Online Automation & Control: An Experiment in Distance Engineering Education

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Abstract— **Online distance education is the latest trend in the education industry. Even though most of the courses offered today are non-technical, there is a large market for online technical education leading to graduate and undergraduate accredited degrees. This paper studies the current state of the online education industry and proposes ways and means for providing comprehensive laboratory based technical degrees through online distance education. The paper also presents innovative approaches and coursework developed at the University of Bridgeport, to provide laboratory-based accredited programs.**

***Index Terms*—Online technical education, Distance learning, Web-based laboratory, Telerobotics.**

I. INTRODUCTION

What began as an internal exercise at Universities to share information and discuss ideas has evolved into a major trend in the education industry. Today, online education is a major part of the current education system. Over 1600 online degree programs, over 2300 career training programs and over 2500 online courses, are being offered online.

Academic emphasis is shifting from course-completion to competency. In many cases, certification or accreditation is becoming more preferable than studying a theory-based set of courses towards a degree [1]. Diplomas are less meaningful to employers; knowledge, performance, and skills are what count for most [2]. Furthermore, there is a growing need for part-time accredited programs at the graduate level.

The majority of accredited programs offered through online education are mainly non-technical programs. There are practically no Universities offering accredited degrees requiring laboratory-based course work in the classical engineering fields at the undergraduate or graduate level. This is because unlike non-technical degrees, engineering programs require comprehensive laboratory work.

There is a great demand for online accredited degrees in the field of engineering. As Bates [3] suggests, “perhaps the biggest challenge [in distance education] is the lack of vision and the failure to use technology strategically”. This paper investigates the advantages and the means of providing classical engineering programs online.

II. WHY ONLINE EDUCATION

The literature is replete with evidence of the growing demand for distance education. The annual market for distance learning was $4.5 billion in 2003, and it is “expected to grow to $11 billion by the end of 2005” [4, 5].

The major factors for the success of online education are the ever growing need for part-time education and the need to keep oneself updated. Lifelong learning is becoming a competitive necessity [14]. Online students are becoming an entirely new subpopulation of higher-education learners. More courses, degrees, and universities are becoming available through distance-education programs. Instruction is becoming more learner-centered, non-linear, and self-directed.

Students are shopping for courses that meet their schedules and circumstances. More and more learners are requiring flexibility in program structure to accommodate their other responsibilities, such as full-time jobs, family needs or geographical separation [6]. With these constraints, students shop for courses that best accommodate their schedules and learning styles [7].

Another major factor in the growth of online education is the huge growth in Internet usage. Not only is technology becoming more ubiquitous, it is being used more competently by more people from all nationalities, age groups, and socioeconomic levels [8]. Technological devices like laptops and wireless internet access devices are also becoming more versatile and ubiquitous.

As universities digitally enhance more courses, the distinction between distance and local education is becoming blurred and vague as most Universities offer online courses as a part of their curriculum [9]. Digitally enhanced courses provide students in traditional classrooms with more opportunities for independent study: Even in a conventional ‘face-to-face’ system, students spend much of their time working on their own.

III. OUTSOURCING AND PARTNERSHIPS

Knowledge and information are growing exponentially. The institutional landscape of higher education is changing: traditional campuses are declining, for-profit institutions are growing and public and private institutions are merging. There is a shift in organizational structure towards decentralization.

Universities are traditionally independent, free-standing, and competitive [10]. On the other hand, distance learning institutions have been more cooperative and accommodating with partner institutions. Interestingly, Rubin [11] has noted that "traditional universities are becoming more like distance learning universities and not the opposite". Higher education outsourcing and partnerships are increasing. With this shift, more institutions are creating partnerships with other colleges, universities, companies, and other kinds of institutions to share technology and to produce and deliver courses [9, 12, 13].

The largest market for American engineering degrees is overseas. There is still great value for American technical education overseas, especially in countries like China and India. In the present socio-political situation, not every aspiring student gets a student visa to pursue higher education in the US. In other words, a large percentage of aspiring students with the necessary technical and financial backgrounds never get an opportunity to acquire such degrees.

