AC 2009-1094: VOICE-VIDEO INTERACTIVE ROBOT DESIGN

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System Design Methodology with Voice / Video Interactive Robot

An Interdisciplinary Course

Abstract

The paper expounds the curricular details of the course that integrates different disciplines of Electrical and Computer Engineering Technology. The voice/video interactive robot design is a senior level course and is an attempt to assemble most, if not all, of the technologies and subjects that are taught in the Electrical and Computer Engineering Technology Department. The course is an attempt to provide the learner the latitude to freely master the art of system design by integrating the hardware and software system design principle. This course is also a showcase course to provide an Experiential Learning Platform.

This course is offered in the form of Learning Modules. The paper discuses the course system design modules in details which encompasses: Power Electronics, Microcontrollers based and Embedded System design and Embedded System Programming, Object-Oriented Programming (OOP), Design and use of Graphical User Interface (GUI), Client – Server Network Distributed System Design and Socket Programming, Digital Encoders, Motor Control, Basic Electronics and use of Analog Devices.

The course theme is to design the voice/video interactive robot that can be controlled over the Internet from anywhere the user can access the Internet, or can be controlled over a local area network. The paper elaborates how a GUI client/server application establishes a Transmission Control Protocol/Internet Protocol (TCP/IP) connection and passes commands and information between the Client and Server. The server application then forwards any commands from the client through a serial link to the micro-controller, which controls the robot's drive motors and monitors the sensors.

The voice/video interactive robot utilizes a set of Net cameras to establish voice and video communication between the environment surrounding the robot and the remote user. The camera located on the robot is a pan-tilt-zoom camera for maximum visibility with the robot in a standstill position. The paper also elaborates the Pedagogical framework in which the course is conducted.

Introduction

Purdue University Calumet is a commuter institution that has a large percentage of part time students. The part time student on the average takes between six to seven years to complete the requirements for the degree. The Electrical and Computer Engineering Technology (ECET) department offers a two plus two program leading from an Associate degree to a Baccalaureate degree. The student can also continue for a Master in

Technology or a MBA degree. The plan of study at the undergraduate degree level is structured with required courses in the fundamentals of electrical circuits, machines, analog and digital electronics, microcontroller applications and basic programming. The students are allowed to concentrate in a specialized area such as electrical power, telecommunications, computer hardware and software, process control and biomedical electronics by selecting advance courses in those areas. In the ECET department we have close to 55% part time students. The work experience of these students varies widely, and the type of work they are engaged dictates the courses they take. For this reason the students are exposed to limited knowledge in many areas of electrical and computer engineering. The rapid changes that are taking place in the engineering field, some of the techniques the students learned or exposed to might have changed since the time they entered the program to the time of graduation.

Thus a capstone course was necessary to bring the senior students up to date in the various fields of electrical and computer engineering and to provide guidance to successfully complete their senior design project. The students take courses based on the plan of study from the freshman year to the senior year when they are required to complete a project for graduation. Also the students may not be familiar with sub field of electrical engineering like power electronics if they have taken the electives in telecommunication area. Technology applications might have changed in four to five years of their stay in the program that the students may not be aware off.

We also wanted the students to get involved in electro-mechanical projects rather than a straight electrical project, with this in mind a new capstone course was developed and offered to a limited group of 16 students. This paper will also describe one of the projects that incorporated a variety of concepts that was addressed in the course.

System Design Methodology

This is a two semester sequence course with a pattern of Lecture: 3, Lab: 3, Credit: 4, offered in modules. The modules time span is adjusted by gauging the learning of the students. A typical module could span over 1to 3 week (s) time frame. Enrollment of the course is limited to 16 students. The class is broken into 4 groups, of 4 students each.

Pedagogy of the Course

The pedagogy of the course is based on Outcome Based Education [1], and utilizes the interactive model of learning. All students maintain an online portfolio of the work reflecting their individual learning. In addition to this each team has its own online portfolio which chronicles the work of the team collectively. All the online portfolios are available to all the students in the class so as to foster horizontal learning. The system designed in the laboratory to perform a specific task is the core measurement of the learning outcome of the course. The laboratory performance of the course is performed in teams of four students. This mode provides a platform for horizontal learning through active and engaged discourse and discussion. Students are empowered to charter their learning and feed their curiosity. The course culminates in a Final Project which is assessed based upon its comprehensiveness and originality. Students are required to master the soft skills of comprehensive report writing on a weekly basis through technical project report writing and an oral presentation based upon the Team's Final Project. These classroom practices and laboratory environment provides a challenging and invigorating environment that prepares them for a lifelong learning process and career path [2].

