Radar for the Blind

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***Abstract*—This paper document proposes a low cost solution for integrating ultrasonic sensors onto a white-cane and a hat, enhancing the detection capability of the visually impaired by providing haptic feedback to the user. Using the devices is made more intuitive by adding an attachment to the white-cane, a device commonly used by the visually impaired. The white-cane attachment detects objects above the white-cane while the sensor hat detects objects in front of the user.**

***Index Terms*—Emerging Technologies, Special Purpose, Microcontrollers, Radio Frequency.**

I. Introduction

A white-cane is a common device used by many people who are visually impaired. The white-cane is used for detection of obstacles while walking. However, the white-cane cannot detect objects above the user's waist. Therefore, the white-cane inhibits many users from walking independently in an unknown area. Our device in development detects obstacles above the user's waist by giving them vibratory feedback of their current environment. In this system, a white-cane attachment provides feedback to the user by detecting objects above the lower tip of the white-cane. The sensor hat detects objects in front of and to the left, and right of the user. The feedback mechanism occcurs through a glove containing vibrating motors corresponding to each sensor.

The available devices for the visually-impaired in todays market tend to be expensive, heavy, and inefficient and tend to have high learning curves. Most visually impaired people use a white cane to assist them with daily activities. The Radar for the Blind (RFB) consists of an attachement on a white cane, a hat and a glove. Many visually impaired people already know how to use a white cane proficiently. Therefore, our devices are designed to be user-friendly. Should the user decide to revert to using just the white-cane, removal of the devices does not negatively or permanently impact the white-cane.

II. System Overview

A. Hardware Components

The hardware section of the system is broken down into two parts. A lower level description of each individual component used to build the modules and a higher level description of the modules and what components they consist of.

1) Low Level Description: The system is based on the Atmega328p [1] microprocessor. The Atmega328p microprocessor is chosen over an Arduino to minimize the size of system units. The Atmega328p can run between 3.3V to 5V which also coincides with the Vcc or powering voltage for the sensors, transmitters, receiver and vibratory motors. It contains features such as two 8-bit Timers, six PWM, and eight 10-bit ADC channels, all of which are needed to interface the system components.

The sensors used are ultrasonic sensors. The sensor's beam operates at 42 kHz. The sensor's analog input can be read every 50 milliseconds (20 Hz) and the serial input runs at 9600 Baud. Although the sensor has a maximum range of 20 feet, the precision at that distance is inadequate (an 11-inch board). The sensors are used at a distance of 5-6 feet and can sense a 1-3 inches dowel. The RFB system utilizes two versions of the sensor: the EZ-4, which has a narrower beam pattern and the EZ-2 which has a wider beam pattern.

The transmitter and receiver both run at frequency of 434 MHz. They have maximum transmission speeds of 2400 bps. To keep the unit packages as small as possible, only the glove interface is equipped with a receiver . The hat and the white-cane attachment each have a transmitter mounted on it to relay sensor readings to the glove.

2) High Level Description: The glove (a thin liner) is the main user interface where sensor data is conveyed. The glove has a receiver that takes sensor data from the hat and/or the cane. Four vibratory motors are mounted on the back of the glove. Each vibratory motor varies in vibration frequecy as the user approaches an obstacle. The frequency is implemented using the PWM and timers provided by the Atmega328p microprocessors. The glove module is powered by two rechargeable 3.7 lithium batteries.

The hat has three ultrasonic sensors mounted on the left, right and center of its brim. The center sensor is an EZ-2 sensor pointed directly ahead of the user (12 oclock) to provide a wide coverage in front of the user. The other two sensors are EZ-4 sensors and pointed to the left and to the right (approximately 10 and 2 oclock) to provide peripheral feedback to the user. Overall, the hat consists of three sensors, a transmitter, an Atmega328p microcontroller, and two rechargeable 3.7V lithium ion batteries. This module calculates the distance of objects within 6 feet ahead and 6 feet on the sides of the user and to send the information back to the glove.

