AC 2008-2072: TEACHING AND USING GPS/GIS IN ELECTRICAL ENGINEERING PROJECTS

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Teaching and Using GPS/GIS in Electrical Engineering Projects

Abstract

This paper will present the work of student's team senior project using effective tools to design and build a voice activated wheelchair that uses Global Positioning System (GPS) and Geographic Information System (GIS). The students will benefit from this project by hands-on and using new and advanced computer tools on GPS/GIS in electrical engineering projects. Even though the main target area of this paper will be focus on the applications of GPS/GIS in voice activated wheelchair by electrical and computer engineering students, however, other engineering disciplines can benefit as well.

The usage of GPS equipment and understanding of GIS is becoming very important in electrical engineering. The benefit of using GPS/GIS becomes obvious in the areas of analysis, modeling, simulation, design and decision making. Many engineering companies are beginning to realize the importance of using GPS/GIS applications in their day to day operations especially in data collection.

Introduction

Voice recognition systems and global positioning systems (GPS) are technologies that are currently thriving in today's market. These technologies are commonly used in handheld devices, automobiles, and are viewed as more of a luxury than a necessity. We sought to use these technologies in a new and innovative way such that their necessities could be harvested. This project incorporates a voice recognition system that can control the movements of a battery-powered wheelchair as well as command a GPS unit to map out a path such that the wheelchair may perhaps autonomously navigate itself to a given destination. This could provide a safe and efficient way for people with excessive disabilities to navigate with ease.

This project consisted of several objectives including designing the voice recognition controller, implementing GPS navigation, as well as incorporating safety features such as collision detection. All the systems were integrated into one, such that the voice recognition would control the GPS navigation. Users will be able to vocally command or perhaps speak a destination point and the GPS navigation unit will to navigate.

Motivation for the project

Quadriplegics and paraplegics who suffer from a high degree of paralysis have less independence and flexibility in their daily lives. Thus, they depend on the wheelchairs for performing the most basic activities, so a wheelchair that controls by voice can provide them a higher level of independence. For patients with extremely limited physical abilities, a joystick or chin controlled power wheel chair may still not be a usable method of independent transport. For these patients, vocal functions may be the only means of controlling a wheel chair.

Goals and Objectives`

The objective of this project was to modify an electric wheelchair with voice recognition so that voice commands can be used to control the movements of the wheelchair. The idea is to better aid the mobility of users with extreme disabilities, such as paraplegics (paralyzes from the waist down) and quadriplegics (paralyzes from the neck down).

The following goals were identified by the faculty and students:

1. Design a new wheelchair controller that uses voice recognition.
2. Interface the voice recognition with the new controller.
3. Interface the controller with the electric wheelchair.
4. Implement sensors to detect nearby objects in order to prevent collisions.
5. Improve the cosmetics and safety restraint system.
6. Use local GIS campus map to navigate around.
7. Implement autonomous navigation using GPS.
8. Provide lighting for night operation.
9. Parallel both voice and joystick control and also provide joystick override

The wheelchair

The wheelchair, Jet 3, is manufactured by Pride Mobility. It consists of two DC motors that operate on 24 volts from two batteries in series. It is approximately 34 inches long and 23 inches wide with 10 inch pneumatic tires. It has a maximum speed of 5MPH and an operating range of 25 miles before a recharge is necessary. Figure 1 illustrates the wheelchair [1].

Figure 1. The Voice Activated Wheelchair.

Project phases

The project life cycle was divided into three stages as following:

The first stage is to probe the wheelchair and learn how the wheelchair works. An analog joystick controls the operation of the wheelchair based on the voltages of four wires. A Spartan 3 FPGA board was used to interface with the wheelchair controller in order to mimic the operations of the joystick. An additional power amplification and a low pass filter was used because the signal should be converted from digital to analog since the input to the wheelchair is analog. The Images SI SR-07 Speech Recognition kit was selected in order to interface with the FPGA. This voice recognition kit allows quick programming and ease of use. We employed four types of movement including forward, reverse, left, right, or stop. We can however deploy angular turns if necessary. In addition, we have a command of “navigate” for the purpose of GPS guidance.

