LEARNING ROBOTICS VIA WEB: REMOTE EXPERIMENT SYSTEMS FOR DISTANCE TRAINING

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Abstract

In this paper two educational environments are described where Multimedia, Robotics, Java and Internet are got together. Both of them provide advanced and interactive distance learning, but each one represents a different educational approach: one gives remote access to a real lab where the user can experiment with a robot, view and practice, and the other provides access to a virtual sophisticated lab where the student can be trained eliminating physical risks for the students and operation problems for the lab material.
The first environment is an educational web site developed to help a non-experienced user to learn a robotics programming language (LeJOS). The idea is to provide the student with access to a real laboratory (set up at the University) endowed with a robot and a web cam so that they can experiment with the real robot.
The second environment, VRMLproCNC, makes use of Virtual Reality providing students with a set of distance training tools via Web for industrial numerical control lathe simulation. The simulator was developed using VRML and E.A.I. (External Authoring Interface) libraries, Java and JavaScript for those tasks that VRML can't do properly. Because of the low-cost of the system, the requirements of the visualization equipment (equivalent to a domestic use PC) and the web-oriented technologies used, the system is specially suitable for being used in distance and continuous training courses.
Both experiences try to contribute to the advance of the new learning methodologies, focused on autonomous and continuous learning, that are been promoted through the European Higher Education Space.

Keywords
E-learning, Robotics, Virtual Reality, Continuous training

1. INTRODUCTION

The use of new didactic resources such as multimedia or the Internet has opened a new world of possibilities, offering a way of communication and exchange among different teaching institutions all over the world.
The new education methodologies are moving from the classical conductist scheme to a new one where the student gains responsibility on his own learning process [1]. Moreover, the European Higher Education Space promotes the autonomous and continuous apprenticeship. The operation of machines and tools and, in particular, those aspects related to education and training (training viewed as the acquisition of competences, with a revised commitment between theory and practice), make up an interesting field in which real and virtual environments can be used altogether via Internet.

In this paper, two educational environments are described. The first one is a web site that gives access to a real lab where the students can experiment with a real robot and learn a robotics programming language. Discovery learning is one of the most ancient and well-known ways of learning. Piaget and Papert extensively wrote about it during the 70's and it was during the 80's when many works about the advantages of games, simulators and role-plays were published. Nevertheless, in these environments and in spite of the increasing student autonomy, the role of the teacher as a guide remains essential.

The second environment presented here is related to virtual reality applied to continuous training. In the last years, great efforts have been devoted to the continuous training, developing new materials and multimedia didactic systems. Nevertheless, in some areas, it's almost impossible to offer an adequate training without the inclusion of some practical contents. The virtual reality systems can partly cover this necessity by simulating, in an interactive way with a computer, the physical and geometric models of some processes. The virtual reality environments offer advantages for the continuous training because:

- Real situations can be "custom made" simulated for encouraging the apprenticeship.
- Modifications and changes can be incorporated and the incidence in the virtual model can be immediately evaluated.
- When the handling of the equipment implies a physical risk, virtual reality is the most suitable choice.
- The use of expensive hours-machine can be avoided.
- The problems derived of an incorrect use of the technical equipment (failure, non-productive materials, ...) can be easily detected.
- The experience acquirement is generalized because of the avoidance of displacement to training centres.

On the other hand, the main problem of the virtual reality environments is the high cost and the complexity of the required equipment. The system presented in this article, VRMLproCNC, with the combined use in a non-conventional way of some of the existent technologies in the domestic PC market, demonstrate what low cost virtual reality formative systems can be done.

Both systems are explained in the following sections.

2. Web and LEGO: Interacting with a real lab via Web

2.1. General characteristics

The origin of this project is the interest in developing a system, adapted to new technologies, that allows every user to learn a robotics programming language (LeJOS). The users can choose among different programming levels with attached information about the robotics and programming language used; learn from examples; design, compile and download to the robot the programs the users want; finally, the user can execute the code and view the results onto the robot through the web cam. The proposed system allows students to exercise and practice remotely and effectively anywhere and anytime they want.

