NORTHERN ILLINOIS UNIVERSITY

Smart Cane: Proximity Sensor and Audible GPS

A Thesis Submitted to the

University Honors Program

In Partial Fulfillment of the

Requirements of the Baccalaureate Degree

With Upper Division Honors

Department Of

Electrical Engineering

By

Tommy Oates

DeKalb, Illinois

May, 11th, 2013

University Honors Program

Capstone Approval Page

Capstone Title: Smart Cane: Proximity Sensor and Audible GPS

Abstract

The Smart Cane is designed to assist the visually impaired population of Northern Illinois University in navigating the campus. To enhance the conventional White Cane's functionality an ultrasonic proximity sensor will be connected and used in the detection of obstacles in the lateral and vertical direction the cane is positioned. The cane will be providing haptic feedback (i.e. vibrations in the handle of the cane) to the user, when encountering an obstruction. The haptic feedback will intensify as the cane nears an obstacle alerting the user to the presence of the obstruction. There will also be an audible GPS system incorporated to help the user. The GPS will be updating in real time every second. This will allow the user to know where on campus they are located at any specific time and if they are nearing an entrance to a building. The design goals are to increase the functionality of the conventional cane, while maintaining lower costs in the construction in comparison to that of current visual impaired aid technologies.

Student Name: Tommy Oates

Faculty Supervisor: Lichuan Liu

Faculty Approval Signature: Lichuan Liu

Department of: Electrical Engineering

Date of Approval: 5/2/2013

HONORS THESIS ABSTRACT
THESIS SUBMISSION FORM

AUTHOR: Thomas Oates

THESIS TITLE: Smart Cane: Proximity Sensor and Audible GPS

ADVISOR: Lichuan Liu

ADVISOR'S DEPARTMENT: Electrical Engineering

DISCIPLINE: Engineering and Technology YEAR: 2013

PAGE LENGTH: 18 pages

BIBLIOGRAPHY: page 17, 18

ILLUSTRATED: Pictures taken by Thomas Oates

PUBLISHED (YES OR NO): No

LIST PUBLICATION: N/A

COPIES AVAILABLE (HARD COPY, MICROFILM, DISKETTE): Hard copy
Electronic Copy

ABSTRACT

The Smart Cane is designed to assist the visually impaired population of Northern Illinois University in navigating the campus. To enhance the conventional White Cane's functionality an ultrasonic proximity sensor will be connected and used in the detection of obstacles in the lateral and vertical direction the cane is positioned. The cane will be providing haptic feedback (i.e. vibrations in the handle of the cane) to the user, when encountering an obstruction. The haptic feedback will intensify as the cane nears an obstacle alerting the user to the presence of the obstruction. There will also be an audible GPS system incorporated to help the user. The GPS will be updating in real time every second. This will allow the user to know where on campus they are located at any specific time and if they are nearing an entrance to a building. The design goals are to increase the functionality of the conventional cane, while maintaining lower costs in the construction in comparison to that of current visual impaired aid technologies.

Smart Cane: Proximity Sensor and Audible GPS

Anthony Boyd Rohan Escabar
Tommy Oates Ray Spence

Adviser: Lichuan Liu

Dr. Veysel Demir
ELE 492
April 29th, 2013

Abstract

The Smart Cane is designed to assist the visually impaired population of Northern Illinois University in navigating the campus. To enhance the conventional White Cane's functionality an ultrasonic proximity sensor will be connected and used in the detection of obstacles in the lateral and vertical direction the cane is positioned. The cane will be providing haptic feedback (i.e. vibrations in the handle of the cane) to the user, when encountering an obstruction. The haptic feedback will intensify as the cane nears an obstacle alerting the user to the presence of the obstruction. There will also be an audible GPS system incorporated to help the user. The GPS will be updating in real time every second. This will allow the user to know where on campus they are located at any specific time and if they are nearing an entrance to a building. The design goals are to increase the functionality of the conventional cane, while maintaining lower costs in the construction in comparison to that of current visual impaired aid technologies.

