Design of a Remote Laboratory on Mobile Robots

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Abstract: *This paper presents the contribution of Carlos III University (UC3M) in the IECAT (Innovative Educational Concepts for Autonomous and Teleoperated Systems) project which aims at create an innovative educational tool on autonomous and teleoperated mechatronics systems. UC3M will contribute in the project providing some experiments in the mobile robotics field. The main benefit of Web-based education systems is the expected growth of the participation level in the education process. This growth is due to increasing system flexibility and expanding the accessibility and availability of updated material.*

1. INTRODUCTION

Mobile robotics subject is currently taught in a traditional way, by means of lectures, tutorials and laboratory sessions. An additional innovative tool can be added by using a Web-based educational environment, which can be another teaching aids such as videos and slide projectors. Very few systems have been developed to teach robotics over the World Wide Web and most of the developed systems have only presented online lectures without covering the experimental issues. Lundquist has presented online introductory course in robotics and industrial robots [4]. Many subjects related to mobile robots have been introduced in online course [9]. In the last decade, many virtual laboratories have been presented to deal with diverse experimental issues of robotics and automation. A flexible architecture is described in [1] that allows the robot to execute commands autonomously, while retaining the ability for the teleoperator to intervene via the Internet in certain circumstances. A Web-based robot experiment has been established using Xavier robot [13]. A mobile teleoperation via Web has been developed to make a museum accessible to remote visitors [12].

2. SYSTEM DESIGN

A remote laboratory for mobile robotics can be built using two kinds of distributed systems models. The first choice is to use a two layer client/server structure, and the second option includes a three tier model that include a middleware. Two tier architectures are very easy to implement as first, but it is very difficult to maintain the application up to date with them. In this case, the client side is responsible for the data access, the business logic implementation, formatting the data, the user interface and data input. Because all the details involved on the client side, programs are very difficult to adapt to Internet, as they don't scale well.

One of the main advantages of Web Based Education systems and Remote Laboratories is that they are live systems, with dynamic contents that can change continuously . It should be possible to add easily new materials (like laboratory experiments), or to visit the materials on a different order in function of the interaction of the students. To achieve the required modularity and scalability it is preferable to use a three tier architecture, including a middleware. In the design we propose, there are three tier (Fig. 1). A client tier, a middleware layer, divided into a presentation logic part and a business logic part, and the last tier including the remote system (the robot).

2.1 Client layer

In the client layer, four different kinds of users will be provided.

2.1.1 Students

Students will interact with the system using three kinds of tours: Demo, Free Tour and Guided Tour.

In the Demo, the student can get an idea of the objectives and structure of the course. If the student want to access the experiment directly, he can go into the free tour. If he want to take a complete course, or to follow a complete class, he will use the guided tour.