The white cane attachment utilizes an EZ-2 ultrasonic sensor. It is mounted on bottom of the white cane to provide upward detection. The attachment consists of a sensor, a transmitter, an Atmega328p, and two rechargeable 3.7V lithium ion batteries. The white-cane attachment calculates the distance of upward objects and sends information back to the glove.

B. Software Development

The software is being developed on a AVR Studio SP 4. The Atmega328p is programmed through the Atmel AVRISP mkII In-System Programmer. The software developed is written in C language [2] and is compiled and built into assembly to be programed into the IC.

In development, a component approach was taken. Initial testing of the components was implemented on a Arduino development board. Upon completion of unit testing verification, developement transitioned to an Atmega328p implementation. After comfirming the the components worked on Atmega328p, developement proceeded to system integration.

The control flow for the hat and the white-cane attachment modules is:

- Poll ADC values from an ultrasonic sensor.
- Convert the ADC values to an appropriate frequency level represented as a 3 bit number.
- Package that 3 bit number along with the ultrasonic sensors corresponding 2 bit motor number and a 3 bit parity into a 1 byte packet.
- Send the packet through the 434 MHz transmitter via USART communication.
- Delay an amount of time.
- Get the microcontroller to start ADC conversion on the next ultrasonic sensor on the device.
- Repeat.

The control flow for the glove attachment is:

- Poll the USART data register for a packet.
- Perform partiy check on said packet
- It parity check passes, set motor vibrating frequency to the frequency level contained within the good packet.
- Repeat

C. System Cost

Table I lists the individual costs of the items used in the system. Table II, Table III, and Table IV show the cost of the hat package, the cane attachment package and the glove packages, respectively.

TABLE I
INDIVIDUAL COST

Item	Cost
Atmega328p	$3.87
Vibratory Motors	$4.95
Receivers	$4.95
Transmitters	$3.95
EZ-2 ultrasonic sensor	$29.95
EZ-4 ultrasonic sensor	$29.95
5V Regulator	$1.99
Battery 3.7 Lithium	$6.95

TABLE II
HAT PACKAGE

Components	Qty	cost	total
Atmega328p	x1	$3.87	$3.87
Transmitter	x1	$3.95	$3.95
EZ-2 Ultrasonic Sensor	x1	$29.95	$29.95
EZ-4 Ultrasonic Sensor	x2	$29.95	$59.90
3.7 Lithium Battery	x2	$6.95	$13.90
5 volt Regulator	x1	$1.99	$1.99
Total			$113.56

TABLE III
CANE ATTACHMENT PACKAGE

Components	Qty	cost	total
Atmega328p	x1	$3.87	$3.87
Transmitter	x1	$3.95	$3.95
EZ-2 Ultrasonic Sensor	x1	$29.95	$29.95
3.7 Lithium Battery	x2	$6.95	$13.90
5 volt Regulator	x1	$1.99	$1.99
Total			$53.66

TABLE IV
GLOVE PACKAGE

Components	Qty	cost	total
Atmega328p	x1	$3.87	$3.87
Vibratory Motors	x4	$4.95	$19.80
Reciever	x1	$4.95	$4.95
3.7 Lithium Battery	x2	$6.95	$13.90
5 volt Regulator	x1	$1.99	$1.99
Total			$44.51

III. RELATED WORK

A. Tuvie

An electronic replacement for the white cane that uses a distance sensor which informs the user of detections via a bluetooth earpiece.

Disadvantages:

- Does not provide textual feedback of the ground.
- People with low vision often rely on the vibrations that the white cane produces.
- Requires the user to ”fan” or ”sweep” the sensor, causing wrist fatigue.

B. vOICe

A device that uses a live camera to convert greyscale images into sounds called soundscapes [3]. These views usually converts every second and provides an audio mapping associating height to pitch and brightness with loudness [3]. According to NewScientist, this helped several people who lost their sight at a young age to detect objects and depth again.

Disadvantages:

- Needs time to scan an image, and therefore lacks the immediacy of vision/detection.
- Requires a nearby computer to translate the information.
- The reliability of this device is also determined by the reliability of the computer.
- Listening to sounds might inhibit the user from hearing the surrounding area.
- Takes a long time to adjust to using this device.

