Cellular Phone Control Application as an Undergraduate Research Project

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Abstract

As technology advances, items like the cell phone have become an integral part of people's everyday lives. Finding new innovative ways to incorporate devices like cellphones into our lives can help improve both productivity and efficiency, and can help reduce the cost associated with the purchase of other, more expensive technologies. Creating a smart phone application that can remotely control motor speed is a demonstration of the capabilities of wireless technology that could lead to many other similar applications of this technology. This undergraduate research project uses smart phone technology as a control device by demonstrating that it can be used to control the rotational speed of a DC motor. Specifically, this project will involve the development of a fast and real time method to control a device that is readily available to the public and relatively easy and inexpensive to implement in industry.

A smart phone application will be created using a graphical user interface (GUI) that represents the controls of a motor. The brand of smart phone must accept custom programmed applications. The smart phone will be programmed to interpret GUI inputs and create wireless signals. The hardware used to create and transmit the wireless signals will be pre-existing in the phone and common to most phones available in the market. An embedded control system will receive the wireless signals from the smart phone and interpret those signals as a desired motor output speed. Separate intelligent hardware devices will likely be needed, one for receiving and translating the wireless signal into a commonly used networking language, and a second device used to interpret the control signals and drive the motor. The motor speed will be varied by a pulse width modulated signal generated in the second device that will likely require a transistor to switch the high currents required to spin the motor.

Creating a control system that interacts with signals generated with common devices can have several uses throughout industry. This work can extend to all areas of automated measurement, instrumentation, and controls. One potential outcome is the elimination of the need for expensive human-machine interfaces (HMIs) at the monitored equipment, thereby significantly reducing overall equipment costs.

The benefits and limitations of incorporating this effort into an undergraduate engineering or engineering technology curriculum will then be explored. Among the issues to be addressed are the technical (hardware and software) capabilities required of both the students and faculty to enable cell phone technology to be employed in control and communication systems courses.

Introduction

As technology advances, items like the cell phone have become an integral part of people's everyday lives. Finding new innovative ways to incorporate devices like cell phones into our lives can help improve both productivity and efficiency, and can help reduce the cost associated with the purchase of other, more expensive technologies.

The ability to demonstrate various uses of cell phones that are not typically encountered makes for an excellent learning opportunity. Part of the learning process is to open one's mind to possibilities that had not been previously considered. The idea that a cell phone could be used as a means of controlling a radio controlled car does not expand the overall knowledge of cell phone technology. In fact, one can find videos showing a cell phone controlling a radio controlled car (see [1] for example). However, students are often unaware of what a cell phone can do, and/or are motivated by working on a project that stimulates them outside of the regular coursework required for their degree program.

Project

In this project, two undergraduate students in an Electrical and Computer Engineering Technology (ECET) program were funded with an undergraduate research grant to demonstrate the capabilities of a cell phone by using it to control a radio controlled car. Grant funding was used to fund the students' efforts and purchase a radio controlled car and the necessary electronics hardware to modify the car to receive the signals from the cell phone. It should be noted that a cell phone purchased and owned by one of the students was used for this project (which for this application did not require a contract for phone service). This student focused his efforts on programming the cell phone, while the other student focused on modifying the radio controlled car.

A high level block diagram of the system is provided in Figure 1.

