A Distance Learning System for Robotics

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Abstract. In order to help students to understand robotics concepts, various types of materials are needed, in addition to real robots. It is difficult for all students to perform actual experiments because of the lack of real robots. In order to solve these problems, this paper describes the development of a web-based distance learning system for robotics, which consists of multimedia contents and a 3D (3-dimensional) robot simulator. Students can easily access the multimedia contents and, in this way, understand the concept of robotics. Also, they can use a 3D robot simulator to perform virtual experiments using a virtual robot which can be connected to a real robot.

Keywords: robot, learning, learning system, 3D robot simulator, simulator.

1 Introduction

Many theoretical concepts are described in a robotics course, and in order to understand them easily, various types of materials and many experiments are needed. However, the amount of robotics material available remains insufficient and not enough real robots are available to allow for every student to perform robot experiments, due to a lack of resources. Therefore various types of materials need to be developed, in order to make it easier to understand robotics. Also, virtual robot experiments need to be made available, which are similar to experiments with real robots. Thus, a web-based distance learning system that can enable students to conveniently access these materials and perform virtual experiments needs to be developed.

In general, existing distance learning systems only provide learning materials using NRT (Non-Realtime Teleteaching), BBS (Bulletin Board System) or VOD (Video On Demand) techniques. This means that the students can study what they need to using the received material, but cannot perform experiments. If the distance learning system allowed them to perform real or virtual experiments that were similar to the real ones, it would be much easier to understand the learning materials. In order to accomplish this, a 3D (3-dimensional) robot simulator needs to be developed that is connected to a real robot.

Existing graphic robot simulators have been developed to make simulation programs for robots, to check manufacturing system software in advance, and to control remote systems efficiently. In previous studies, in order to make a robot program, virtual robots were developed using the VR (virtual reality) technique [1, 2]. In order to check manufacturing software, a virtual simulator was developed [3]. In a remote

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control system, the VR technique is used to predict the result of a robot command before sending it to the remote robot. In a previous study, remote robot tasks were performed using a task sequence script that was used to control the sequences of robot behavior [4]. A virtual robot and its environment were designed using the VR technique and this virtual robot was used instead of a remote real robot to send the information, in order to reduce the time delay [5, 6].

A remote robot system using the internet appeared in Goldberg's Mercury project and Taylor's Australia's Telerobot project [7, 8]. Since previous remote robots were controlled through a dedicated line, it was only possible to control them within a fixed area. In these two projects, however, multiple users were able to control the robots through the internet without any limit as to their location. Research into the sharing of robotic devices through the internet has also been performed in various universities and research institutes [9, 10]. A remote robot controlled through the internet is called an internet robot or internet-based robot. If a web browser is used as the user interface, the internet robot is referred to as a web robot or web-based robot.

In this study, we prepared multimedia contents for robotics materials and developed a 3D robot simulator for the purpose of building a web-based distance learning system for robotics. The multimedia contents and 3D robot simulator can be accessed through a web browser. The proposed web-based distance learning system can be used to access the robotics multimedia contents and to perform virtual robot experiments having similar effects to real robot experiments without any limit of time and location. Also, the 3D robot simulator can be connected to a real robot through the internet, thereby allowing the virtual robot experiments to be compared with the real robot experiments.

In sections 2 and 3, the structure of the proposed web-based distance learning system for robotics and its contents are explained. In section 4, various experiments are performed, including the connection of a real robot. Finally, the conclusion is presented in section 5.

2 Structure of the Proposed Web-Based Distance Learning System for Robotics

The proposed web-based distance learning system for robotics consists of lecture materials, complementary materials, and a 3D robot simulator, as shown in Fig. 1. Both the lecture and complementary materials are organized in the form of multimedia contents that can be inserted in a webpage. A multimedia tool, Authorware of Macromedia, is used to develop these multimedia contents. The web-based 3D robot simulator was developed using Java Applets to allow for its insertion into a web browser and a Java3D API is used to provide the 3D effect. Because all of the materials and the robot simulator are viewed in a webpage, students can conveniently connect to the web site through a browser to peruse the contents and to use the robot simulator.

The web-based 3D robot simulator used as a training tool is designed to allow several students to access it through the internet in the form of a client/server application. A student can connect to the web server as a client and download the executable interface through a web browser. The user interface is a Java Applet application program that can show 3D robot motions and control real robots using the motion results. As shown in Fig. 2, a real robot can be controlled by transmitting robot commands to the robot control server. That is, the robot server receives robot commands from a student and drives the real robot. Fig. 2 shows the internet based remote control system using the web-based 3D robot simulator.

The remote system consists of a web-server, a camera server, a robot control server, and a robot. Using a mouse and keyboard, a student can perform virtual robot experiments and remotely control a real robot. Before sending commands to the real robot, the student can check the robot motions by performing virtual robot experiments using the simulator. When the real robot moves after receiving commands from one student, the camera server obtains images of its motion and sends them to the other students. The virtual robot in the simulator was developed using the 3D graphic API Java3D and the real robot is a FARA SM3 of Samsung electronics.

