LEARNING ENVIRONMENT FOR TEACHING ROBOTICS AND SENSORIAL SYSTEM: APPLICATION TO THE ROBOTS GUIDANCE

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ABSTRACT

In this paper we described our experience in teaching Robotics and Sensorial Systems in Computer Science degrees at the University of Alicante. The work presented in this paper has been done during the last three academic courses, with about 150 students being registered annually. VISUAL and ROBOLAB tools are jointly used for teaching this subject because they allow students to evaluate their developed algorithms and use them in practical experiences in robotics environments. The system does an automatic evaluation of the students' results, verifying whether the trajectories chosen are optimal for the problems solved.

KEYWORDS: Learning Environment, Robotics Teaching, Visual Servoing.

1. INTRODUCTION

This paper is based on the teaching of the "Robots and Sensorial Systems" [1], which is an optional subject in the studies program for degrees in Computer Engineering, Computer Systems and Management Computing at the University of Alicante (approved in 2001).

The optional nature of the subject is an important factor to be considered in the planning of its teaching. We should emphasize that it is the only subject in these study plans in which the basic principles of Robotics are taught, although there is another subject in the study plans program that includes mobile robots programming, entitled "Autonomous Robots".

Due to the great number of students registered in this subject, it has become necessary to considered more effective methods for the students' practices that would allow each student to have access to expensive and limited resources like robots. This approach to practices is very important, since the program considers 4 hours weekly, 2 theoretical and 2 practical, for a period of 4 months.

Considering the characteristics of the subject [1], we can consider several different objectives: to present Robotics in general and Industrial Robotics in particular, as well as sensorial systems and techniques for the processing of sensorial information, which are the most commonly employed nowadays in the field of Robotics; to provide the suitable tools for resolving the kinematic problem; to demonstrate the link between artificial vision and robotics through visual-control, showing its functions, architecture and control methods; and finally, to teach different robot programming languages.

2. RESOURCES, TOOLS AND VIRTUAL LABORATORIES

The set of practical exercises is aimed at illustrating the results obtained in the theoretical classes, as well as affording the students the abilities for handling the instruments and equipment used in real situations. At the moment, with the use of new technology (Internet, virtual reality, etc.) it is possible to improve the teaching of subjects though virtual laboratories [2][3]. The virtual laboratory used in teaching this subject is described next, describing not only Robolab but Visual as well. This laboratory is available on the Web at: http://www.disclab.ua.es/robolab/labvir.htm

2.1 Robolab: Virtual and Remote Laboratory to Simulate and Execute a Manipulator Robot.

The section describes the characteristics of RoboLab: Virtual and Remote Laboratory to Simulate and Execute a Manipulator Robot [3][4][5]. Robolab permits the simulation and handling a robot-arm by means of tele-operation.

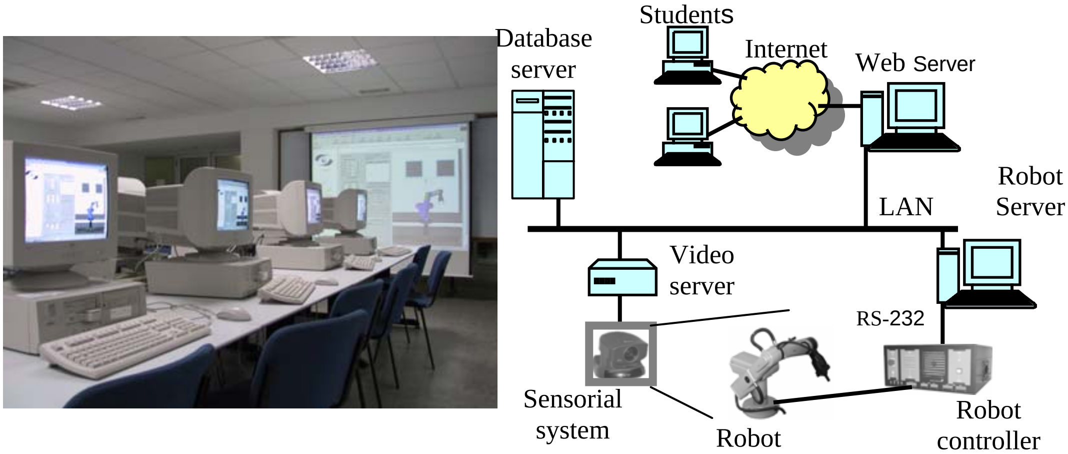

Figure 1.Architecture of the system.