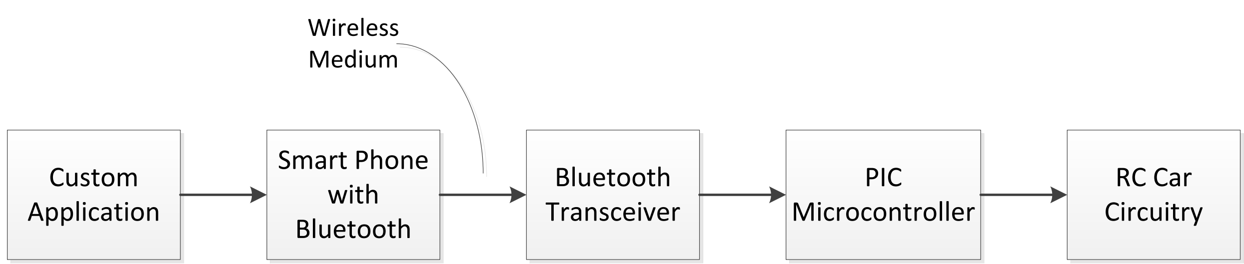

Figure 1. High Level Block Diagram of a Cell Phone Controlled Car

The philosophy was to have each student start at one end of the project and then meet in the middle. One student started by focusing on the control circuitry for the car that could switch the polarity of each motor (drive and turning) and ensuring that pulse width modulation (PWM) could be implemented. A microcontroller was then selected that had PWM output capabilities and serial communication that could be interfaced with a Bluetooth device. The second student started with a smartphone with Bluetooth capabilities and implemented a custom application that would interact with the Bluetooth hardware in the cellphone. A Bluetooth module was then selected that had a long range that could serially send commands to the microcontroller.

The major parts used in this project were:

- An RF7A-5AA new bright circuit card in a typical RC car
- A PIC24F04KL100 microchip microcontroller
- A Roving Networks RN-41-SW Bluetooth module

- An Android smartphone

Additionally, software used for the project included:

- Eclipse Juno for Java programming
- Android Development Tools for Eclipse
- Java Development Kit
- Android Development Kit
- MPLAB IDE with the C30 compiler (for the microcontroller)

The students determined that Bluetooth would be used since one student was already familiar with it and it was already incorporated into the Android smart phone. They then determined an Android application would be developed since the one student already had an Android phone and since using the Android development environment required no additional cost. On the vehicle side, a PIC microcontroller was chosen because the students had already been exposed to Microchip microcontrollers and the MPLAB environment in prior coursework.

The vehicle design portion was accomplished by examining the circuitry that came with the vehicle. By noting the functionality associated with each pin a microcontroller was then selected, ensuring the proper functionality on the associated pins. An SOIC to DIP adapter was then purchased so the existing XB type of controller could be replaced by the microcontroller. The voltage that powered the XB (approximately 3.0 volts) was also compatible with the microcontroller. Manipulation of some board traces was necessary to connect power and ground to the appropriate microcontroller pins. Ultimately, the following modifications to the vehicle were accomplished:

- Removal of the antenna
- Removal of the XB controller
- Removal of the protective coatings from power and ground traces so pins could be soldered
- Soldering of the rest of the SOIC to DIP adapter pins
- Cutting of an access hole into the plastic circuit board cover
- Soldering of wires for power, ground, and serial communication onto the circuit board

The Bluetooth module was connected to the PIC microcontroller via an SOIC to DIP adapter using wires external to the circuit board. The supply for the Bluetooth module was the entire battery pack array which was 7.5 volts. A regulator incorporated into the Bluetooth module circuit board created the necessary supply voltages to power the actual Bluetooth chip. Figure 2 shows the circuit board that was created to replace the original board on the car.