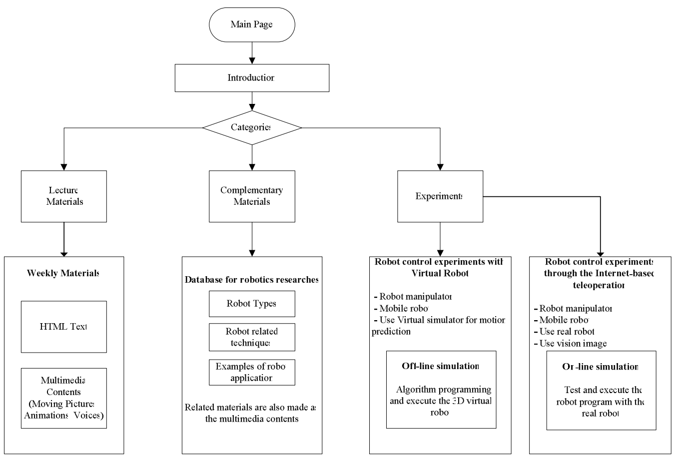


Fig. 1. Web-based distance learning system

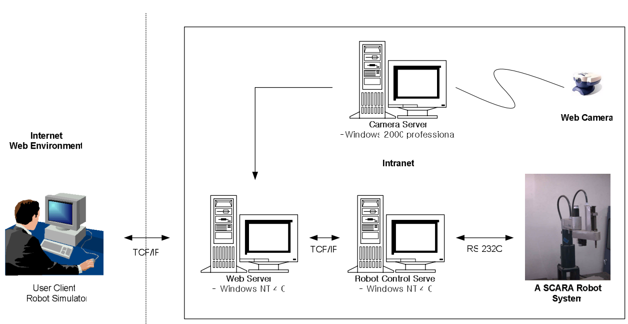


Fig. 2. Web-based distance learning system

3 A Web-Based Distance Learning System for Robotics

3.1 Lecture Material

The robot lecture materials in the distance learning system for robotics consist of multimedia contents that comprise a moving picture, animation, and synthesized voice. These multimedia contents are inserted in the webpage so that students can peruse the lecture materials through a web browser. The sixteen week lecture materials include robot related vector theory, robot kinematics, and robot dynamics [11].

Fig. 3 shows a screen capture of the 'Introduction to Robotics' section, that makes up the first week lecture materials. Each page of the lecture materials contains text, clip art, video, or multimedia material such as animations and synthesized voices that are used to explain the lecture. In order to download the lecture materials from the web server, the web page indicates the necessary metadata and it is organized so as to download data by using the streaming service of the web server and to execute some of lecture materials.

It is difficult to express robotics theory efficiently using only algebraic expressions and text data. Thus, the IGRIP (Interactive Graphical Robot Instruction Program) software package is used to make the lecture materials, which consist of 3D animations that help the students to easily understand robotics theory. IGRIP can show robot motions based on 3D graphic animation using robot kinematics, robot dynamics, and many robot parameters. For example, to explain the structure and motion of a Cartesian robot, IGRIP can show each axis motion and task space of a Cartesian robot in the form of a 3D animation.

3.2 Web-Based 3D Robot Simulator

In this study, a 3D robot simulator is developed using the 3D graphic API, Java3D, and it is shown in Fig. 4. This 3D robot simulator allows students who have studied web-based robot lecture materials to perform virtual tasks by using a virtual robot. Also, this 3D robot simulator can be used as a user interface for controlling a remote robot. Since the 3D robot simulator is web-based, it can be used anywhere.

Since a function allowing for the visualization of the image from a remote camera is included in this simulator, it is possible to watch the motion of a remote robot.

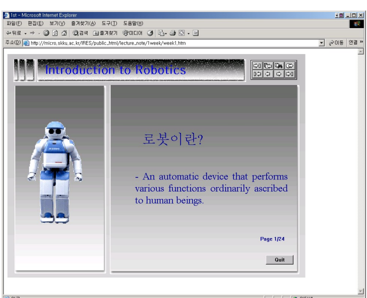


Fig. 3. Lecture material on the web page

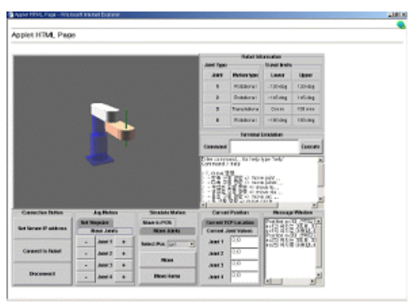


Fig. 4. Web-based 3D robot simulator

Also, the students can easily watch the virtual environment, since the simulator allows its view to be rotated, translated, expanded, and contracted.