C. Prosthesis Substituting Vision for Audition

A device similar to vOICe. The device uses a head-mounted video camera that captures images and sends it to a standard digitizing board in a computer. The computer then processes the information and produces sounds using dedicated printed circuit boards. The sounds are then outputted to headphones [4].

Disadvantage:

- Same disvantages as vOICe.

D. Israeli Radar for the Blind

Two university students have created a system which uses two video cameras and a light source to provide audio feedback [5].

Disadvantages:

- It can only scan objects on the ground much like the white cane.
- It has a limited range based on the reflection of the light source.
- May have difficulties in different lighting environments.

E. Sensor Vest

Produced by a student from North Carolina State University who put ultrasonic sensors in a vest and shirt. The sensors each coordinated to its corresponding vibrator in each part of the shirt to give feedback for which direction an obstacle is located [6].

Disadvantages:

- Uses an ultrasonic sensor that is limited to an effective distance of 3 feet.
- The weight distribution of the sensors may be uncomfortable.

IV. Theory

A. Assumptions

Some of the assumptions we make about our users are:

- User is no taller than seven feet.
- User can distinguish tactile feedback on the back of the hand.
- User is able to use a white-cane.
- User will not use our product in wet conditions.
- User is at least seven years old.

B. Sensing Range

Documentation of the sensors EZ-2 and EZ-4 show effective sensing (1-3 inch dowel) of up to six feet. The difference between the EZ-2 and the EZ-4 sensors is the beam width. The EZ-2 has a width of four feet and the EZ-4 has a width of two feet at their widest point.

C. Timing

The current baud rate of the transmitter, receiver, and ultrasonic sensors is 2400 bps. Since each packet transmitted takes up exactly 8 bits per update, the transfer rate is then 300 bytes per second, or 300 updates per second maximum. The hat, cane and glove are a 2-transmitter-1-receiver system. There is no effective way to synchronize the two transmitters because there is no way of indicating when the user turns each device on. To generate alternating transmissions for the two transmitters, the transmitting times were offset to 7 milliseconds and 13 milliseconds for the hat and the cane, respectively. Prime numbers are chosen to guarantee a certain window of time during which one device is transmitting and the other is not. However, most of the time invalid data is recieved due to mixed signals of the same frequency.

$$BAUD = f/[8*(UBRRn+1)] \tag{1}$$

- f - microcontroller oscillation frequency.
- UBRRn - USART Baud Rate Register containing a hex value that corresponds with desired baud rate.

D. Filtering Methods

The RF receiver is subjected to noise interference and attenuation at 434 MHz. Amplification of the signal is not implemented because it is too costly in terms of money and battery power. Noise is filtered via parity check and immediately discarded in order to optimize processing speed. There will also be some noise on the analog output of the ultrasonic sensor. This will be rendered less significant by taking an average of 10 analog output values per transmit update.

V. Testing

A. Product Test Plan

Testing is conducted in three phases: Unit Testing, Integration Testing, and Acceptance (System) Testing. In Unit testing, the function(s) of each hardware that is planned to be implemented in the system is verified and noted. Test description is summarized below.

Subsequent to Unit Testing, Integration Testing ensued to ensure proper integration of the modules, ultimately resulting in development of a functioning system (prototype), i.e sensors, motors and wireless communication. Results of the Integration Testing are summarized in the Unit Testing Summary section.

Integration Testing is followed by Acceptance Testing. Acceptance Testing remains in progress and is expected to be completed in the middle of Spring quarter 2011. Unit Testing Summary section shows the results of the Acceptance Testing. This section will be gradually updated until completion of the final product.

These three testing phases provide great confidence that the final product will function in accordance with our Marketing and Engineering Requirements. However, functionalities of the systems (cane, hat and glove) are only guaranteed when the systems are operated in accordance to the Users Manual.