The second stage of the project is to incorporate a few safety features. A cause for concern when operating a wheelchair is collision. Whether a collision occurs from a wall or an object such as a human being, it must be prevented to ensure safety for the user and others around. Therefore, four ultrasonic sensors have been incorporated onto the wheelchair. When an object or wall is within 40 inches of collision, the wheelchair will be informed to decelerate and stop. Likewise, another issue that needed to be addressed was to enable parallel control for the joystick and the microphone. In an event that the wheelchair is unstable or another user notices a problem, he or she can override the voice operations of the wheelchair by controlling the joystick. This feature requires the use of an analog-to-digital converter circuit in order to convert the analog joystick to digital signals to input into the FPGA board. In addition, the wheelchair was customized by redesigning the seat. A bucket seat was selected and custom mounted onto the wheelchair’s base. To ensure safety, a 4130 aircraft-grade steel was used to customize a bracket adapter in order to adapt the base bracket to the bucket seat. Also a 4-point harness belt was incorporated for maximum restraint in the harshest operating conditions. This allows the user to remain stable at all times.

The third and final stage of this project deals with incorporating convenience features that allow the user to operate the wheelchair to the fullest of daily activities. This feature is called GPS guidance and allows autonomous motion of the wheelchair to a predefined location or waypoint after giving a voice command. For example, if the user gives a vocal command such as “marketplace”, the wheelchair will then navigate from its current position to that destination without any further additional inputs. Once the wheelchair has reached its destination, it will stop. At any time during the autonomous motion, the user can also change his or her decision and return to manual operation. The GPS guidance system uses a PIC microcontroller and a Garmin eTrex GPS receiver to receive data from the satellites and calculate a route. Likewise, a Garmin Street Pilot C550 was mounted for aesthetic purposes to serve as a neat mapping guide.

Design and Flowchart

The FPGA is the heart of the entire design and interfaces with other external devices. The user presses the on button the wheelchair controller and also a push-button to turn on the rest of the associated hardware. Then, the user wears the microphone and can now choose a vocal command. The possible vocal commands are: 1) Forward, 2) Reverse, 3) Left, 4) Right, 5) Stop, and 6) Navigate. The following flowchart in figure 2, illustrates the basic design of this project:

