oriented languages (C, Python) Lineal data structures Non lineal data structures: trees Other non-lineal data structures
Computer fundamentals (90 hours)	Digital systems: information representation, Boolean algebra, combinational and sequential circuits CPU fundamentals: architecture, instruction set, address modes, assembler, interruptions CPU peripherals: memories and memory hierarchy, input/output, Communications
Electronics (120 hours)	Electrical circuit basic laws Permanent and transient analysis Semiconductors: diode, transistor, opamp Technology: bipolar and MOSFET Introduction to data acquisition
Algebra (105 hours)	Matrices, vectorial spaces, linear applications, rings, polynomial operations
Calculus (120 hours)	Differential calculus and differential equations, integration, Fourier fundamentals

B. *The robot for a PBL in computer studies*

The robot is a perfect tool to introduce and to motivate students into computer studies. The robot is a packed unit that contains all the components and structures to introduce students to computer fundamentals and computer programming in a first year course. All subjects can be exposed using the components and the structure of the robot.

Software is the first great subject students learn in a first course in computer studies. At this level, the robot can be used to model any behavioral conduct, programming it using a high level language. Typical languages used in computer studies (talking about the learning of algorithms or data structures) spread from the classical C to more actual languages, as Ruby or Python for example. The main routines can be programmed into the robot, or the robot can be a slave that performs accordingly to actions mastered by the computer. This later case implies that the computer request the robot its sensors state, make decisions and sends actions to the robot. In any case, an algorithm could be implemented in the robot and data structures must be used.

At the hardware level (the second great subject) the kernel of the robot can be exploited to introduce computer hardware fundamentals. Simple robots are based in known microcontrollers. Scribbler is based on a PIC microcontroller. RUAB1 (our own robot) is based on an Atmel microcontroller. Deep in the microcontroller there is a typical CPU core, memory and peripherals that can be used as examples when computer fundamentals are introduced. Of course, any of these robots can be used in a PBL in computer studies.

In the planning stage professors must be aware that not all the robots perform correctly with the competences and with the didactics established for the course. For example, in our first year application of the PBL we used the Scribbler robot. Scribbler showed to be a gentle robot when used in software problems/projects. But when we tried to use it in a mixed hardware/software PBL we had to solve some not evident problems because the robot lacks of facilities to incorporate hardware in its core. Furthermore, the robot architecture is based in a PIC microcontroller which internally interprets the pBasic, the language used to program the robot behavior. Furthermore, the PIC CPU core is a rather tough CPU to introduce students to computer hardware fundamentals.

The third topic involved in the first course is electronics. Electronics is the basic subject that is behind the functioning of any electrical device. The robot is a perfect example to introduce the subject. All (not mechanical) devices in the robot work accordingly to the electrical rules. Thus, electronic basics and devices are introduced using as examples the different components of the robot in case studies.

In the end, mathematics is a subject that covers an important part of the first course studies. Maths can be introduced in a PBL through calculus equations and modeling approaches. However, and due that maths are not fairly related with hardware and software subjects, in this first experience they has not been involved in it.

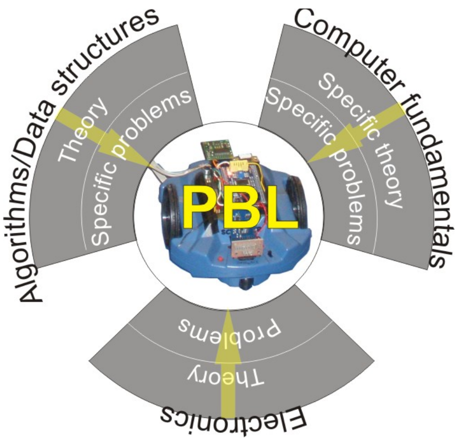

Figure 1. PBL scheduling

III. PBL SCHEDULING

A. Subject scheduling for a PBL in the first course of computer studies

The PBL approach is done in the first course studies of computer engineering in a subgroup of 20 students. In fact, this is a reduced set of the total number of students that enters in computer engineering studies, more than 100 students. The reason to do the experience with only a subgroup is that the cost that would imply to address to all students is not affordable neither recommendable in a first year experience.