Online engineering accredited programs are an excellent solution for this problem. Not only is the student able to pursue a degree of his or her choice and from the desired University without leaving the comfort of his/her home but also able to concentrate on other social and economic responsibilities.

Such a program is also ideally suited for the working population who wish to pursue higher education but either do not have the time to commute or are not willing to relocate for various reasons.

A possible model for offering distance education in this scenario would be one in which U.S. institutions partner with other local Universities or private institutions overseas with the necessary the facilities and infrastructure. Such an outsourcing model will move the service closer to the target students. This will not only help in better management and marketing, but also inspires a regional flavor and helps in delivering courses effectively. Model introductory classes, helps sessions and exams can be conducted at local centers or franchises.

IV. SOME EXAMPLES OF ONLINNE LAB-BASED COURSES OF INSTRUCTION

This section describes three innovative online laboratory-based programs in robotics and automation offered as a part of the graduate programs in computer science and engineering, electrical engineering, and mechanical engineering at the University of Bridgeport.

A. Tele-operation of Mitsubishi Movemaster robot

Software developed at the RISC Lab, University of Bridgeport, enables user from around the world to access and operate a Mitsubishi Movemaster robot. The Mitsubishi Movemaster is a 6 Degree of freedom (DOF) manipulator. This tool is very helpful in learning the forward and inverse kinematics and dynamics of a manipulator.

This software tool is being effectively used in the instruction of the following courses at the University of Bridgeport: Introduction to Robotics (CS 460), Advanced Robotics (CS 570), and Control System Engineering (ME 217).

The software can be utilized in three ways. First, it can be used as a virtual simulation tool, where the student can verify his or her computation by entering the link joint angles and verifying the coordinates and orientation of the end effector and vice versa. The software visual interface is shown in Figure 1.

Second and the most interesting is that this tool can be used as a learning guide to operate the robot. In this mode, only the instructor is directly connected to the manipulator, all other students or users are connected to the manipulator but cannot command it. The instructor can operate the robot either through a serial port of his computer or via the internet. Every operation that the instructor makes is reflected in the students' three dimensional views of the robot. This is a very realistic means for teaching and also monitoring the system while students are operating the manipulator. Remote, controlled tele-operation also helps in reducing the wear and tear on the mechanical parts, which is otherwise common with all equipment.

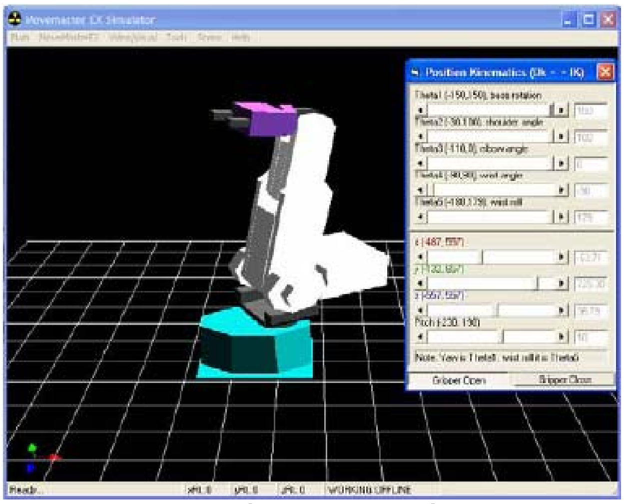

Figure 1: The Movemaster Simulator

Finally, when the student has gained enough experience in handling the robot he/she can control the robot and solve in real-time kinematic, dynamic and control problems from any location in the world through the internet.

B. RISCBOT: An Autonomous Tele-robotic system

This section describes RISCBOT, an experimental 802.11b - enabled mobile autonomous robot built at the RISC Lab of the University of Bridgeport. RISCBOT localizes itself and successfully fulfills www - enabled online user requests and navigates to various rooms, employing a visual recognition algorithm.