The system has been designed as a virtual laboratory that allows any type of basic practice in Robotics subjects through the Internet. It has a distributed architecture which is easily accessible to the students (Figure 1). Furthermore, behind the Web server there is a computer in charge of controlling the robot, a data base and equipment to send video images as a system feedback [4][5]. The system is based on a Java Applet [6] that can be downloaded into the students' computers, which is shown in Figure 2.

By employing this sort of architecture, the need to buy a great amount of expensive equipment is considerable reduced and the equipment is better employed by the students.

2.2 Visual: Programming Environment for Image Processing.

VISUAL is a distributed Artificial Vision environment [7][8] which consists of a set of tools for working with computer vision applications, and which allow the acquisition of images, processing operations (software and hardware), and the visualization of results.

With the artificial visual environment developed, the user can specify an algorithm for processing images using a graphical scheme composed of OPIs (Image Processing Objects) to execute them [8]. The aspect of the application if shown in Figure 2.

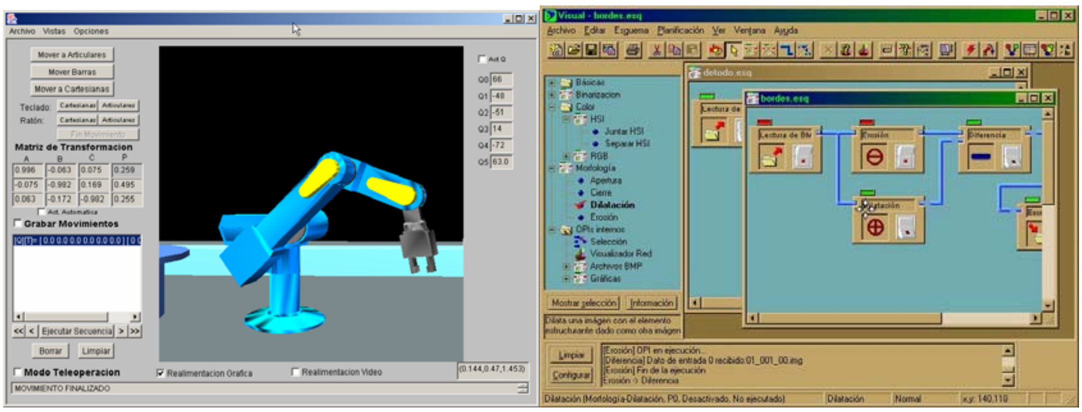

Figure 2 .Interfaces of Robolab and VISUAL

Each OPI represents an operation to do in a scheme, it has a set of entrances that get the images from other OPIs, and it has a set of exits that return the results after the execution.

These objects can be connected to each other by means of pipes that represent the interchange of data or images. The pipes connect exits with one or more entrances. The user can see the image in an exit or in an entrance of an OPI locating the mouse over it.

We should emphasize that to execute an OPI it is necessary that the other OPIs of that their input data come have executed already correctly and have generated exits. That is to say, a single OPI is executed when it has available all the entrances. In addition, each OPI has characteristics or general properties of the OPI, which represents values that have all the OPIs like the number of entrances, number of exits, etc., and on the other hand they are the particular properties of the OPI, that are specific of the operations that it performs.

Examples of particular properties can be the selection of concrete operation that the OPI must execute, the name of a file in a reading disk OPI, the threshold in an histogram operation, and so on.

3. PRACTICAL LESSONS

Considering the questions expressed and the knowledge that the students gradually achieve when they study the theoretical lessons [1], we propose a set of experiments for them to do during their hours of practical lessons in the laboratory (Figure 1).