System Design Methodology I

The first course in the sequence consists of the following subject area modules:

1. Transducer applications in system design.
2. Power Electronics
3. Embedded System design and Embedded System Programming
4. Motor Control
5. Digital Encoders
6. Wired and Wireless Data Communication

System Design Methodology II

The second course in the sequence consists of the following subject area modules:

1. RF Modules applications in system design.
2. Object-Oriented Programming (OOP), Design and use of Graphical User Interface (GUI)
3. Server Network Distributed System Design.
4. Socket Programming.
5. System Integration.
6. System Reliability and Testing.

Following is an outcome project which incorporated the knowledge acquired by the students from the course.

The major components of the system are outlined below. Refer to Figure-1 at the end of this section for a complete block diagram of the system.

1. Voice/Video Interactive Robot

All system components but the client is located within the robot itself. The robot movements are based on a differential drive design. The body of the robot is made of aluminum, acrylic sheet and steel.

a. **On-Board Microprocessor (Laptop) – DELL INSPIRON 4100**
The laptop was chosen for voice/video control as it was much more convenient to use. The laptop also contains its own power source, a battery that was upgraded from a 1.4Ah to a high-capacity 4.4 Ah battery. This battery also serves as the power supply for the microcontroller and other electronics devices. The laptop has a Pentium 3- 600MHz processor and 320MB RAM.

b. **On-Board Wireless Router – LINKSYS WRT54GL[3]**
The WRT54GL was used because it is the most modifiable router. In order for this project to work over the Internet a communication link must be established with an external wireless network. The default Linksys firmware that comes with the unit will not allow for this configuration. The WRT54GL was modified with a third-party firmware called DD-WRT. DD-WRT allows for complete customization of the router, including a mode called client-bridge. Client-bridge allows the on-board router to act as nothing more than an access point for external network.

c. **Microcontroller Development Board – ARDUINO DIECIMILA[4]**
The Arduino Diecimila is the link between the laptop and the rest of the hardware on the robot. It controls the motors speed and direction and polls the distance sensors to make sure that the robot is not going to run into any obstructions. It was chosen for many reasons, one of which was that we had never used it before and wanted to see how the IDE functioned. In addition to that, it offered many features, a small footprint, and was reasonably priced. It is based around the ATMEL Atmega series of microcontrollers, specifically the Atmega168 microcontroller. This microcontroller has 16KB of program memory, 6 pulse-width-modulation channels (used for analog control and motor control), and 2 external interrupts. The Arduino is programmed in a language based off of Wiring. It is an adapted version of C, and includes many microcontroller specific functions that make it relatively easy to setup and use. The Arduino IDE

is available at no cost, and is developed under the General Public License (GPL). This means that it can legally be used for any purpose, it can be shared, and it can be changed to suit the user's needs, and can be redistributed with any changes made.

d. Net Cam – LINKSYS WVC200

The Linksys WVC200 was purchased for the robot because it was inexpensive, has a built in microphone, and pan, tilt, zoom ability. In addition it is a Net cam. Net cams differ from web cams in that they do not require a computer to function; they contain their own web server and processor. This means that they can broadcast these images directly to a client connected to them over the Internet. This reduces latency due to encoding video streams, and reduced the potential strain and battery drain that a web cam would have produced for the laptop. This camera functions as the eyes of the client/controller. As the system is designed to be controlled from remote locations, which can be miles to thousands of miles away, it is ideal to have a way of seeing what is around the robot. The pan, tilt, and zoom functions are used to minimize movement of the robot to monitor the robots environment.

e. Motor Controller – Sabertooth 2x5

The Sabertooth 2X5 motor controller was chosen as it could handle the current load of the DC motors for the project, and also had settings that can be modified should the drive train of the robot change in the future. The Sabertooth 2x5 is the only motor controller in its class that facilitates regenerative braking. This means when the motor controller begins to slow and brake, it actually helps conserve and restore battery power. It is a dual channel motor controller that can handle 5 amps per channel, and in the required configuration for this application are controlled using two pulse-width-modulated (PWM) signals. The control voltages are 0 v – 2.5v – 5v. Anything within 0 v to 2.5v reverses the motor, 2.5v is stop, and 2.5 to 5v are forward. During development it was noted that the motors continued to whine at the stop voltage; a small relay circuit was included to the Arduino board controls. The circuit functions as an internal timer, if the Arduino is not given a command from the Server within 30 seconds the power to the motor controller is disconnected via the relays. In addition to stopping the whine, it also helps to conserve battery power.