Introduction

The number of non-institutionalized, males and females of all ages in the United States that are reported to have a visual disability is approximately 6,636,900 (facts about blindness). The number of visually impaired that have a bachelor degree in the United States as reported in the 2011 census was 374,400. That is 5.6% of the visually impaired population that finished college. This statics is staggering and was one of the motivations behind the Smart Cane. The Smart Cane will allow the navigation of NIU campus to easier so that people with visual imparities can feel comfortable and safe in navigating the NIU campus and in return allowing them to further their educational career.

There are currently two prevalent forms of navigation on the Northern Illinois University campus for the visually impaired, a conventional White Cane and a seeing-eye dog. The conventional White Cane is swung in front of the user, detecting obstacles only when the cane strikes the object. The seeing-eye dog walks alongside the user stopping or going based on its training. The seeing eye dog avoids obstacles that will it encounters or that it cannot continue through. There is an alternative choice to these two options, the Ultra Cane. This can uses a proximity sensor at the tip of the cane and will vibrate the handle to alert the user of an obstruction. There a problems with all three of these current technologies. Both the Ultra Cane and the conventional White Cane cannot detect any obstruction that is above the hip, thus putting the user at risk of hanging objects. A seeing eye dog is an animal and will always have error with how it reacts and judges potential problems. There are other Assistive Technologies that are out there that range from proximity gloves, audible compasses, and many more pieces of advanced technology. The Ultra Cane, these Assistive Technologies, and the training and maintaining of the seeing eye dog all have a very large capital investment. These are a few areas that can be improved for the benefit of the visually impaired at Northern Illinois University. A new idea for the operations that is not seen in the technologies for the NIU campus is the addition of an audible GPS that will allow the user to know when they are near a building on campus or if they are heading towards one of its entrances.

The development the Smart White Cane system will be done through communication with the users through vibration from a proximity sensor. This sensor will detect obstacles in front of the user up to 1.5 meters in front of them and up to 3 meters above the user. The vibrations will increase as the object crosses three different ranges. These ranges occur at 4 , 6, and 9 feet. With the crossing of each of an individual ranges the vibrations sent through the handle will intensify. There will also be an audible GPS implemented into the Smart Cane's design. The GPS system will be based off building locations and entrances of that specific building. The GPS will be coded to recognize when it is within a specific latitude and longitude. It will emit a tone that will be unique for each building. Then as the user approaches an entrance a variance on the original tone specific to the entrance that the user is approaching.

Design

In the Smart Cane's proximity senor design was initially connected to an Arduino Uno, the micro-controller used for this design, that was programmed to configure the sensors that will detect the obstacles that the user will encounter. The Arduino Uno has small, light weight and operates at a low voltage of 5 volts. This is a small device and will fit comfortably in the housing designed for Smart Cane.

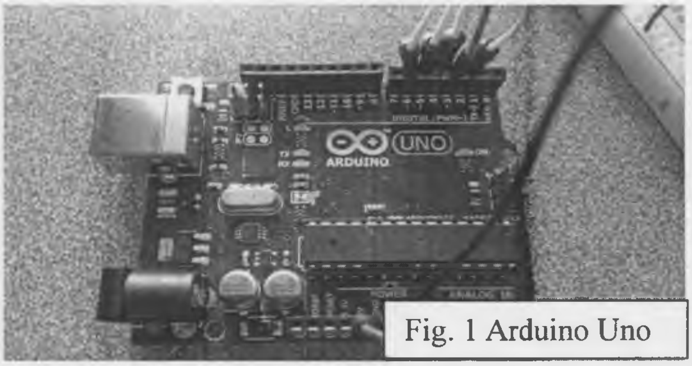

Fig. 1 Arduino Uno

The Arduino was coded was to emit a burst of ultrasonic noise (40kHz). The ultrasonic transmitter and receiver is a HC-SR04 Ultrasonic Ranging Module. This model was easily integrated with the Arduino and the code that was written for the ranging module. The ultrasonic noise is projected from the module in front of the user. The Arduino delays 5 micro seconds before have the ranging module emit another ultrasonic burst. If there is an object in front of the user then the ultrasonic frequency will be reflected back at the user where an echo feedback senor is located. The Arduino takes the time in between the emission and the reception of the ultrasonic burst and