We now describe the practical lessons. First, there is an introduction to the virtual laboratory, described previously, which is used for practical experiments. In the second practice, the components and sub-systems of a robot are shown and studied, and the students do a self-evaluation of their knowledge by means of a test available ont the Web. The third practice consists of solving the direct kinematic problem for a robot. The fourth poses questions about kinematic control and the generation of kinematic trajectories for a robot with the help of Robolab. The students later do practices on techniques of artificial vision as well as 3D-vision, using VISUAL as their main tool for image processing. In another practice, the students have to do the visual servoing for guiding a robot. Finally, robot programming is practiced.

4. DEVOLPMENT OF THE PRACTICAL EXPERIMENTS

A fundamental aspect of Robotics is the use of sensors for the inspection and recognition of objects and elements present in the work setting. Among sensoring techniques, artificial vision is a form of technology that is in constant progress and is very present in current research. The use of artificial vision in robotic systems allows the computation of the positions of the objects to be manipulated, without any need to make a contact with them.

Along these lines, a set of experiments and practical lessons have been designed over the three last years. The students use the VISUAL tool, and with it acquire a fast and intuitive understanding of different schemes of image processing. The aim is to familiarize the student with the resolution of different types of problems related to the detection of objects in the work space of a manipulating robot which can be tele-operated by means of the tool ROBOLAB. In addition, this tool is capable of simulating the movements and trajectories previously calculated, allowing the tele-operation of the robot. Also, it is possible to verify the guidance of the robot until the location of the object to be manipulated has been identified. The object is previously detected by using of the VISUAL tool and then the type of object template is recognized as well as its location with respect to the robot. We shall now describe some of these practical lessons.

4.1 Image Processing to Detect Objects.

The first step to be considered for grasping and manipulating an object with the robot is to capture and process the images acquired from the robot’s work setting. Therefore, the aim is to recognize the object to be manipulated. As such, the student does several experiments aimed at processing the image and extracting characteristics. Thus, some VISUAL processing schemes have been designed with the OPIs programmed in the tool (Figure 3). For example, the students have to design elimination schemes for noise produced during the acquisition process, elimination schemes for undesired brightness which appears in the images, extraction schemes for edges and contours by means of masks (Sobel, Prewitt, Roberts, Wallis, etc.), or morphological operations, segmentation with thresholding techniques using the histogram, the computation of Hu's moments, the detection and labelling of blobs, etc.

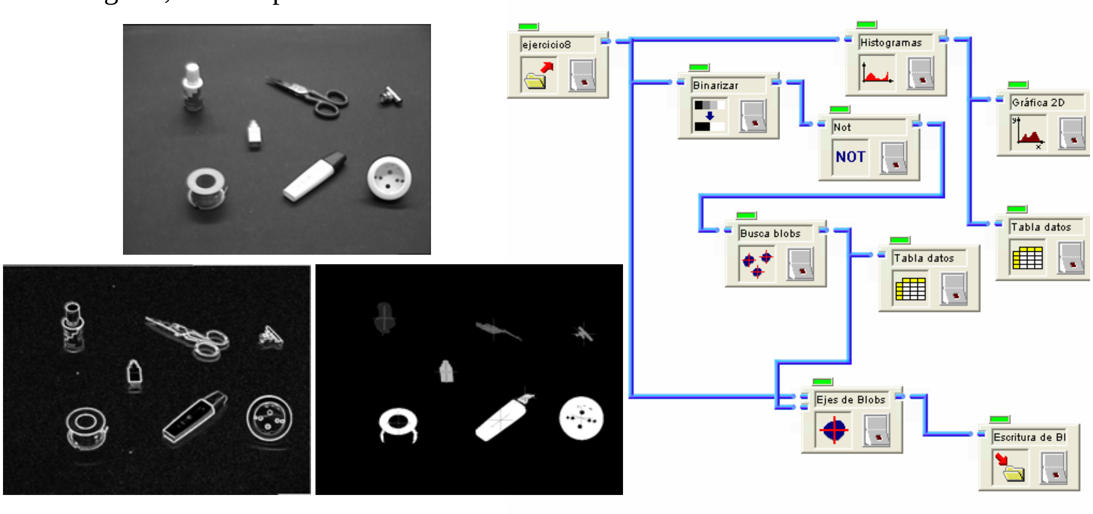

Figure 3. Example of scheme for the detection of an object in the image.