The experimental online robot we built, RISCBOT, utilizes visual room identification for localization. RISCBOT was built with the purpose of operating in a commercial office environment. RISCBOT is equipped with an onboard PC (personal computer), WLAN (Wireless Local Area Network) card, NM6403 based DSP (Digital Signal Processing) board, batteries, cameras and ultrasonic sensors. Online users receive real time video feedback from the robot and can also view the robot position. Navigation is performed with the help of the cameras and ultrasonic sensors. The robot processes images from the camera to differentiate between doors, walls and obstacles. The robot can navigate the University of Bridgeport (UB) Engineering Technology building and successfully fulfills online user requests from the internet. It can run uninterrupted for about an hour, but has to be recharged hourly.

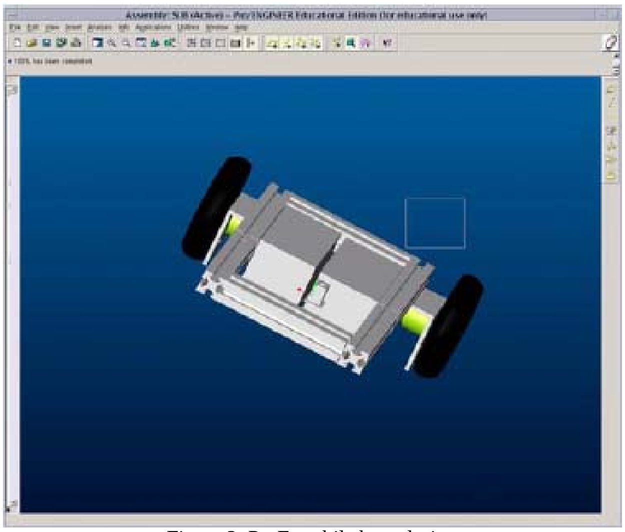

Figure 2: ProE mobile base design

RISCBOT was designed and built to provide a simple telerobotics platform with visual feedback. The initial design of the robot was implemented using Pro Engineer (ProE), shown in Figure 2. An ATM103 MCU controls the ultrasonic sensors and the two motors. The PC sends commands to the MCU through a serial port at 9600 bps baud rate. A MATLAB program that checks for doors runs on the PC continuously. The NM6403 DSP board performs a visual recognition algorithm when signaled by the PC. Atmel's ATM 103 is an 8 bit RISC MCU [15] being used to control the dc motors and interface with the PC board (serially) and the ultrasonic sensors. The data from the ultrasonic sensors is monitored in an interrupt based embedded C code on the ATM 103. The main program running in the 8-bit CPU for controlling the motors depends on the instructions sent serially from the PC.

The robot waits till it receives information from the server. Once it receives a command from the server it starts searching for the requested room. Figure 3 shows the navigation module.

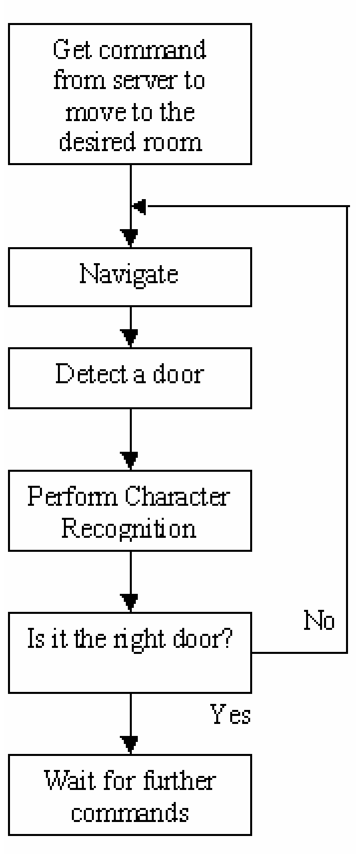

Figure 3: Navigation module

The robot navigates along the wall to the left side of the corridor. With the help of the onboard ultrasonic sensors the robot maintains a safe distance of 45-50 cm from the wall. If the robot gets closer to the wall, it turns right, if it gets further away it turns to the left and if the distance from the wall is within 45-50 cm the robot continues to move straight. If the robot encounters a wall right in front of it (example, at corners), it takes a right turn.