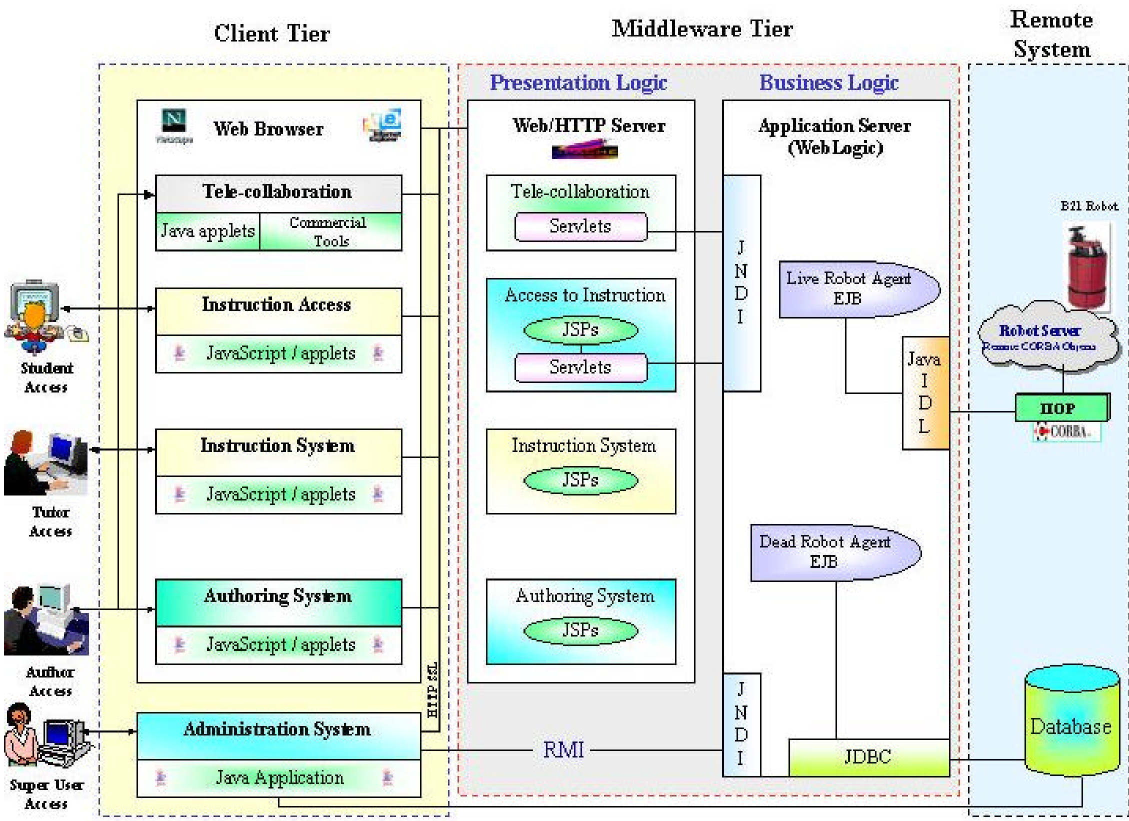

Fig.1 System Design

2.1.2 Tutor

The tutor will interact with the students using the instruction system. Several tutors should collaborate in the network. The tutoring system will be implemented using HTML page with Java applets and JavaScript forms.

2.1.3 Author

With and edition system, several authors can collaborate to define, modify or delete his own instruction process. This interface will include the desired planning, the list of task to be performed and the possibility to modify the work plan.

2.1.4 Super user

The super user is responsible for creating and administering users and group, as well as managing the communication possibilities between different users.

A telecollaboration agent will be used to handle several cooperation schemas.

- An author wants to collaborate with other authors during the authoring process.
- Students wants to collaborate with other students during a group work.
- Students wants to communicate with tutors to get advice on some matter.
- Tutors wants to coordinate groups of students.
- Software developers wants to inform users of new version of programs and tools related with the system.

2.2 Middleware tier

This middleware tier is divided into the presentation logic part, and the business logic. This tier isolate the client and server part, providing modularity to the system.

2.2.1 Presentation logic

This handle all the aspect related with formatting and presenting document, and the most important component is the web server. In this work, the Apache Web Server have been used.

2.2.2 Business logic

This part deal with that part on the middleware tier that require specific knowledge of mobile robotics for its development. To built this part, two agents are used.

The live robot agent dealt with the real robot, when the robot is on. It is used on all the experiment that access the hardware of the robot.

The dead robot agent, include the general information, and all the web pages, that don't requires the robot to be on (i.e. simulated data, demo, etc.)

2.3 Remote System tier

This tier dealt with the on board applications in the robot. All the programs in the robots are constructed as CORBA modules. In this way, it is possible to use the same modules that are used in the real control of the robot in the teleeducation system. The way of using this modules is the same if it is a low level module (i.e. data acquisition) or a high level one (i.e. relocation module). In this way, as new algorithm are developed on the robot, they can be extended to be used in the teleeducation system with few effort.

3. MOBILE ROBOTICSTELE-EDUCATION SYSTEM

A Web-based education system in the field of indoors mobile robotics is currently being developed at Carlos III University. This system will cover different theoretical and experimental issues of mobile robots. It is supported by online lectures, online practices, which provide the ability to do real experiments remotely and assessment tools.

This model is based on the very simple protocol commonly used in distributed computation "The Request/Response Protocol". The client interacts with the system using any Web browser to make the request. Client' requests are translated to HTTP requests, which satisfied by the Web server. These requests are converted to high-level control requests that received by the robot controller to transmit them as low level control requests to execute the required task. Sensory feedback must be provided to give the user information about the remote robot's environment and the consequences of his commands.

By using the concepts derived from this simple model, we have established two online experiments to cover the practical parts of the first course in our system, which aims at introduce the basic concepts of mobile robotics to the student. The following subsections describe the two parts of the proposed system

3.1 Online Lecture

Three tutoring tours can be presented to the student to deepen and apply the learned systematic knowledge of mobile robotics. They are classified according to the level of guidance into fully guided tour or demonstration tour, guided tour and free tour. By using these tours, student can learn different theoretical and experimental issues of mobile robots. Fig.2 shows the interface of the mobile robots fundamental course.