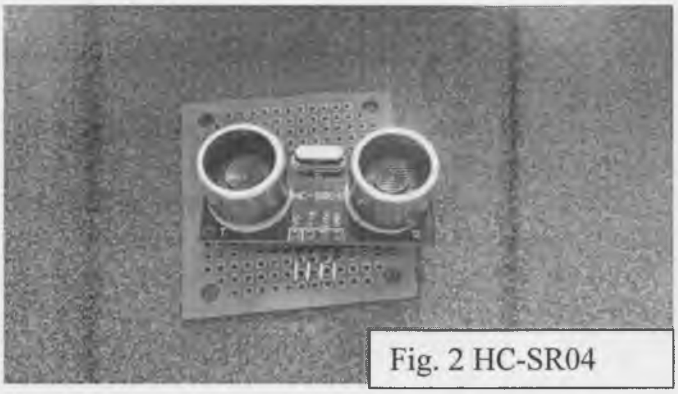
Fig. 2 HC-SR04

calculates the distance that the sound has traveled and extrapolates the distance the object is from the user. With the distance known the micro-controller then sends a vibration through the handle of the cane to alert the user with one of the three different strengths of vibrations. Then this process is repeated as an ongoing cycle till the device is turned off.

For the Smart Cane the housing is a 1" PVC pipe that is 4 feet long. The pipe has a wheel screw on the bottom of the PVC pipe to eliminate the need to tap the cane on the ground and gives ease in mobility with the elimination of the need to carry the cane. The cane can be pushed long the ground, this still allows the user to use it like a conventional White Cane if need be.

Fig. 3 GPS Receiver

For the Smart Cane's audible GPS system it was implemented to allow the user to accurately pin point where they are on campus. Also, the design will output an audible response when in range of buildings on campus. For this design a 66 Channel LS20031 GPS 5Hz Receiver was used. The LS20031 includes an imbedded antenna and GPS receiver circuits. It can output positional information every second. In our design it is used at its this limit. This GPS can track up to 66 different satellites. It's time to first fix is also very quick. It also has a very low power consumption, it only runs off of 3.3V at 41 mA. This provides us with a long battery life. Its signal strength is very good. It meets the requirements for a car GPS and can be used in a heavy forest canopy or a dense urban environment.

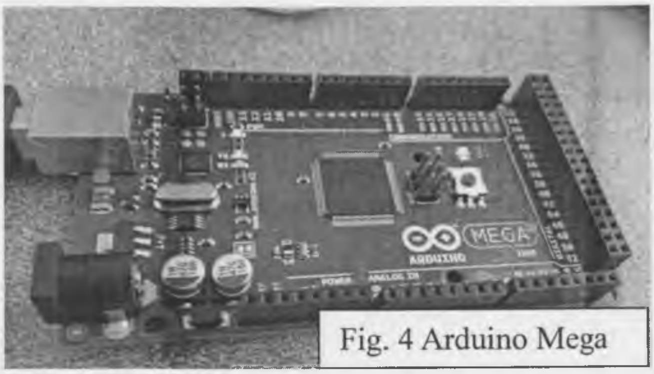

Fig. 4 Arduino Mega

The board we are using to test our design is an Arduino Mega 25600. The Arduino is an open source physical computing platform. It has a wide range of uses. It has a processing/writing language, so that different software can be implemented or created for it. Libraries can be added and dropped for different needs of the Arduino. This board has 56 digital input/output pins. This gives a large area to work with for the design on the GPS. It also has 256k flash memory and a 16Mhz clock speed. Both of these limits will not be exceeded for the design. This Arduino may be replaced by a smaller version in the final design step to save space and make it more transportable.

The audio aspect a piezo element was used. This element can be used as a audio transducer with a pulse width modulation to output different tones. The different tones will indicate different buildings or doors as they are approached. This in later designs can be changed out for a more sophisticated audio device that could give full audible names of the buildings and entrances as they are approached.