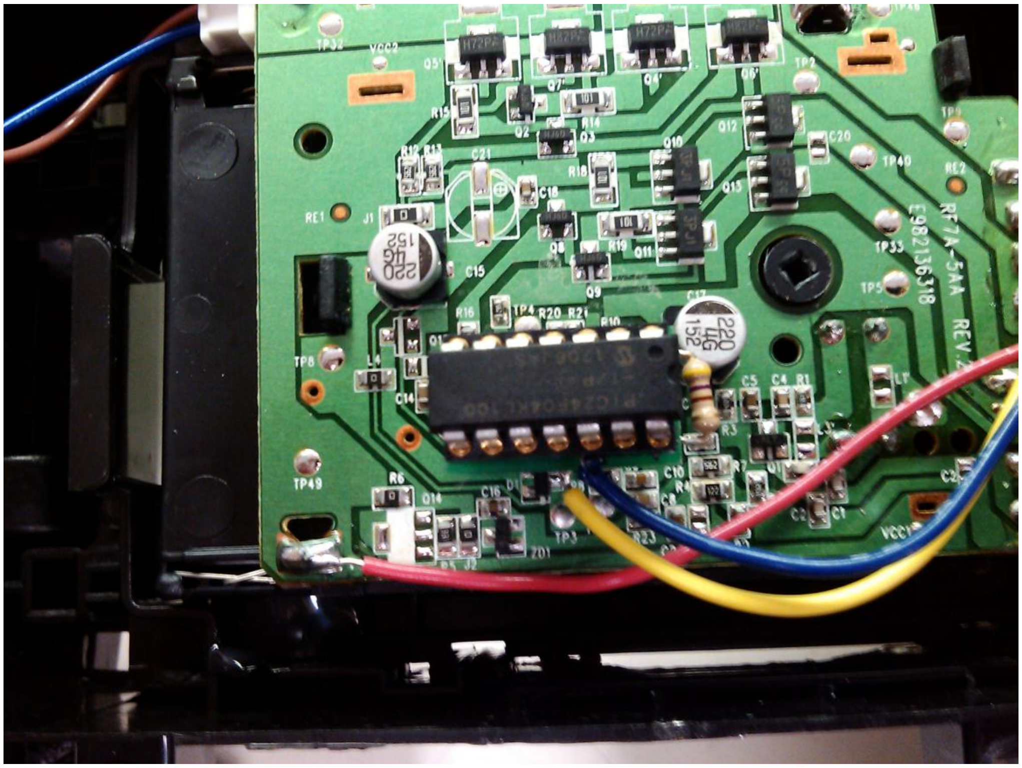

Figure 2. Modified Circuit Board on the Car

The final software GUI for the Android remote control is shown in Figure 3 below.

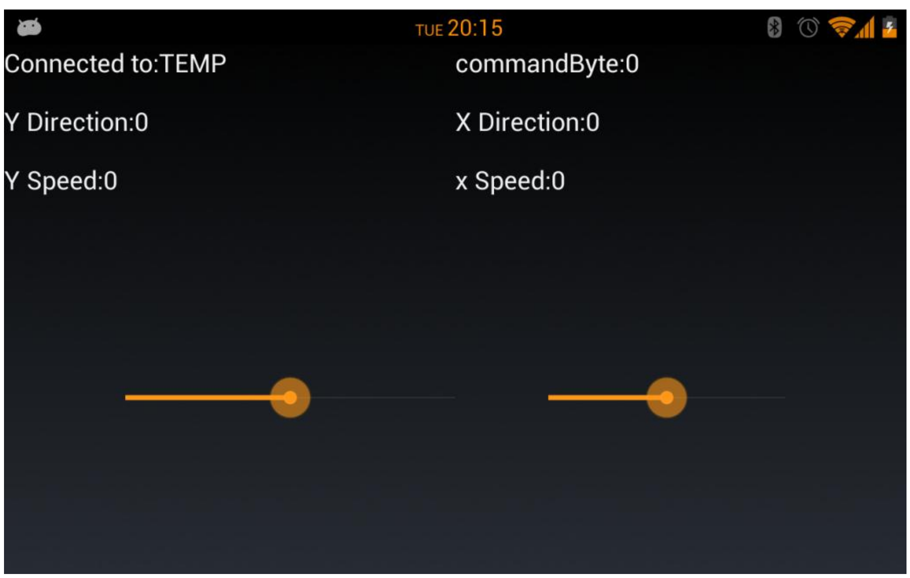

Figure 3. Android Application User Interface

The left 'seek-bar' controls the car's movement in the Y direction, forward/backward. The right 'seek-bar' controls the car's movement in the X direction, left/right. The progress of these seek-bars is packaged into a byte of data called a 'commandByte'. Table 1 illustrates the format of the byte. The car extracts the movement information from the byte to determine how the motors should be controlled. Only one bit is required for X speed because the left or right movement is on or off and not PWM controlled. Thus, the car will only turn if the X speed is one. In this case the car will turn left if the X direction bit is zero and right if the X direction bit is one. However the Y direction governs the forward or reverse motion of the car. The Y speed bits govern the speed in the forward or reverse Y direction, establishing PWM control. The five bit resolution yields 32 different speeds for each direction.

Table 1. Command Byte Structure

Bit	7	6	5	4	3	2	1	0
	Y direction	Y speed					X speed	X direction

A wireless serial connection to the car is created using the Android Bluetooth application programming interface (API). Users of the application can initiate a connection by pressing the menu button on their Android device. They are given a list of paired devices to choose from. Once a device is chosen and a connection is made the application will stream packaged commandBytes to the car.