Also, depending on the kind of problem to be solved, the students are not only able to contribute to the solution of the problem by combining the different processing techniques incorporated in the VISUAL tool with OPIs, but they can also participate in the development of the tool. This way, the student is motivated to incoporate new OPIs modules which implement other techniques or algorithms that they consider suitable or necessary to improve the image processing for the detection of certain objects. It is important to emphasize that the implementation of new OPI is made in language C, and can be added as OPIs any file with extension 'exe' or 'dll' which has structured its inputs and outputs of a concrete way.

4.2 3DVision to Locate Objects in the Robot's work setting.

The 3D-vision groups all the techniques and algorithms that allow to obtain three-dimensional information from the analysis of bidimensional information registered in images [9]. Therefore, the main application of the 3D-vision experiments made by the students are oriented to calculate depths in robotizados surroundings. The calculation of depths does reference to compute the distances between sensors, videocameras, and objects into the surroundings of work.

The knowledge of the distances when it works with manipulator robots is very important to estimate the the location (position and direction) of three-dimensional objects which are taken hold by the end of the robot. From the information extracted by means of the application of the experiments commented in Section 3, and having additional information provided by a previous calibration of the sensorial system formed by the cameras, the student must to obtains the spacial coordinates (3d-coordinates) of each object detected in the image. For this, a matching process is applied to make correspond the characteristics in both images that represent the same object. Afterwards, a triangulation process for those correspondences are make and different geometrical transformations are applied to obtain a certain matrix of homogenous transformation that allows to change of the reference system of the cameras that form the sensorial system to the refence system of the robot. This way, the student is able to determine the displacement that must be carried out, and so calculate the more suitable trajectory of the robot to make the taking hold of each one of the detected objects.

4.3 Visual servoing to guidance.

Firstly, the visual guided robotic systems worked in open loop, these systems are known as "look-and-move". In this case, the robot first look at and recognize the setting using a computer vision system and then carries out the movement depending on the information captured in the previous step. An alternative to the previous exposed method is to use closed loop control by means of visual feedback to control the location of the final effector of the robot in relation to an object, which is known as visual servoing (Hill and Park [10]).

Tipically, the visual servoing systems are position-based and image-based classified [11]. The position-based visual servoing [12] requires the computation of a 3-D Cartesian error for which a perfect CAD-model of the object and a calibrated camera is necessary. These types of systems are very sensitive to modeling errors and noise perturbations. In image-based visual servoing the error is measured directly in the image. This approach ensures the robustness with respect to modeling errors [13]. The velocity applied by an image-based visual servoing system is $\boldsymbol{v}^{\mathrm{C}} = -\mathrm{k} \cdot \mathbf{J}_{\mathrm{f}}^{+} \cdot \left(\mathbf{s} - \mathbf{s}_{\mathrm{d}}\right)$ where **s** is the set of image features extracted from the imagen, $\mathbf{s}_{\mathrm{d}}$ are the desired features, i.e., the set of features observed by the camera once the robot has reached the desired position, $\mathbf{J}_{\mathrm{f}}^{+}$ is the pseudo-inverse of the interaction matrix and k is the gain of the proportional controller.

In order to be able to experience with this type of visual servoing systems, the student uses the two tools described throughout this article in a coordinate way. On the one hand, using VISUAL the student determines the desired features corresponding to the observed landmarks of the object from the final position of the robot (an eye-in-hand camera is used). Once these features are determined, the features extraction process during a visual servoing task is simulated using VISUAL. The trajectory that the robot describes in the 3-D space during this task can be determined using ROBOLAB (Figure 4). With the objective to verify the behavior of these type of visual servoing systems, once the simulation ends, the student can observe the real behavior of the robot making the teleoperation from the simulation data of the image-based visual servoing system.