Fig. 5 Piezo

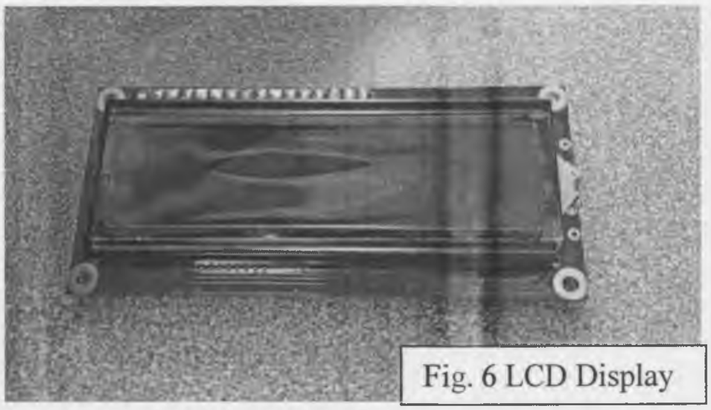

Fig. 6 LCD Display

For the testing also added an 16x2 LCD digital display. This will give up to date display of the latitude and longitude of the GPS system so that constraints for when the tones are used can be written for the design. For the final design this will be removed to save space and battery life of the device.

The code for the Arduino the tutorial in the TinyGPS library was the basis for the code. The example of "test with GPS device" checked to see if there was communication between the GPS and the Arduino. This was done by outputting the different data that can be gathered from the GPS. The code as was did not work, and needed to be modified to get a connection between the two. Using a similar design from Jeremy Blum the correction that were made to the code implemented. After completion of testing of GPS and LCD display, deletion of extra nonessential information was made to create more space in the Arduino.

```
#include <TinyGPS.h> // needed to be addded to the Arduino library for GPS functions
#include <LiquidCrystal.h> //added for testing on the LCD display

TinyGPS gps;          // calls for the tinyGPS's functions
LiquidCrystal lcd(52, 50, 28, 26, 24, 22); // the LCD'd display pin location
```

Fig. 7 Code Libraries

Fig. 8 Latitude and Longitude Coordinates


```
// the if statements control when an if the piezo creates noise when the GPS is in range
//of a building

if (    (41.940719  >= flat >=  41.93923 && -88.763013>= flon >=-88.761898 ) &&
        (41.939693 >=' flat >=! 41.939426 && -88.762732<=! flon <=! -88.76242)&&
        (41.939799 >=! flat >=! 41.939478 &&  -88.762128<=! flon <=! -88.761898)
   )

{
tone (9,161,50);
} //engineering buidings corrdinates

if (    (41.939693 >= flat >= 41.939606 && -88.76242 >=flon >= -88.76242) &&
        ( 41.939426 >=! flat >=! 41.939557 && -88.762732 <=! flon <=' -88.76249)
   )
{
tone(9,261, 50);
} // west end entrance of the engineering building's first larger range around door

if (flat<=41.939606 && flon>=-88.76249&& flat >=41.939557 && flon <=-88.76242)
{
tone(9, 261, 50);
} //// west end entrance of the engineeri
```

Fig. 9 Code Ranges

After finding the latitude and longitude ranges around the Engineering building and two subsequent smaller ranges around each of the Engineering building's two main entrances the audible code was constructed. The code was to make the piezo to vibrate at different frequencies to make different audible tones, thus informing the user of where in relation on campus, and when closer which side of the building they are. This will also assist them in confirming they are walking in the correct direction to reach the entrance. To avoid overlapping tones from being in two areas at the same time, a complicated if statement with restrictions of when the piezo should vibrate was created. The if statement covered a broad box area around the Engineering building with holes to be filled with by other if statements that will have their own unique frequencies that the piezo will output. Along with having the piezo make a tone when it is in range of a building an initial tone was added to inform the user that there is not a sufficient satellite fix. When using a GPS there needs to be at least 4 satellites transmitting to the GPS to get an accurate latitude, longitude and altitude. If these three parameters are not being calculated the GPS does not write to the serial monitor. With the tone added the user is aware that there is no signal and is not getting accurate reading.