So the project has been developed for a group of 20 students that voluntary decided to participate. The condition imposed to PBL instructors is that all the students of the course must acquire the same competences independently of the educational method carry out during the course. In order to achieve this, a planning of the course was made according to a study about the methodology used in each subject (Fig. 1) and the requirements imposed by the PBL:

- Theory is adapted in the subjects for the PBL students whenever it is necessary. This involves mainly the subject of computer fundamentals that needs to be reviewed in order to address the experience, and affects digital systems part as also the classical part of computer fundamentals. In what refers to digital systems topics, as they are not directly involved in the project, the subject is taken out of the PBL. So, this subject is given with the rest of the students. The more classical part of computer fundamentals (introduction of the CPU, memories, peripherals, etc.) is reviewed in order to fit the AVR architecture (the ATmega128 is used in the practical classes) in the computer fundamentals theory.

- Problems of each subject were adapted to the robot architecture in both hardware (except digital systems problems) and software. Problems are rearranged in order to fit with the PBL and with the devices that compound the robot.

- In the end, theory and problems focus towards a final project in which students must demonstrate the acquired skills in software and hardware. The hardware practical lessons were all reviewed in order to fit with the robot expertise that students must acquire. The software is more versatile and, with little changes practical lessons are adapted to control the robot. In the end, hardware and software are joined in a robot guiding problem/project. In it students must demonstrate that have developed the course skills in software and hardware.

B. Components of the PBL

The project to be developed by students comprises elements that address software and hardware subjects. This is accomplished using:

- A host to control the robot. In the host the students must implement high level algorithms to control the robot. Such algorithms are responsible of the robot behavior: line follower, light dependent tendencies, avoiding obstacles, guiding problems, etc.

- Fundamental computer hardware set on the robot. The student works on ATmega128 microcontroller in order to implement a low level hardware that fits with computer fundamentals subject. The objective to the final practice is that robot must send to the host the orientation of the robot. The task of the microcontroller is to send this message. The task of the student is to take expertise with the CPU and assembler language using this finality. So, a low level driver must run in the microcontroller and send data to the robot brain. To do this, in this first year experience students developed an orientation driver based on a compass sensor. In the end, the students must be confident with the microprocessor concepts introduced in computer fundamentals subjects.

- Introduction to elemental communication protocols can also be introduced in the PBL. In this case. The communication between the host and the robot is performed via RS232, a low level protocol easily understandable by first course students.

- At the software level students may introduce a high level conduct into the robot. In this case, the robot must run in a labyrinth with doors that have to be opened asking for a key.

- In the end, and though many good wishes always are expected, instructors were confident that the work in real time is difficult. In order to overcome it a setup based on a camera in the final practical lesson is prepared by authors in order to help the robot to follow the path.

IV. SETUP AND COST OF THE EXPERIENCE

If the aim of the experience is the motivation of students in a career, professors cannot expect to obtain it without investment. Of course, a teaching experience using robots has an important associated cost due to the need to work with robots. In this experience a robot is lend per group of students (2 persons per group). During the course students have the robot and can work with it at home. In the last class, students brings back the robots and in a plenary session must demonstrate the software and hardware knowledge and competences acquired by means of the evolution of the robot in a competition. Teachers think that this is a good strategy in order to increase the motivation of the students.

The market offers several robots that can be used in the experience. Scribbler is one of the last introduced educational robots. It is nowadays used in a lot of learning experiences. Associated with Scribbler useful software can be downloaded without any cost. We used Scribbler in this first year application of the learning approach, but we had to tune the robot in order to adequate it to our mixed hardware/software experience.

That is, Scribbler is adequate if the experience is to be held using only a software approach. The robot has enough devices (sensors and actuators) to create good software programming projects in order to achieve good learning skills in software. However, when the experience takes as a basis a PBL using hardware and software topics, the robot lacks for facilities for interfacing hardware elements on it.

In order to introduce computer fundamental topics additional hardware was built and mounted over Scribbler (see Fig. 2). Of course, this implies that (in addition to the hardware changes) several software changes are introduced in the Scribbler software kernel in order to work with the new hardware.