B. Unit Testing Summary

1) Sensors: Before committing to the EZ-2/EZ-4 ultrasonic sensors, the sensors are tested to detect object of at least six feet away. Results of the test are shown in Table V. The first column lists the distance of the object from the sensor being tested. The second and third columns lists the measured outputs from the EZ-2 and EZ-4. The measured outputs from the sensors is converted fromt digital to inches using equation

2. In the sensors test, a cardboard box and a tape measure are used as obstacles.

$$Y(inches) = 1.0 * (ADC)/1024 * 5 * 1000/9.8 \quad (2)$$

- Y - converted sensor output in inches.
- ADC - digital sensor output.

TABLE V
SENSORS TEST RESULTS

Distance (ft)	EZ-2 Output (inches)	EZ-4 Output (inches)
1	12	12
2	23	40
3	34	50
4	47	55
5	57	57
6	69	69

2) Vibratory Motors: The four vibratory motors are tested by mounting them in t-formation on a glove. The vibration as well as the rate of pulsation of the motors are detected by one hundred percent of the seven-plus-year olds participating in the testing.

3) Atmega328 AVR Microcontroller: The microcontroller used in the system is the Atmega328p AVR microcontroller. Its computational functionalities are verified by programming it to output 5 volts on all its possible output pins. A Multimeter is used to measure 4.98 volts on the output pins.

4) Wireless (RF): An Arduino programmer was used to program the transmitter to transmit a packet and the receiver to receive a packet. A LCD was used to display the received packet which served as verification for successful wireless transmission. Test results show successful implementation of wireless communication between the hat microcontroller and the glove microcontroller.

C. Integration Testing Results

TABLE VI
INTEGRATION TESTING RESULTS

Integration Test	Pass	Fail	Comments
Sensors-Atmega328	X		Scanned varying objects
Motors-Atmega328	X		Vibratory patterns generated
Wireless-Atmega328	X		Transmitted/Recieved packet
Sensors-Motors	X		Corresponding Motor(s) vibrated
Cane-Hat-Glove	X		Prototype functioned as needed

D. Acceptance Testing Result (In progress)

System testing is to be completed near the end of Spring quarter of 2011.

VI. CONCLUSION

In todays market of Electronic Travel Aid [7] (ETA), existing devices are either expensive (vOICe), heavy, or uncomfortable to wear (Sensor Vest) or prevent the use of a white-cane (Tuvie). The 'Radar for the Blind' (RFB) is inexpensive, light weight, comfortable to wear, and it does not prevent the use of a white-cane. The RFB consists of three modules: a hat sensor, a white-cane attachement, and a glove.

The hat sensor and the white-cane attachment are the sensing modules of the RFB while the glove provides haptic feedback to the user. Ultrasonic sensors, Atmega328p microcontroller, vibration motors and RF transmitters and receivers are used in the system. The use of these hardwares provide the system to be low cost eliminating financial burden to consumers. These hardwares also allow the system to be lightweight and comfortable eliminating wrist fatigue and other possible discomfort potentially resulting from using heavy ETA for long periods of time.

The RFB is designed to provide visually impaired people with obstacle detection above the waist, to the front and sides while maintaining it to be a user-friendly device. The design of placing a sensor on the tip of the white cane allows the system to detect obstacles above the waist and to minimize the carried weight when the white-cane is used via rolling technique. Attaching sensors on the center, left and right of the brim of the hat allows the RFB forward and side detections. Lastly, wireless communication between the modules is used to make the system as discreet as possible. Unit and integration testing results are evidence that the 'Radar for the Blind' is a feasable system that can enhances the detection capability of the visually-impaired.

VII. ACKNOWLEDGMENT

Embedded Innovations would like to thank Professor Lupo for providing us with the necessary guidelines to complete our Capstone and Senior Project.

We also would like to thank QL+ for funding this project and for their continuing support of the team.

Embedded Innovations would like to thank the following persons for giving the team their time, answering the teams questions, and providing the team with useful informations.

- Jennifer Allen-Barker - Disability Resource Center, Cal Poly.
- Professor Mase, Tom - Mechanical Engineering Faculty, Cal Poly.
- Professor Oliver, John - Computer Engineering Faculty, Cal Poly.

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