Method and Measurements

The Smart Cane and the Ultra Cane were both compared in two different categories. The max distance and the lateral distance were measured and compared. A chair was set in a room that was 30 X 20 and was not near any other obstructions. The canes started an inch away from the chair and were slowly walk backwards in a straight path until the sensor could not register the chair anymore. The Ultra cane max range was 8.6 ft, while the max range for the Smart Cane was 9 ft. The lateral distance for both canes were measured by taking the chair and setting it in a fixed position and while holding up each cane at the end of the left foot of the chair was moved away from the left foot of the chair by .5 inch intervals. The Ultra Cane stopped registering the chair at 6 ft, while the Smart Cane registered the chair till 8 ft. laterally. The ease of use and weight of both canes were tested by using 5 subjects who walked around with each cane blindfolded for a 5 minute duration around the same path on the Northern Illinois University campus. After completion of the trial with the cane the students were asked to comment on the experience throughout the test. The students commented on how comfortable each cane was and how helpful the vibrations were.

When trying to make the GPS work properly, there were many tests run. Slowly building on one another. Initially the first measurement taken was to verify that the GPS was communicating to the Arduino. The communication was done by running the test code example from the TinyGPS library. After the GPD was found to be communicating properly with the Arduino the GPS was taken outside to verify that it would gain a satellite fix with enough satellites to get a reliable latitude and longitude. An LCD display was needed to have a way of reading the latitude and longitude of the GPS's current position while moving. When that was designed and implemented the testing on whether the GPS and the code were updating in real time was verified. After all the previous was accomplished, the latitude and longitude boundaries of the Engineering building and the two main entrances were gathered. The GPS was taken around the Engineering building and recording the maximum and minimum latitudes and longitudes. The values found were added to the code to create the area in which the GPS's audible portion would react. The areas for the entrances of the building were done in two ranges. One being 20ft out and the second being 5ft away. The GPS audible device is a piezo that operates based on a frequency emitted from the Arduino. Each range was given a different frequency to verify that the code was working properly. While looking at the LCD display the GPS was walked in and out of the different ranges and the audible piezo changed its pitch correctly. A additional tone was added to notify the user that after turning on the GPS that they have not yet received an initial satellite fix.

Results

Smart Cane vs. Ultra Cane Lateral Sensor Strength

In"	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
Smart Cane	3	3	3	3	3	3	3	3	2	2	2	2	1	1	1	0
Ultra Cane	3	3	3	3	2	2	2	2	1	1	1	1	0	0	0	0

Smart Cane vs. Ultra Cane Forward Senor Strength

Feet	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9
Smart Cane	3	3	3	3	3	3	3	3	2	2	2	2	1	1	1	1	1	0
Ultra Cane	3	3	3	3	3	3	2	2	2	2	2	1	1	1	1	0	0	0

Sensor Strength

3-Strong

2-Medium

1-Weak

0-No Sensing

Student Evaluation		
Subjects	Vibration	Comfort
Soloman: Engineering Student	I like the idea of the Vibrations, the range is pretty good	Smart Cane look bulky but after using it, it was a better concept

		and ended up being lighter.
Janae: Visually Impaired person	The vibration will take some time to get use to.	Smart Cane is lighter over time. Ultra cane feels big.
Joshua: Engineering Student	The vibration are really accurate for the smart cane. Maybe adding a voice feature would be great	Ultra cane is lighter with the wheel design , if it did not have the wheel I would go with the Ultra cane
Virgina: Random Person Selected	The idea is innovative. The vibrations really helped me avoid collisions.	It's annoying holding up the Ultra Cane all the time.
Steve: Visually Impaired Person	The vibration came in handy with object detection. After some getting used to, the vibration can be very useful.	The Ultra cane is lighter but I like the concept of the wheel on the Smart Cane it really takes away from holding up the Ultra Cane