The image processing program checks for doors continuously. Once the program detects a door, it signals the NM6403 DSP board to check for the room ID. If the room ID matches the requested ID, the robot stops. If not, the robot continues moving till it finds the desired room.

The door recognition algorithm is computationally fast, so that doors can be recognized in real time and appropriate commands can be sent to the Navigation module to stop the robot in front of the desired door. Our algorithm employs edge detection to differentiate between the wall and the door. This module is programmed in MATLAB. Images from the camera are captured on the run using the vcapg2 utility [6], since MATLAB 6 does not have native support for the USB port. Figures 4a, 4b and 4c show different views of RISCBOT.

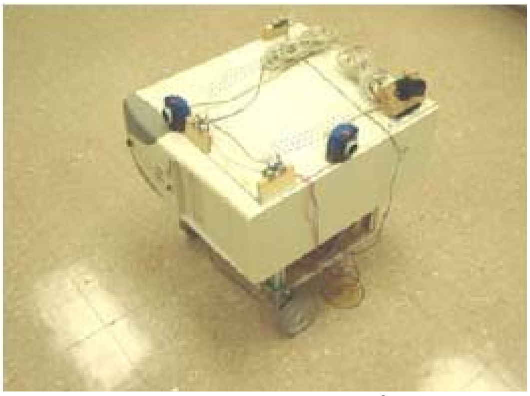

Figure 4a: RISCBOT Top view (front).

Figure 4b: RISCBOT Top view (Back).

Figure 4c: RISCBOT accomplishes its task.

The door ID character recognition algorithm runs on the NM6403 DSP board. The room numbers have been printed on a plate and stuck on the doors. The image - processing algorithm identifies the plate on the door. We have implemented this task by using the Hough transform for detecting lines first, and then checked the relative dimensions of the lines for detecting the plate. This algorithm is carried out on both horizontal and vertical lines. The resulting pairs from the list of horizontal and vertical lines are then compared and the end points not contained in both regions are discarded. The remaining regions are the final candidate regions, which contain the plate. A detailed explanation can be found in [16].

Characters are extracted using a region - growing method [16]. When a connected component is found it is then tested to see if it meets the requirements of a character (e.g. size). This whole process is carried out iteratively until all the characters in the page have been extracted. Each character is labeled. A detailed explanation of this algorithm can be found in [16]. The complete architecture of RISCBOT is shown in Figure 5.

The web interface is an integral part of the mobile navigation and identification process. The mobile robot is connected to the Internet through an onboard WLAN 802.11b card. The robot can be controlled and viewed from the internet, through its website: www.bridgeport.edu/sed/risc/html/proj/RISCBOT/index.htm.

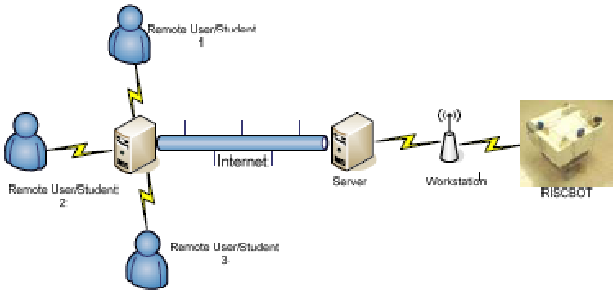

Figure 5: RISCBOT Network Architecture.

Updates on the web services and server availability information are posted on the website. Users can also download videos and pictures of sample navigation and recognition tasks performed by the robot. The web interface for the robot is simple, consisting of three windows: the control window, top view window and the camera view window.

Figure 6 shows a view of the web interface while the robot is navigating. Once logged on, any user can send a request to move the robot to a particular door by selecting the appropriate door ID on the control window. A real time video feedback is provided as the robot broadcasts video while moving. The feedback is implemented using Microsoft Media Encoder [17]. This video can be seen on the Top view window and the camera view window.