The electronics chosen has been ROBOLAB[2], the robotics set created by LEGO Mindstorms™ for educational purposes. LEGO Mindstorms™ [3,4,5] appeared in 1987 when the MIT Media Laboratory created the first programmable block. One year later, Lego launched the first version of the block, the RCX (Robotic Command Center). The RCX is microcomputer which its own CPU, RAM, serial infrared communication port, buttons, sight, and in/out ports. The ROBOLAB kit includes several parts, connectors, sensors, lights, cables and motors to build the desired robot. It does not include the programmable RCX, onto the different pieces and devices are placed; therefore, it has been acquired separately. The programming of the RCX is done with a PC and the program is stored in it through the infrared communication tower connected to the PC through the serial or USB port.

2.2. System description

The goal of the project is to develop a user interface via web so that every user can access several services:

1. Access to the documentation:
   - Introduction to the LEGO Mindstorms™ technology.
   - Additional information about robotics and programming.
2. Didactic:

- LeJOS programming course.
- Programming examples. For every example it is possible to choose among different actions:
  - Code visualization and explanation
  - Code compilation
  - Code download to the robot
  - Visualization of the results through the web cam.
- Personal programs: the user can do all the foregoing actions but with its own examples.

The web site has been developed with the JSP-servlets technology; this is why it has been necessary the implantation of the Apache Jakarta-Tomcat server. To program the RCX, the LeJOS development environment [7] has been used. In Figure 1 a diagram showing the operation environment is presented.

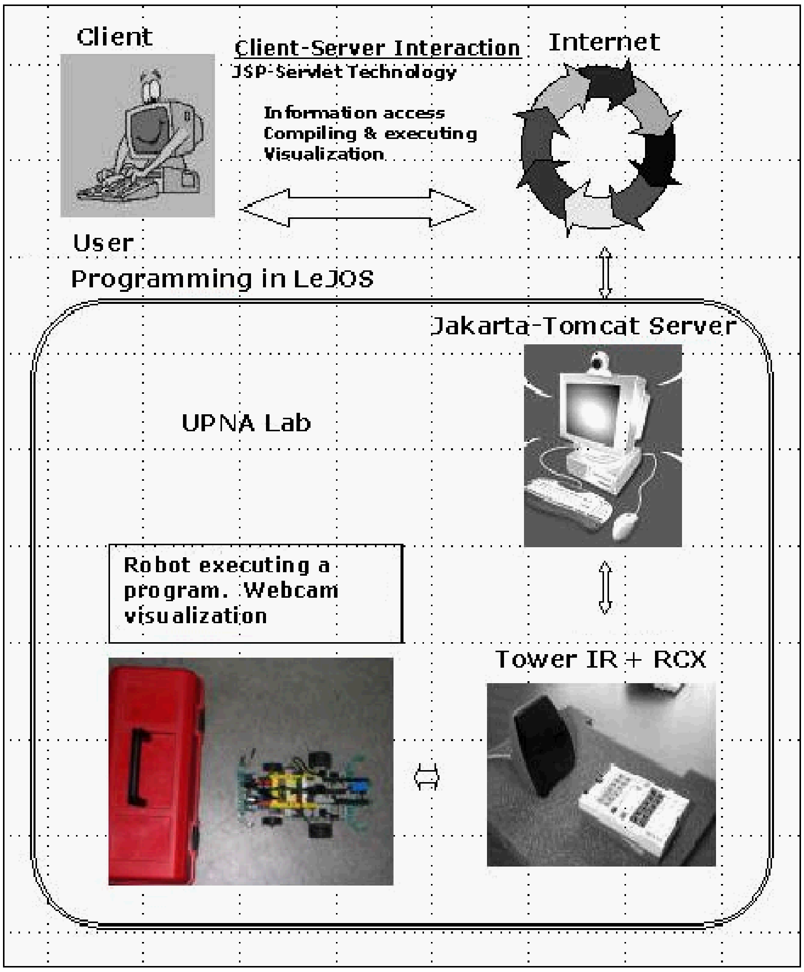

Figure 1. Diagram showing user-robot communication

Let see an example of use of the learning environment. We suppose that the user is already familiar with LeJOS programming (by means of the course provided in the web page). Now, the student is able to generate and try its own programs in the robot. The process will be (Figure 2):

- To edit the program ("BehaviorTest.java" in the example).
- To compile and download it to the robot.
- To visualize the behaviour through the web cam (in the example shown, obstacle avoidance: when the robot encounters an obstacle, it turns to avoid it).

The robot has its own sensors and the kind of behaviours the user can implement are: to follow a path, to seek maximum or minimum illumination zones, to avoid obstacles,...