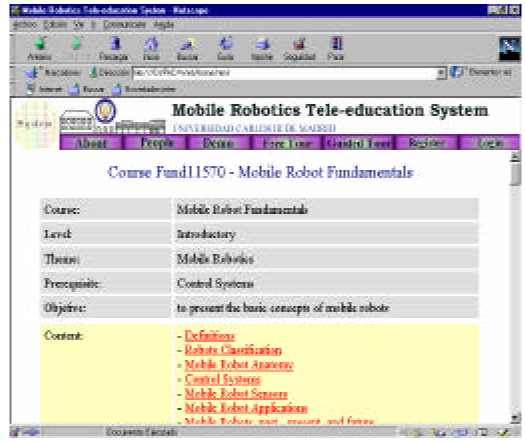

Fig. 2 Mobile Robot Fundamental Course

3.2 Online Experiments

This course contains two experiments:

- **Direct Control Experiment**

It aims at familiariz e the user with the mobile robot motion control and positioning. By using the applet shown in figure 3, the user can use the mouse to control the robot's motion.

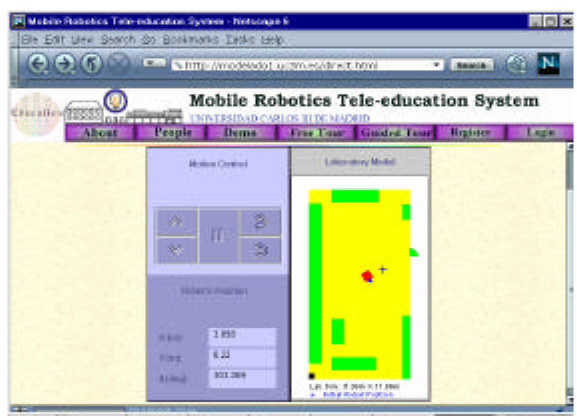

Fig. 3 Direct Control Experiment

This experiment is implemented according to software archit ecture shown in figure 4.

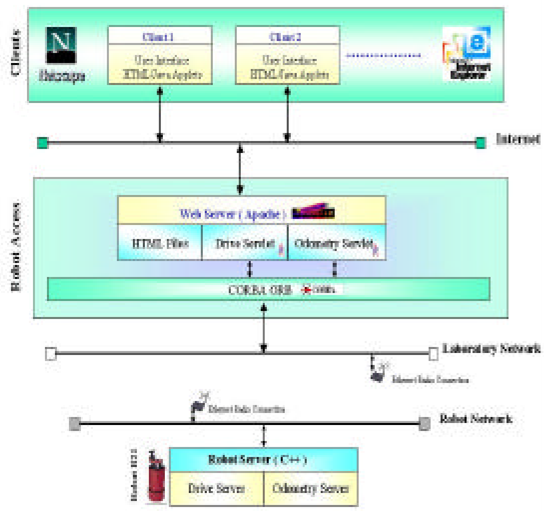

Fig. 4 Architecture of Direct Control Experiment

User requests are received by a Java applet and then sent to the corresponding Java servlet by using a method called InteractWithServlet, which provides the applet-servlet communication. Two Java servlets are inserted. The first one is the Drive servlet, which responds to motion requests (forward, backward, clockwise and counter clockwise). The second servlet is the odometry servlet, which provides the actual robot position and it is called by a separate thread. The communication between the servlet and the remote robot server is done via the Object Request Broker (ORB) of the Common Object Request Broker Architecture (CORBA) [10] where the Java servlet acts as a client to a remote object server. The ORB provides the communication via the unified interface language Interface Definition Language (IDL) and based on the Internet Inter-ORB Protocol (IIOP).

- **Sensorial Data Acquisition Experiment**

The objective of this experiment is the environment perception using multisensor data (sonar and laser). The used robot is an indoor mobile robot B21 from Real World Interface [11], which has a laser scanner (Sick, 180º & 50 m scanning range with resolution 0.5% and +/-50mm) and 24 sonar sensors (Polaroid, 27cm-10.7 m sensing range). Figure 5 shows the request/response scenario, which is used to implement this experiment

The experiment is divided into two parts, without robot motion and with robot motion. The first part objective is to understand the operation of sonar and laser sensors and to be familiar with these readings. The second part aims at recognize the real environment using sensorial data.

Steps of Part I:

- Read the practice instructions.
- Obtain the sonar reading using any view mode (vector, arcs or segments).
- Repeat the previous step until you have four reading without moving the robot.
- Observe the cumulative reading.
- Make a preliminary map for the real environment.
- Repeat the previous steps using another view mode.
- Repeat the previous steps using laser sensor.

Steps of Part II:

- Read the practice instructions.
- Obtain the sonar reading.
- Interpret the data and draw a possible map of the environment.
- Move the robot to another position using the interface and repeat the second and third previous steps.
- Repeat the previous steps until you have four readings.
- Make a brief schema for the lab environment using the cumulative data of the four readings.
- Repeat the previous steps using data from laser range finder.
- Compare the previous results with the real environment.
- Determine the obstacle zones and evaluate the errors.