Results

A demonstration of the completed project is provided in [2]. Between 200 – 300 hours were required by the two students to complete the project. A number of obstacles were encountered, including:

- No experience with a16 bit microcontroller, since the students had only previously worked with an 8-bit microcontroller
- Bad information in the manual for the 16 bit microcontroller
- Incorrect programming device listed in the microcontroller manual
- Having to learn a new development environment (Eclipse & Android SDK)
- Having to learn a new operating system (Android)
- Having to learn a new object oriented programming language (Java)

The system will work with any Android device with at least Android version 2.2 (Froyo). See Reference [3] for an illustration of the percentage of devices across the market running each of the present and past Android revisions to date.

Conclusion and Student Evaluation

In this project a cell phone was used to control a radio controlled car by modifying the vehicle and programming the cell phone to communicate with the vehicle via Bluetooth. This project will then be used as a foundation for future curricular development using these latest technologies as part of a wireless communications, instrumentation, controls, or software engineering course.

The students were asked some questions about the value of this project. Here are their responses.

What were the most important project outcomes?

The most important outcome for me personally was that I learned a lot of new things. I also proved myself able in a situation that I was unsure I was able. And finally, I see the ability to program mobile applications as a potentially marketable skill so this was a bonus.

The sense of accomplishment, of a task that sometimes seemed impossible, with minimal assistance from instructors. Accomplishing this project was a major boost to my self-confidence which made me believe I could accomplish large tasks with enough effort and help from a hard-working team member.

How do the students believe future students could benefit from this project?

Future students could use this project as an exercise in PWM, Micro-Controller programming, wireless networking, and mobile application development. If the android application was given to students they could potentially build the motor control aspect of the project. Another project could have students build the android app when given a motor control system. The amount of work done by students could be reduced by giving them the UI or other java classes to build from.

After completion of this project I did some internet searches that found Bluetooth controlled vehicles and associated applications readily available on the market. Although PWM control in those cars is unknown, future use of controls in RC (Bluetooth) cars might be old shoe with cellphone technology. This may lead students to become less interested in projects that have been done before.

What possible projects could build upon what was achieved with this project

This project uses one-way communication. The phone application tells the motor controller what to do and receives nothing back. It would be interesting to implement sensors and have their data reported back to the application. It would also be interesting to explore WiFi direct as a means to communicate versus Bluetooth. WiFi direct is a relatively new communication standard and would allow for faster data rates and internet networking capabilities.

Future projects involving cellphone applications would be interesting. Cell phone control of a PLC?

Do the students feel this project was a worthwhile endeavor, and why?

I believe it was at least a worthwhile endeavor for the students involved. I feel I learned more than I could have had I taken a class on the subject. Whether or not this was a worthwhile endeavor for course material development is still indeterminate.
It would probably be possible to complete the android side of the project in a semester but any student not familiar with Java could easily fall behind in the course.
Most students at the class level of us have worked with the PWM functionalities of a micro-controller before. If using familiar hardware and appropriate documentation the car modifications could be accomplished during a semester

Absolutely. I tend to learn more working on projects as opposed to learning theory in a classroom, although this project would be impossible without previous microcontroller and programming experience in the classroom. I think this project reflects some current trends in the direction technology is heading which makes it valid and exciting. Projects near the cutting edge of technology make it possible for students to contribute in the future.

Was the time spent appropriate?

Yes. There was a large amount of learning involved in completing the project.

Yes, however encountering unexpected problems led to at least 200 hours of time being spent of this project.

Based on the above student comments, it is clear that the students felt the project was a worthwhile learning experience. But if this material were to be transferred into a traditional course, the structure of the course and associated lab would have to be modified to allow students to learn this material in smaller pieces. For example, labs could be broken up into modules that focus on:

- Introduction to the PIC microcontroller
- PWM control using the PIC
- Introduction to the Android operating system
- Introduction to Bluetooth on a smart phone
- Programming the operating system in Java to access the Bluetooth module
- Receiving and decoding Bluetooth information on the PIC
- Integration of technologies to complete the project

Potentially, this material could be broken into two courses, one for the PIC and the other for the Android operating system.

References

[1] https://www.youtube.com/watch?v=E-p5qIJaXPs (check out the video at the 3 minute point)
[2] http://www.youtube.com/watch?v=A4VJnsOkDsE
[3] http://en.wikipedia.org/wiki/File:Android_historical_version_distribution.png