Figure 2. Example of use

Editing the program *BehaviorTest.java* (left). Compilation and robot download (center).

Visualization through the web cam (right).

3. VRMLproCNC: A virtual lab for continuous and distance training

3.1. General characteristics

The second environment, VRMLproCNC is a simulation tool for the practical learning [8] of a numerical control machine-tool. VRMLproCNC makes use of Virtual Reality providing students with a set of distance training tools via Web. Possibilities of simulation environments for practical training are well-known but general use is impeded by their high costs. Therefore, the main goals when designing the system were the final cost, the hardware requirements and the technologies used so that it could be used either in training classrooms or in distance learning.

The simulator was developed using VRML and E.A.I. (External Authoring Interface) libraries, Java and JavaScript for those tasks that VRML can't do properly. The simulation tool contains two subsystems both allowing real-time control of the scene and user interaction. The first is focused on the training of a machine-tool operator and the second is oriented to the programming of the numerical control code of the CNC (Computer Numerical Control) lathe. The VRML specification also permits the design of 3D acoustic spaces and this feature was used for giving an spatially immersion and a realistic sensation to the students.

3.2. System description

The geometry, manipulation and all mechanize physical processes have been simulated for the Gurutzpe A800CNC lathe, including a CNC Fagor8010T control (with a CN editor[9]). The simulation tool is divided into two components: Simulator-Operator and Simulator-Programmer.

The first is focused on the training of a machine-tool operator and introduce the handling basic systems, manual and automatic, that have to be known in a numerical control lathe. The student actions are enforced by the movement of the different parts handled by the control panel and synchronized with the use of the 3D audio.

The second subsystem, the Simulator-Programmer, is developed for the person in charge of the CN code programming of the pieces of the CNC lathe. At any moment, the programmer can do an interactive simulation of the edition, handling and operation of a CN program and can work over the three components of this subsystem: Warehouse, Virtual Trainer and Micrometer Caliper.

The material and the different cut tools are loaded from the Warehouse with a friendly user interface. Technically, this is solved with DHTML, JavaScript and ADO, having access in a dynamic way to a database that consists in the knowledge motor of the system. Different kinds of materials, tool holder models, features of the cutting tools, equipment configuration and other characteristics are stored in the MS Access database. The technical and geometrical specifications of all the elements of the turning process are directly given by the manufacturer. This method makes the application to be continuously updated with the market data.

Every set of guided practices for reinforcing the theoretical knowledge acquired by multimedia materials can be done in the Virtual Trainer. The aim of this component is the user's development of a CN program by generating the code in the control panel. This code is processed through an analysis that leave out all possible lexical mistakes and, after that, the simulation in the virtual lathe is generated. All the turning process can be visualized, including stops and broken effects when problems are detected. Therefore, the interactive introduction and manipulation of a correct CNC program immediately produces a piece.

Finally, in the Micrometer Caliper component, the student can do exact measurements of the obtained piece using a "virtual calibre" in order to check and control the quality of the achieved results.

In the simulation of turning processes in industrial manufacture, it is necessary to show the continuous geometry transformations that produce complex geometry pieces. Taking the advantage of the hardware ability for representing the polygonal models and the possibility of modelling the process as a continuous transformation of revolution pieces, the E.A.I. libraries were used for the generation and manipulation of a "double buffer". In this way, while a state of the process is displayed using a polygonal representation of a revolution piece, the following instant is calculated with the modified piece in accordance with the physical simulation and in synchronicity with the cut tool.

Figure 3. VRMLproCNC simulador

4. Conclusions

The two learning environments presented here offer the possibility of learning programming and robotics via web. They bring several advantages:

- E-learning advantages: simplicity, access to multimedia information, disappearance of geographical barriers and low cost.
- The real environment allows the experimentation and the immediate and real verification of the results.
- The virtual environment tries to fill the existent gap between the teaching of theoretic knowledge and the carrying out of practical activities in workshop. The virtual workshop eliminates physical risks for the students and operation problems to the material. Besides, its affordable cost allows its generalization. In fact, it has been used in several distance learning courses.

In the other hand, the experiences shown in this work try to contribute to the construction of the European Higher Education Space. Both of them seek the student autonomous apprenticeship, with the always necessary teacher support. Moreover, the web access tries to take the learning environment out of the traditional classrooms and, therefore, to facilitate the continuous and distance learning, two fundamental concepts promoted by the European Higher Education Space.

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