Result Analysis

After finishing the experiment steps, the user can have the following superposition of 4 readings as shown in figures 6 & 7.

From these results, the user can easily predict the obstacles zones and s/he can draw the environment map from the sensorial data. The out of range unpredicted values in both sonar and laser readings are due to existence of some transparent objects in the lab as windows or firebox or due to the sharp edges reflections.

4. CONCLUSIONS

In this paper different issues related to Web-based education systems have been discussed, such as the feasibility of building these systems and the main challenges, which face the development process. A description of a tele-education system for mobile robots is presented in this contribution.

The most important expected benefit from this system is the growth of the participation level in the education process. Well- organized theoretical content, live performance laboratory and reliable communication mechanisms are considered the rule of thumb of any Web-based education system with competitive advantage.

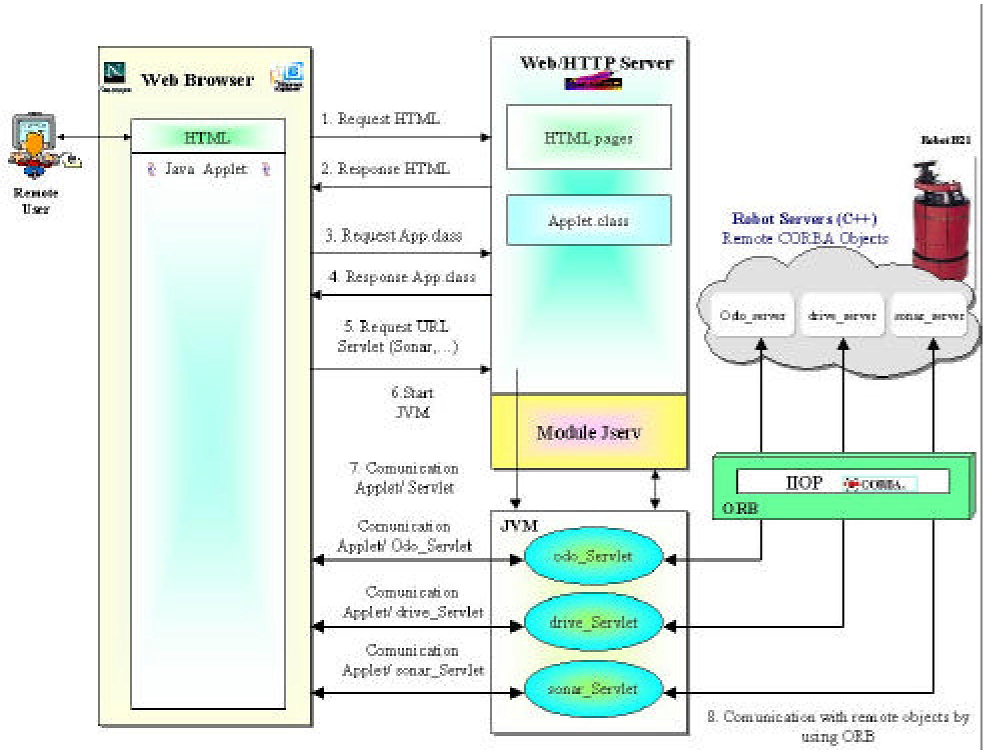

Fig. 5 Scenario Request/Response

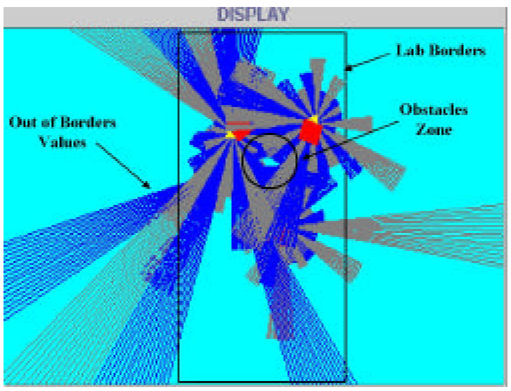

Fig. 6 Superposition of Sonar Readings

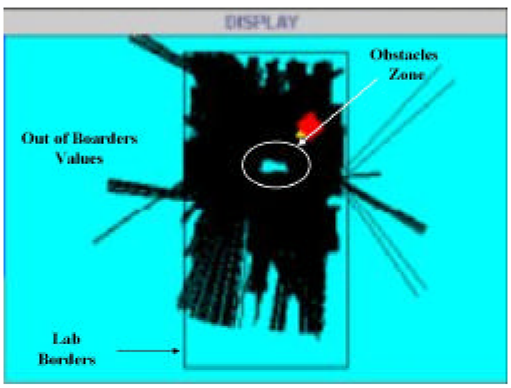

Fig. 7 Superposition of Laser Readings

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