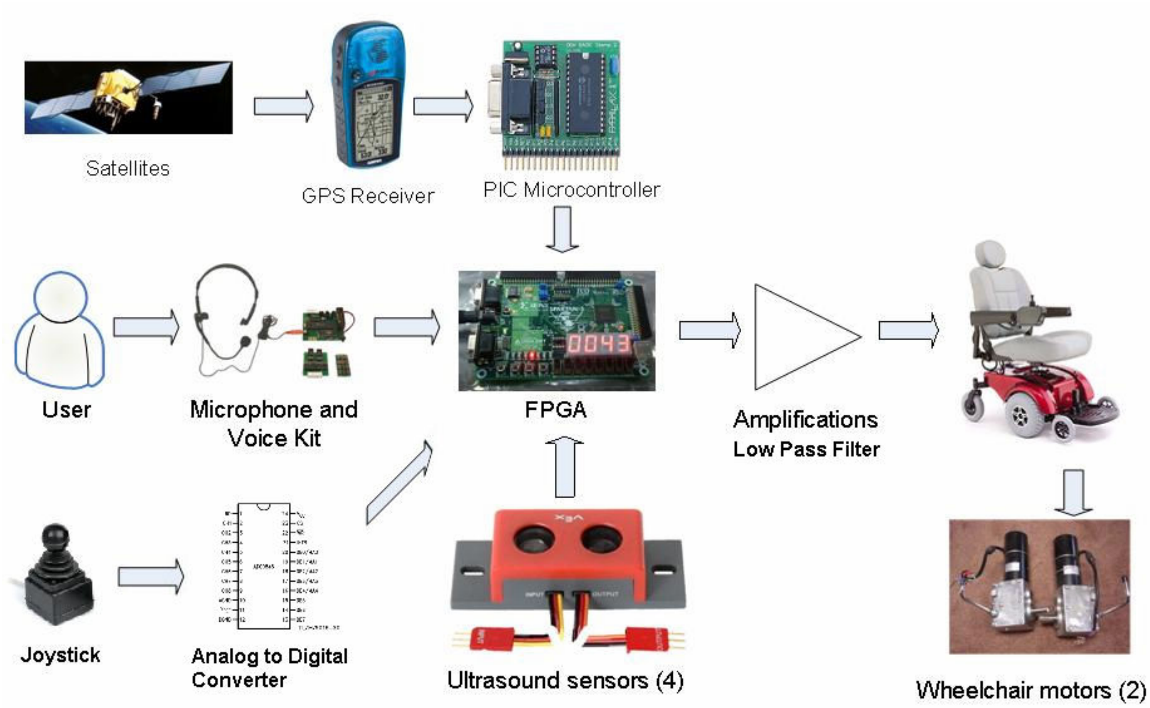

Figure 2. Design and flow chart.

GPS Guidance

One of the coolest features to implement was having the ability to navigate to a preprogrammed position after giving a voice command. Essentially, the user would give a voice command such as "navigate" and the wheelchair will move to predefined waypoints along the way until it reaches the final destination. Further user inputs would no longer be necessary. It was felt that this feature greatly enhances the operation of a wheelchair as it allows minimal input from the user as he or she can relax until the wheelchair reaches the user's desired destination. It was hoped that one would be able to start from any location on campus say "market place". Then the wheelchair would essentially navigate straight to the door step of the campus market place.

Usually, implementing GPS guidance on many robotic devices takes a considerable amount of time because there is a significant amount of trial and error involved. The trials must also be conducted outside of the laboratory and therefore, takes up even more time than usual. The reason is due to the fact that GPS signals can not travel through buildings and walls. They are only best with a clear view of the sky.

GPS Navigation

The purpose of GPS navigation is to allow motion after giving a single voice command. The wheelchair will then navigate to its intended destination through the use of waypoints and will not require further inputs until it reaches the destination. The following steps show the process of input command as it reaches through different stages of the system:

Step 1: The user gives a command such as "navigate" into the microphone.
Step 2: The FPGA controller sends a start signal to the PIC microcontroller. The microcontroller begins receiving data from the Garmin eTrex Legend GPS receiver and parses the necessary data.
Step 3: The PIC microcontroller will then transmit any of the following five commands to the FPGA: Forward, Reverse Left, Right, and Stop.
Step 4: The FPGA will now commence the movement based on the received control data from the PIC microcontroller. Again, the FPGA will now transmit the necessary PWM signals to the low pass filter and operational amplifier.
Step 5: The PIC microcontroller is constantly calculating and parsing the data received from the GPS receiver and will make immediate changes whenever possible.

When the PIC controller has determined that the destination has been reached, a stop command will be transmitted to the FPGA to stop the wheelchair.

Planning and Analysis of GPS

We shall now state our intent and objective for GPS guidance.

1) To use as a visual guidance for the operator of the wheelchair
2) To be able to perhaps autonomously navigate to preprogrammed waypoints after giving a voice command.
3) To continuously monitor current heading and bearing and make necessary corrections.
4) To stop after reaching the final destination waypoint.

One of the issues with GPS is that it is heavily affected by dense trees, terrain, satellite position, signal delay, satellite clock errors, multi-path distortion, as well as the quality of the GPS receiver. The receiver we decided to use is a Garmin eTrex Legend which is a WAAS capable device. WAAS stands for Wide Area Augmentation System. WAAS allows not only satellites in space but ground stations on earth to help improve its accuracy.

The design consists of the following devices as illustrated in figure 3.