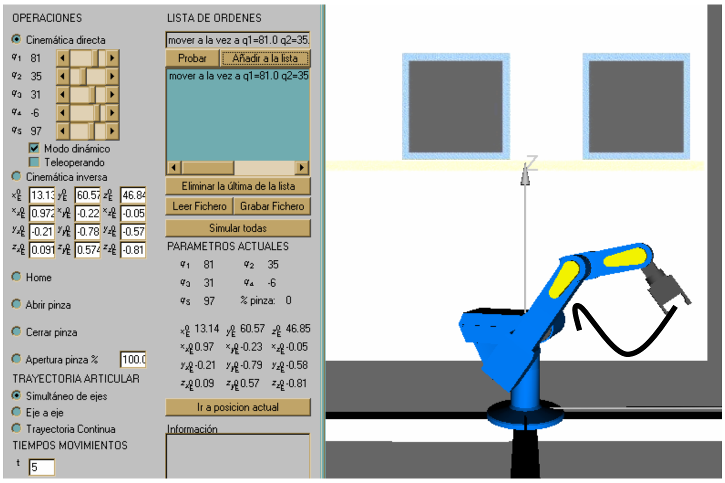

Figure 4. 3D Trajectory generated by the visual servoing system.

5. CONCLUSIONS AND ANALYSIS OF LEARNING.

To analyze the learning process, several experiments described in Sections 3 and 4 have been developed. These experiments have been evaluated by means of questionnaires stored in a database server (Figure 1), the questions of which have been chosen randomly. Furthermore, during the last few years, a statistical study has been carried out to detect the advantages and anomalies of this type of teaching, using tools like Robolab and VISUAL [14]. The progress of the students who did the practices either from their homes or in the laboratory of the University, has been evaluated.

Robotics is a subject that generates great interest between the students, this aspect motivates that the number of students registered during the last courses is elevated (Figure 5). This causes the necessity to design effective methods for the development of the practices. An important aspect for evaluating the impact of this type of tools is the facility to assimilate its fuctioning from the students. It is possible to emphasize that 90% of the students need 1h or less to understand the Virtual Laboratory and 46% consider that it is enough to him with 30 minutes. Of these, only the 5% of the students say to perfectly understand the simulator but they are not able to make the experiments, which indicates that really they have not understood the simulator correctly.

Figure 5. shows that 20% of the students have chosen to carry out the practices from their house. However, 71% have preferred to make it from a laboratory in the University with connection to Internet and to access via web to the remote laboratory where is located the robotic system. The students prefer to carry out the practices in the laboratory of the University because of great part of they considers essential the explanations of the professor (65% of the students). This data contrasts with the present tendency to decentralize education, doing it less dependent to the explanations of professors.

The data obtained reveal, that although the students consider interested this type of tools to have access to limited robotic resources with a flexible schedule, also consider important the support of a professor to guide them. Therefore, this type of tools is very useful if they are used as support to teaching and reinforcement of the lessons previously described by the professor.

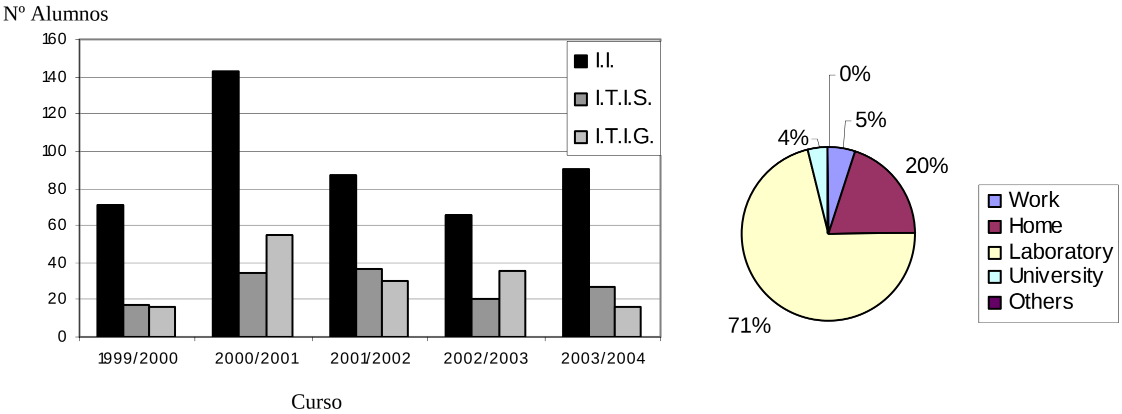

Figure 5. Evolution of the number of students registered in the robotics signature and preference of the student to carry out the practices.

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