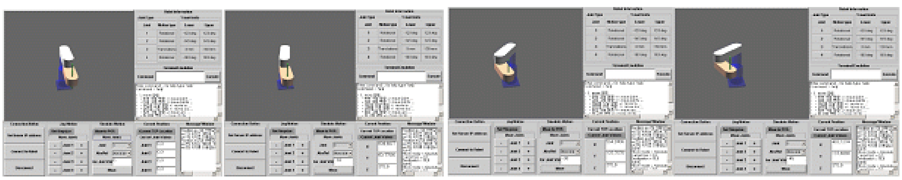
The simulator includes a user interface for robot simulation, a robot information display, and a connection to a real robot, as shown in Fig. 4. The students can access all of the functions that are provided using a mouse or send commands to the virtual robot using text input.

4 Experiment

Students can study robotics related lecture materials and perform real experiments using the system developed in this paper. In the experiments we performed using the web-based 3D robot simulator, an offline simulation is performed first. Then, the 3D robot simulator is linked to a real remote robot in order to remotely control it.

Students can understand robotics concepts, such as dynamics and kinematics, by performing offline simulations using a virtual robot. Fig. 5 shows an offline simulation in the web-browser, in which a robot moves an object along a straight line.

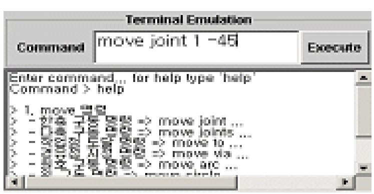
The simulator provides three modes which allow the robot to be moved and shows the resultant robot motion: jog mode, simulation mode, and virtual terminal mode. Fig. 6 shows the panels used to control the robot in these three modes. In the jog



(a) (b) (c) (d)

Fig. 5. An offline simulation

(a) Jog mode (b) Simulation mode



(c) Virtual terminal mode

Fig. 6. Robot control panel

mode, it is possible to make one joint of the robot move without moving the other joints. As shown in Fig. 6-(a), the displacement amount of one joint can be adjusted by varying the stepsize, in order to perform more precise tasks. In the simulation mode shown in Fig. 6-(b), students can enter a displacement value, either for one joint or for the robot end-effector, and make the robot move to the designated position. In virtual terminal mode, as shown in Fig.6-(c), students can move the virtual robot by using robot commands. Some explanations in Korean are included in this figure.

As shown in Fig. 7, the execution results obtained using the simulator can be checked with the present position of the robot and the messages provided by the simulator. As shown in Fig. 8, the displacement range of each joint is displayed, in order to prevent input errors related to the joint displacement.

Students can use the graphic functions of the simulator to execute the virtual robot and check its action. In this way, the students can understand the commands and parameters of the robot. In order to control a remote real robot using the simulator, robot commands must be sent through the internet. Fig. 5 shows the motion of a virtual robot when it executes the commands: Move joints -10 10 0 0, Move joints -30 45 0 0, and Move joints -45 70 0 0. The operation codes and necessary parameters for these robot commands are converted into network messages which are sent through the internet. The robot control server shown in Fig. 2 receives these network messages and translates them into a form which is understandable by the controller of the real robot, in order to control it.

After observing the motion of a virtual robot in the offline simulation, an online simulation can be performed to check the motion of the corresponding real robot. In the online simulation, the virtual robot shows the same motion as that observed in the offline simulation and the virtual robot communicates with the corresponding real robot.

During the online simulation, the virtual robot and its corresponding real robot show synchronized motions. Since this synchronization is performed using robot commands and their motion result, continuous communication is not required between the virtual robot and the corresponding real robot.

During the online simulation shown in Fig. 9, the real robot shows the same motion as that shown by the virtual robot during the offline simulation illustrated in Fig. 5. A camera is used to obtain the images, as shown in Fig. 9, and these images can be watched on the web. Thus, many students can see the motion of the real robot without connecting to the additional vision server.

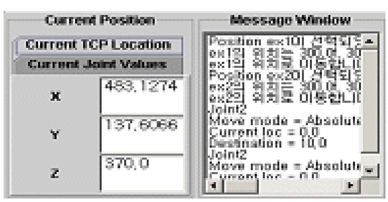
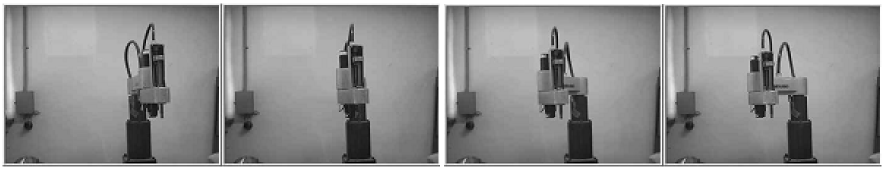


Fig. 7. Robot position information and simulator message

Fig. 8. Robot information display



(a) (b) (c) (d)

Fig. 9. Online Simulation

5 Conclusion

In this study, we developed robot lecture materials and a web based 3D robot simulator system. Students can study the robot lecture materials through the internet and perform experiments related to them using a virtual robot. Since the web-based 3D robot simulator can be connected to a real robot through the internet, the programs of the virtual robot can be sent to the real robot in order to execute them, so that the students can compare the motion results of the virtual robot with those of the corresponding real robot.

In contrast to previous robot simulators, the robot simulator developed in this study consists of Java Applet software modules that are executable in a web browser and, therefore, it can be used as a web-based user interface for remote control.

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