Garmin eTrex Legend GPS Receiver
WAAS-capable (~3m accuracy)
Storing 1000 waypoints and 20 routes
Outputs NMEA 0183 Sentences
Data is constantly sent @ 1Hz

PIC Microcontroller (SIP)
Microchip PIC16C57c
20MHz @ ~4000 instructions/sec
16 I/O Pins
5 VDC @ 3mA run / 50uA sleep
2.0" x 2.0" form factor
Low Cost, Low Power and Compact
Extractable parts if damaged
Instantaneously reprogrammable
Takes power from FPGA

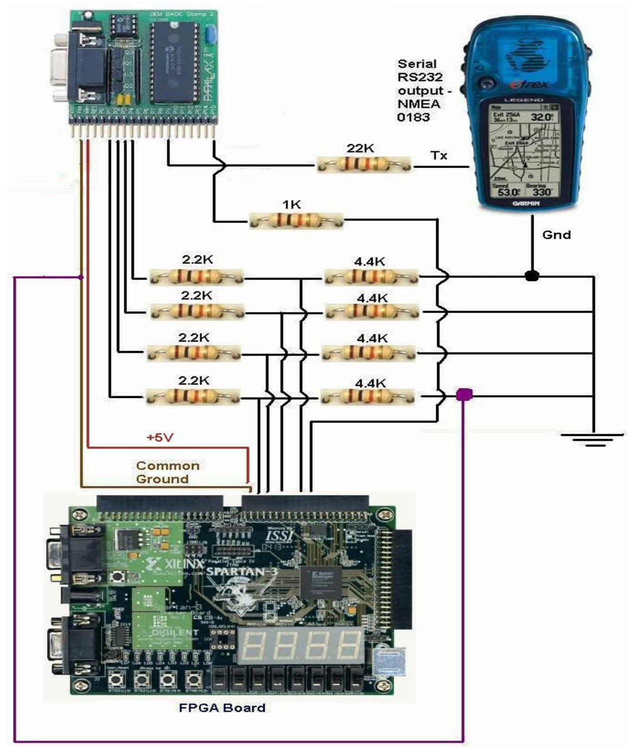

Figure 3. Components used in design of GPS system

Problems with GPS

One of the most gruesome problems that we had with the GPS was the fact that the wheelchair performed erratically. Early field tests showed that the programming and the controller was fine but real world performance proved to be less than acceptable. After nearly a week of diagnostics, we decided to run a simulation at home and with a debug terminal. With a GPS receiver connected, the microcontroller will display the heading and bearing information captured from the GPS receiver.

In the debug terminal we ran a test for hours at home. We wanted to see if the microcontroller was operating correctly, randomly, erratically, or if there was an anomaly. Fortunately, we discovered the problem! It appears that for a while, the microcontroller is capturing and parsing the correct data each time. We know this because the Garmin eTrex is capable of showing us the heading and bearing angles on its own LCD. Notice how in the debug window, the bearing value suddenly jumped from 11 degrees up to 11804 degrees! What was even more amazing was the fact that the problem was actually random! Sometimes the bearing or heading would be correct and sometimes it would capture the wrong data. This kind of problem was the root cause for the erratic behavior of the wheelchair during its navigation sequence.

The problem appeared to be caused by overwhelming the microcontroller with too must task to do in one operation. For example, we had a single command to look for the three data that we need, and then save them accordingly. What happened was that, each time the microcontroller was saving data, it may have lost synchronization with the incoming serial data from the Garmin eTrex. The delay appeared to be negligible until when the delay finally adds up, it began to throw off the timing of capturing the correct data in a particular sentence structure. Yet, sometimes it is able to synchronize itself back up. Had it not been for running an analysis and a debug window for long periods of time, the problem would have been hard to detect.

Student's Accomplishments

Students met all of their primary goals mentioned in their objective. They designed a new wheelchair controller using a Spartan 3 FPGA that interfaced with our SR-07 Voice Recognition module, and receive voice commands. They interfaced the new controller with the original wheelchair controller by generating various voltages with pulse width modulated signals that are converted back to analog signals using signal condition circuits and amplification. Ultrasound sensors were used in our design to prevent collisions from the rear and front by detecting objects and stopping the wheelchair.