Sat	Latitude (deg)	Longitude (deg)	GPSRX
****	*******	*******	20021
****	*******	*******	20214
****	*******	*******	20406
****	*******	*******	20599
5	41.93968	-88.76258	20845
5	41.93967	-88.76258	21102
5	41.93966	-88.76256	21359
5	41.93965	-88.76255	21618
5	41.93965	-88.76255	21876
8	41.93965	-88.76255	22136
8	41.93965	-88.76255	22398
8	41.93963	-88.76250	22659
8	41.93963	-88.76246	22923
8	41.93964	-88.76246	23186
7	41.93965	-88.76247	23450
7	41.93965	-88.76250	23713
7	41.93966	-88.76251	23985
7	41.93967	-88.76251	24253
7	41.93968	-88.76253	24519
7	41.93968	-88.76255	24787
7	41.93969	-88.76255	25056
7	41.93969	-88.76256	25321
7	41.93969	-88.76256	25591
7	41.93969	-88.76258	25859
9	41.93969	-88.76258	26123
9	41.93968	-88.76258	26394
9	41.93968	-88.76258	26659

Satellite and Arduino Serial Monitor Output

Discussion

From the tested distance of the range of the Ultra Cane and the Smart Cane it can be seen that both the lateral distance and forward distance was greater for the Smart Cane. The Smart Cane was programmed to reach a max distance of 9 feet, and the max range was 8.9 feet which was close to what we programmed it for. The Ultra Cane had a max forward range of 7.7 feet. When testing the lateral distance about every .5 inches the Ultra Cane, dropped from a sensing level from strong, medium to weak. The Smart Cane on the other hand had a longer range for the strong sensing distance, which ranged from 0-4 inches. The medium range on the Smart Cane ranged from 4.5 to 6 inches and for the

Ultra Cane from 2.5 to 4 inches. The weak sensing range for the Smart Cane are 6.5 -8 inches and for the Ultra Cane it ranges from 4.5 to 6 inches.

5 subjects were asked to use the Smart Cane and Ultra Cane. Each of the subjects were blind folded if they were not visually impaired. After using the cane for 5 minutes each subject gave their opinion on the both canes and the vibrations of the Smart Cane. The overall consensus on the comfort of the Smart Cane vs. the Ultra Cane was ended up being related to the wheel. The users overall thought of the Smart Cane was that it was heavier, but with the wheel they found it to be more comfortable than the Ultra Cane. In a sense the subjects conveyed that the wheel made the Smart Cane lighter because of not having to hold up the entire weight of the cane. The subjects were also asked about the vibrations and if they felt it aided there movement. Overall 4/5 subjects liked the sensing and said that it helped them navigate the campus better. One of the subjects who liked the vibration feature was visually impaired, the other who did not like it was also visually impaired. The person who did not like the vibration feature said it will take her some time to get use to, and she like to use the ordinary white cane because she can feel and have a sense of her environment.

The output seen in section above shows the Serial Monitor. This is where the GPS and Arduino are dumping the values that they are transferring between each other. There number a satellites in range are shown in the far left column. Then the latitude and longitude is shown next. Then finally the GPSRX is to verify that the GPS and the Arduino are communicating properly. This specific code is of the GPS walking from being in range of a door to an area that is outside of all ranges. This is not seen very well while looking at the code, because there is no visible sign that the GPS has crossed over the range threshold. The only acknowledgement is the audible noise that was produced that stopped as the GPS left the last range.

Conclusion and Recommendations

The final design of the Smart Cane was to produce a prototype that can detect objects or obstacles in front of visually impaired students on the Northern Illinois campus and then relay feedback warnings, in the form of strengths of vibrations to the user. In conjunction with a proximity senor, a positioning service was also provided via an audible GPS module. The GPS module gives an accurate location of the user's position for the Engineering Building and its two main entrances as the user may use. As the user moves towards the entrance the pitch changes. Both entrances and ranges have their own tones to make them unique. The developed prototype achieved all the objectives that were set. The cost, mobility, and functionality of the conventional White Cane and the Ultra Cane were improved upon. Even with labor time and mass production of the Smart Cane the estimated cost fort the user will still be half of that of the Ultra Cane.

While working on this for the visually impaired, a lot was learned about the difficulties presented to the visually impaired that people with vision take for granted. While researching canes and other aids for the visually impaired we were asked to give up our sight while testing the devices. This is when we noticed how much we relied on sight and how losing it caused us to become very nervous and second guess all of our movements. When we were given a device we seemed to latch onto it and use all the help it gave us. This was a driving factor in making this cane as helpful as possible. Trying to add as many conveniences that we were able to design for.