So, the cost of the experience is the sum of the costs of the robot plus all the elements introduced in order to realize the programmed PBL. It consists of:

- The robot. We used a Scribbler robot.
- Additional hardware mounted on the robot. It was necessary in order to introduce the computer fundamentals subject in the PBL experience. It is based in an ATmega processor, the compass sensor and related passive components.
- A serial-Bluetooth connection between the robot (that acts as a slave in our experience) and the host (a PC). So, the host and the robot can communicate via the simple UART port of the ATmega board and the PC in a wireless way.

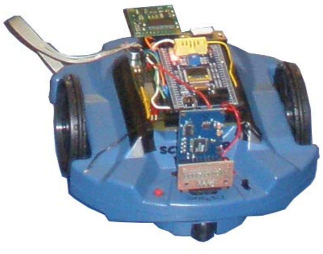

Figure 2. Robot and tuning

Figure 3. Practical setup

- A setup based on a vision guided program introduced in the host in order to help robots in the final session.

The first three items correspond to the hardware that students take in a leasing form during the course. The fourth item is built for the setup of the PBL (see Fig. 3). In it students practice during the course and make the final examination.

And though it was not yet namely, surely, the more expensive item is the cost in people involved in the experience. During the PBL planning and developing, the people involved in the experience must foresee to spend a lot of hours trying to get along the hardware components in the robot and the projects to be done by students with the robots. It was rather cumbersome to get all the components working together because of:

- The physical connection at the hardware level. Scribbler only has a port that can get free in order to allow any hardware connection to it. It is the hacker port, used only to control three LEDs. In it we connected the ATmega microcontroller, responsible of two main tasks: to control the orientation behavior of the robot and to perform the communication with Scribbler.
- The software communication between the robot and the hardware just added. In order to work with the data sent by the ATmega that gives the orientation of the robot, communication between the low level language (assembler) of the board and the high level language (Python) in the host has to be established via the PBasic language interpreter running in the PIC.

V. PBL APPLICATION AND RESULTS

The PBL in robotics has been introduced in the Computer Science studies. During the school year students work with the different subjects with the finality to joint in the hardware and software learned topics in the final session demonstration. The qualifications of the subjects are composed of the theoretical qualifications, obtained in a written examination for each subject, and the practical qualification that is unique for all the subjects participating in the PBL.

Fig. 3 is a picture of the final class of the PBL in robotics. The main components of the PBL can be recognized in the picture:

- The robot is the kernel of the PBL. In this first year experience a tuned Scribble robot was used. On the robot there is a landmark to help tracking the pose of the robot with a camera
- The camera setup of the experience. A host follows the path of the robot via a camera in order to help the robot in its movement. We introduced this improvement once we realize that real time programming can be rather frustrating for novelty students.

In respect to the results of the PBL experience several comments can be stated:

- Academic results were rather good. Students acquired the established PBL skills (knowledge and competences) in software and hardware. Students get also aware that they get with the particular competences stated in each subject.
- Students get also self satisfied with the experience
- And several students commented to the instructors that their self regard had grown.
- However, students also said that the experience was hard.

VI. Conclusions

This paper resumes a robot-based PBL experience joining hardware and software subjects in the learning process. The experience has been done in the first course of computer engineering studies with the aim to motivate first year computer engineering students.

The conclusions of the experience are:

- The kernel of the experience is the unification of software and hardware topics in a project. The aim is the motivation of the students. The objective is achieved and also has been fruitful.
- The authors are satisfied with the expertise demonstrated by the students at the end of the experience. The main learning topics were introduced and the students passed with qualifications the course.
- A poll made to students reinforced that students were satisfied with the experience. Students were aware of the knowledge acquired during the course.
- The success of the experience has been demonstrated. But a lot of hours must be dedicated by professors in the setup of the whole experience.
- Perhaps the most critical part of the whole experience has been the need to work with different hardware resources. As introduced, a tuning of the robot had to be done in order to coordinate hardware and software practical classes. In order to improve this, the authors are developing this year the experience using RUAB1 a robot specially designed and built for the PBL activities. It is based in an ATmega microcontroller and for the PBL has a clear advantage: all the hardware and software topics can be done using a unique microprocessor.

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