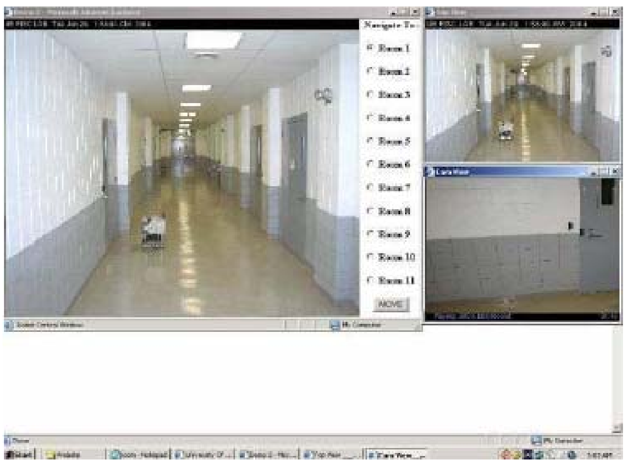

Figure 6: RISCBOT website.

RISCBOT offers a stable telerobotic platform to remotely test new image-processing, computer vision and navigation algorithms.

RISCBOT is being currently used for instruction in graduate courses such as Artificial Intelligence (CS 504), Image Processing (CpE 540), Machine Perception (CS 584), Computer Vision (CpE 585) and Control Systems Engineering (ME 417). Students can program and configure different application layers over RISCBOT's basic telerobotic architecture and test them.

C. *Online Process Control*

Our current efforts at the RISC Lab. are directed towards developing a remotely operable process control machine. The main aim of this exercise is to provide a tool to remotely operate and monitor a FESTO process controller (Figure 7). Remote users will be able to direct a Mitsubishi Movemaster (Figure 8) robot to perform different experimental setups for the FESTO machine.

Figure 7: FESTO Process Controller

Figure 8: Mitsubishi Movemaster

This internet enabled setup will enable online users to access and telerobotically operate and study different adiabatic and isothermal processes. Furthermore, the cameras mounted on the robot will provide real-time video feedback and visual monitoring of the control parameters.

A visual depiction of the system architecture developed for the tele-operation of the FESTO machine is shown in Figure 9. All remote users who are logged on the distance learning website are connected to the server. The users are queued on a First In First Out (FIFO) basis to control the machine. Irrespective of whether they are controlling the machine or not, every user connected to the server receives real time video feedback form the Laboratory.

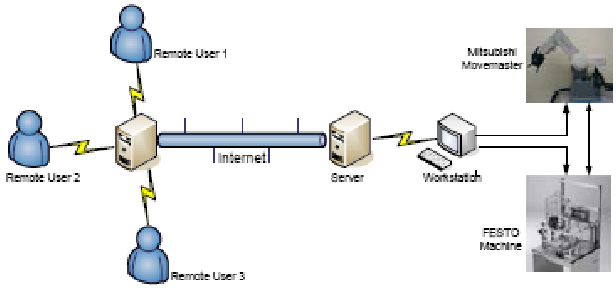

Figure 9: Tele-operation System Architecture

All the commands received from the remote users are directly forwarded to the workstation, which issues appropriate commands to the Movemaster robot, camera and FESTO machine. The Movemaster robot as well as the FESTO machine is connected to the workstation via the serial port (RS 232). The main functions of the Movemaster robot is to physically setup the experiments on the FESTO machine,, for example opening/closing appropriate valves on the process controller and to provide proper visual feedback by maintaining the necessary camera position and orientation as desired by the remote user.

This remotely interactive system is being employed in the instruction of courses in the controls area, like the Controls Lab. (EE 461)

V. CONCLUSIONS

Although most distance learning programs offered today are non-technical, through the proper and strategic deployment of technology, it is possible to offer technical programs and degrees with comprehensive laboratory work via distance learning. As examples, the paper detailed three innovative methods currently being employed at the University of Bridgeport in the delivery of distance engineering laboratory-based courses. Using these innovative techniques, students can remotely interact and perform experiments in real time without being physically present in the laboratory. Telerobotics and automation not only makes distance learning more interactive and interesting, but also provide the means for offering technical programs and degrees via distance learning.

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