As the project came to a conclusion there were a few recommendations that incorporated into the design to improve the overall design. The PVC pipe can be replaced with a metal or fiber glass to make it more durable or lighter. If the PVC pipe is found to be the best possible material then the size of the PVC pipe that was used could be thinned. A 1"thick PVC pipe was used, but a 1/2"or less could be constructed. Another way to implement a small design is utilizing a PCB from the bread board design.

The case is water resistant, but weather proofing the casing by making the case water proof and shock resistant could improve the durability and effectiveness of the cane. A final design would be to have all the sensors and GPS housed inside the cane.

More buildings can be added to the code till the whole of NIU campus is fully mapped out and stored so that the Smart Cane can be used all over campus. Also there is a problem with losing satellite fix. The tone that is played when there is no satellite fix only does so on initial start up. At the moment the code cannot emit this tone after satellite fix is lost. Steps are being taken to correct for this problem, by trying to add another variable that records the number of satellites in range and repeating the no fix tone. Also instead of a tone to indicate the building and entrances a fully audible speaker could be added to specifically say which building the user is approaching and the distance the user is from the entrance. For the production of the board it could be printed to accommodate all the design aspects need for the design to run. The Arduino, the audible output device, a power supply and the GPS are needed. The Arduino at the moment is very large compared to what is need for the final design. For a production design of the GPS system could be the size of the GPS just with a little larger thickness to fit the micro-controller and the speaker. This could be implemented on top of the Smart Cane's proximity sensor, only added negligible weight and negligible battery drain.

Acknowledgments

Dr. Gaylen Kapperman - Professor and Coordinator

Dr. William Penrod - Associate Professor

Dr. Kocanda - Technical Advisor

Budget

Item	Cost
Starter Kit for Newsite Uno R3	$31.88
Wall Adapter Power Supply 9V DC	$5.80
PVC Pipe	$1.50
Ultrasonic Module HC-SR04 Distance for Arduino	$5.80
Wheel	$2.10
Wires	Free
9V Battery	Free
Sparkfun MicroSD Shield	$16.95
Sparkfun 32 Channel LS20031 GPS5HZ	$60.95
Sparkfun LCD ADD-On for Inventor	$16.95
Vibrating LED: 3 total	$15.00
GHEO ELEC ARDUINO MEGA2560 REV3	$34.99
Shipping	$10.87

Tax	$12.84
Total	$215.63

Ethics

The battery system for the GPS and Sensor can turn into a safety issue with the current prototype. The cane would be lose a lot of its abilities without a power source. One way this issue can be solved is by adding power meter that allows the user to know when the battery is low via vibrations. The current design which is still a prototype and lacks weather protection. Weather proofing the device is very essential because if any part of the circuit gets damage from water it renders the device useless or in a worse case scenario cause the user harm.

The GPS updates at a relatively slow rate of once a second. This poises a problem to the user, because if the GPS updates slower the users velocity it can create problems with location service. This may cause a collision. The GPS should also be kept up to date if any obstruction is created in the users path, such as construction, new paths or new buildings.

References

Blum, Jeremy. "Tutorial 15 for Arduino: GPS Tracking." *JeremyBlumcom*. N.p., 16 July 2012. Web. 29 Feb. 2013.

G., Pradeep. "ULTRASONIC PROXIMITY DETECTOR." *Electronicsforu.com*. EFY Group, n.d. Web. 30 Jan. 2013.

"Language Reference." *Arduino*. Arduino, Feb.-Mar. 2013. Web. 21 Mar. 2013.

"Latitude and Longitude of a Point." *ITouchMap*. N.p., n.d. Web. 12 Apr. 2013.

"Product Categories." *SparkFun Electronics*. Sharing Ingenuity, 1 Jan. 2013. Web. 12 Jan. 2013.

"Statistical Facts about Blindness in the United States (2011)." *National Federation of the Blind*. N.p., 2013. Web. 30 Mar. 2013.

"TinyGPS Satellite Count Mod." *Code:arduino_tinygps_satellite_count_mod [Rogue Robotics WikiDocs]*. N.p., n.d. Web. 7 Apr. 2013.