f. DC Motors – Lynxmotion 12VDC 200RPM Gear Motors [5]

These motors were chosen as they come equipped with a rear-shaft encoder, and have a relatively high torque (255 oz/in). Encoders are the key in a differential drive system; as no motors are exactly the same, there has to be some type of feedback so that the microcontroller can equalize the speed of the two motors, and the robot can drive in a semi-perfect line. It is difficult to achieve a perfectly straight line in a differential drive system, as there are many factors that can affect the travel of the robot, such as obstructions.

g. **Battery Power – 12VDC Lead-Gel Cell, 12VDC NiMH**
In addition to the laptop battery, two more batteries are also contained on the robot platform. The 12VDC Lead-Gel Cell battery is used to power the motors exclusively; it is rated for 7 Ah to allow for long run times. During testing it was found that the battery could not provide sufficient power for all the devices on the robot. Also this power source when running a motor was putting noise to the power bus. The 12VDC Nickel-Metal-Hydride battery powers the on-board NET cam (WVC200) and the on-board router (WRT54GL). The WRT54GL is connected directly to the output of the battery, as it requires 12VDC at 1 amp max. The WVC200 however requires a switching supply of 5VDC at 2.5 amps max. Two linear switching power supplies connected in parallel, with a rating of 1.25 A were used to power the camera.

h. **Ultrasonic distance sensors – MaxSonar LV EZ0**
. The MaxSonar LV EZ series ultrasonic transducers come in a variety of configurations; the EZ0 has the widest view of them all, and can see a distance up to 6.45 meters. It can output several signals modes including serial, pulse-width-modulated, and analog. For this application they are providing the microcontroller with an analog signal of 0 – 5 VDC, with a resolution of ~0. 01 volts per inch.

2. **<u>Client/Server Graphical User Interface</u>**
   a. The client/server application was written in Turbo C++ using the Tserversocket and Tclientsocket controls that are provided with it. The following functions are software controlled.
      i. The Serial Server software is started on the robot's on-board computer.
      ii. The Serial Server establishes a connection to the microcontroller via a Serial link using the Tserial_event.cpp module provided by Thierry Schneider.
      iii. The Serial Server then begins to listen for TCP connections.
      iv. The client runs on the remote computer, the user inputs the IP address of the robot's on-board computer and the appropriate port that is being used for communication, and then clicks connect.
      v. A TCP connection is completed between the client and server.
      vi. The user then inputs the IP address of the robot's net cam into the Remote Net cam Address field and clicks the Go-To Net cam Button.
      vii. The client then opens a second form that navigates to the Net cams video feed and controls.

viii. At this point the user can control the robot's camera and drive train using either a text interface or with the arrow keys on the keyboard.

ix. To start a voice/video conference, the user sets up a Net cam on the client end, and then sends a command to the server which will then open a second form on the robot that fills the screen and navigates to the video feed on the clients' Net cam.

3. Voice/Video Interactive Robot – Video Clip

The Robot operation could be viewed at the addresses given below:

http://vids.myspace.com/index.cfm?fuseaction=vids.individual&VideoID=32484481

http://vids.myspace.com/index.cfm?fuseaction=vids.individual&VideoID=32545953

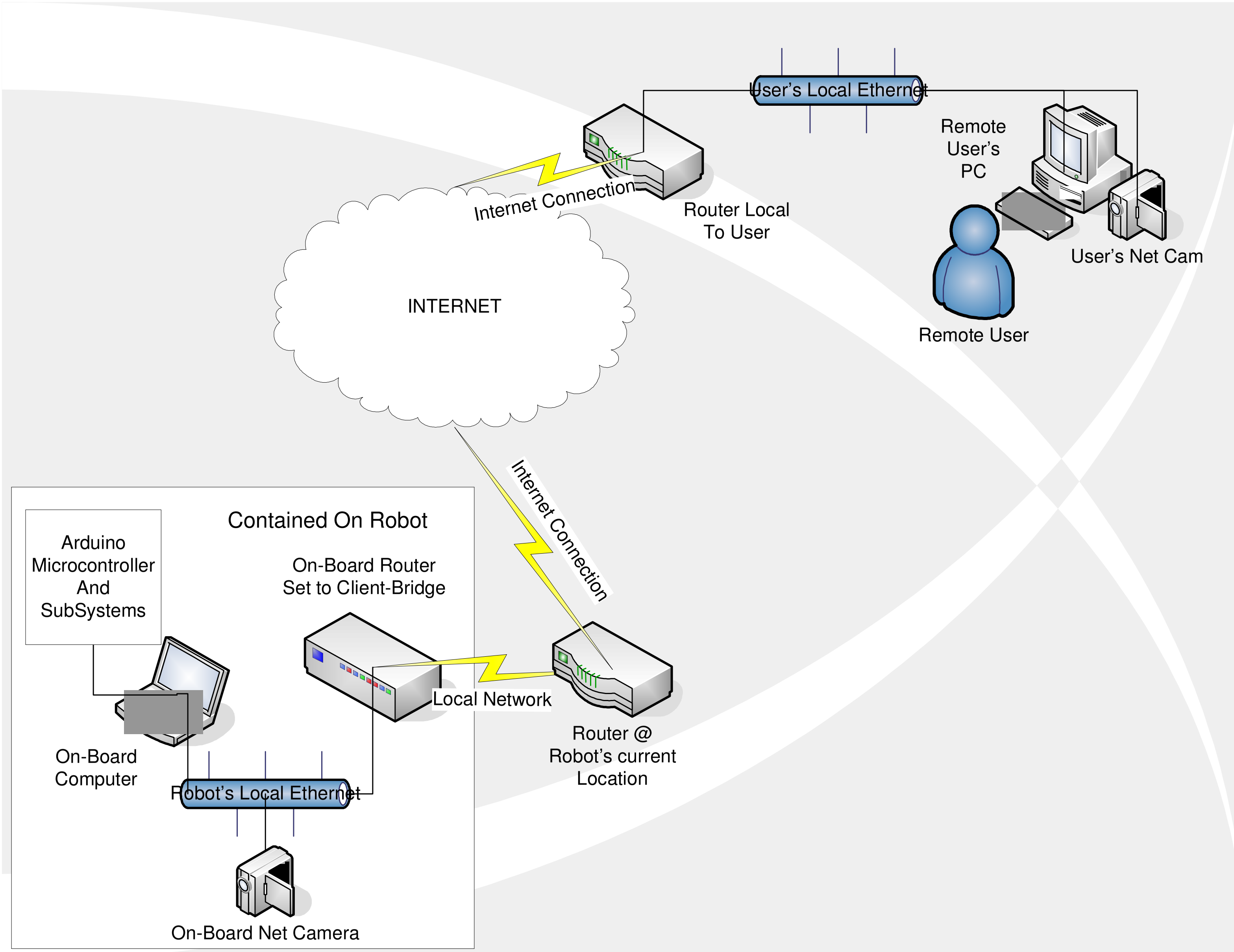

FIGURE 1: Block Diagram of Overall System.

Summary

The intent of offering the two course sequence of **System Design Methodology (SDM)** is to provide the students of Electrical and Computer Engineering Technology a solid foundation in the area of **System Design**. The students were able to assimilate all the basics of Electrical and Computer Engineering knowledge and integrate the theory into a tangible design of their own. This guided and chartered approach has been tried in the place of traditional senior design two course sequences. The side by side student satisfaction index gathered for the System Design Methodology course compared with the tradition senior design two course sequence showed a 15.40% advantage. On this single indicator alone the **SDM** approach of delivery is significant enough to be given serious consideration.

These two courses are designed to cover accreditation. criteria d, e, f, and g of Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (***TAC/ABET***). The criteria d, e, f, and g are as follows:

- d. An ability to apply creativity in the design of systems, components or processes appropriate to program objectives
- e. An ability to function effectively on teams
- f. An ability to identify, analyze and solve technical problems
- g. An ability to communicate effectively

The student satisfaction index gathered in a survey also indicated that the course sequence was quite demanding in terms of time allocated for this two course sequence of **System Design Methodology.**

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