Students also accomplished all of their secondary objectives in the project. They modified the wheelchair with a racing bucket seat with a four-point safety harness, mounted on a custom bracket that is made with aircraft-graded steel for maximum stability. The wheelchair also incorporates autonomous navigation using GPS by comparing the bearing and heading from waypoint to waypoint. High Intensity Discharge (HID) lighting was used to provide adequate illumination for night use. And lastly, they were able to incorporate both voice and joystick control with the use of analog-to-digital converters to pass joystick information to the new wheelchair controller

Student's Assignments and Contributions

A total of four students (Adianto, Tianxiao, Sandy, and Verney) assigned to this project. The project started on September 2006 and was completed on May 2007. The following table describes each student's responsibility per quarter.

Students	**Fall 2006**
Adianto	✓ Researched on signal conditioning and amplification for pulse width modulated signals. ✓ Helped design and test the filtering and amplification circuit for the digital-to-analog conversion of the pulse width modulated signal.
Tianxiao	✓ Researched on signal conditioning and amplification for pulse width modulated signals. ✓ Helped design and test the filtering and amplification circuit for the digital-to-analog conversion of the pulse width modulated signal.
Sandy	✓ Interfaced SR-07 Voice Recognition Kit with a Spartan 3 FPGA. ✓ Designed and created a basic wheelchair controller. ✓ Researched on digital-to-analog conversions of pulse width modulated signals.
Verney	✓ Researched, designed, and fabricated the collision detection using

	ultrasound sensors. ✓ Tested and troubleshot the collision detection. ✓ Integrated the collision detection circuit with the wheelchair controller.
	Winter 2007
Adianto	✓ Troubleshoot problems and issues with the signal conditioning and amplification circuit. ✓ Researched on power distribution schematics. ✓ Aided in the research of methods to parallel joystick and voice control.
Tianxiao	✓ Fabricated a final version of the signal conditioning circuit. ✓ Aided in the research of methods to parallel joystick and voice control. ✓ Researched, designed, and fabricated lighting schematics.
Sandy	✓ Redesigned a more complex wheelchair controller to incorporate more complex functions such as timed turns and collision detection overriding. ✓ Researched on joystick and voice control paralleling.
Verney	✓ Designed and fabricated a custom seat bracket to mount a racing bucket seat ✓ Designed the mounting for the four-point harness safety restraint system. ✓ Mounted, tested, and calibrated the collision detection on the wheelchair.
	Spring 2007
Adianto	✓ Designed and partially fabricated the power distribution circuit. ✓ Tested the power distribution circuit. ✓ Aided in the calibration of the GPS autonomous navigation.
Tianxiao	✓ Completed the fabrication of the power distribution circuit. ✓ Troubleshooting hardware anomalies. ✓ Aided in the calibration of the GPS autonomous navigation.
Sandy	✓ Research, designed, and fabricated the analog-to-digital conversion to allow joystick and voice control paralleling and joystick overriding. ✓ Aided in the calibration of the GPS autonomous navigation. ✓ Integrated the wheelchair controller with the analog-to-digital converter.
Verney	✓ Researched and designed the enclosure for all electrical components. ✓ Designed and mounted High Intensity Discharge lighting onto the wheelchair. ✓ Designed, fabricated, tested, and calibrated the GPS autonomous navigation unit for the wheelchair.

Conclusion

The Achievements of the students and their team works were great. The instructor deliberately mixed students with different levels of experience in this project. The purpose is so that the experienced students can pass the technical expertise to the inexperienced students and demonstrate how team works should work.

Here are quotations from a couple of students of what they learn:
Student 1:"*I learned a lot from this project. First of all, I learned how voice activated system and GPS works.*
Student 2: "*It did enhance my interest in learning more about setting up a smooth team work and managing it, it also helped me learn more about myself and how I react to such working conditions***.**"

References

1. Chen, Danusasmita, Kwan, and Yeh, "Voice Controlled Wheelchair with GPS Guidance and Collision Detection", Senior Project 2006-2007