EYE CONTACT

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Abstract— Our primary aim is to aid free and fearless movement of the visually challenged in seemingly unknown environments. Our device which will assist the blind in averting obstacles by the use of sensor-vibration feedback mechanism. The objective is to make a cost effective, user friendly and compact device, which can drastically alter the locomotion of the visually impaired by making it dynamic. The device would help identify obstacles ranging from individuals approaching the user as well as inanimate objects which are normally out of the purview of conventional mobility aids by providing feedback from vibrating motors based on the data collected by positioning devices, such as GPS, digital compass and ultrasonic sensors. In spite of a considerable range of mobility aides already available in the market and intensive research on the same, the instances of they being successful in areas are scarce. Hence, we aspire to make to a device which can be affordable to the masses along with being efficient.

1. Introduction

1.1 Project topic.

This project is about a special garment, equipped with detection sensors, positioning sensors and feedback actuators. The intent is to help people with vision problems to avoid obstacles and reach a predetermined location, helped with all the embedded components on the shirt.

1.2 Project motivation.

The project was born from an old device we knew, that was using the motors to guide cyclists to a desired address, also taking measurements of the breathing volume of the athlete to track his performance. Based on that, we started to ask ourselves how could we make it a helpful tool, and solve an actual problem in our society.

Many people suffer from serious visual impairments, preventing them from travelling independently. Accordingly, they need to use a wide range of tools and techniques to help them in their mobility. One of these techniques is orientation and mobility specialist who helps the visually impaired and blind people and trains them to move on their own independently and safely depending on their other remaining senses. Another method is the use of guide dogs which are trained specially to help the blind people on their movement by navigating around the obstacles to alert the person to change his/her way. However, this method has some limitations such as difficulty to understand the complex direction by these dogs, and they are only suitable for about five years. The cost of these trained dogs is very expensive, also it is difficult for many of blind and visually impaired persons to provide the necessary care for another living being.

To overcome the above-mentioned limitations, this work offers a simple, efficient, configurable electronic guidance system for the blind and visually impaired persons to help them in their mobility regardless of where they are, outdoor or indoor. The originality of the proposed system is that it utilizes an embedded vision system of two simple ultrasonic sensors and brings together all reflective signals in order to codify an obstacle through gumstix. Furthermore, the user of the system does not need to carry a cane or other marked tool. It has high immunity to ambient light and colour of object. It has typical response time about 39 ms, and it is very suitable for real-time applications.

As a part of the development of this device, we have also studied the various other electronic devices that have been developed along the years to improve the locomotive ability of the visually challenged. The study of these devices, their working principles and limitations has provided valuable insights on how to make an efficient and user-friendly device which boosts the self-confidence of the visually challenged user. There have also been several research papers on related topics such as analysis of the vibro-tactile feedback information (refer to the References section) which will serve as guidelines on developing this device.

1.3 Project main components.

To achieve this goal, we first added **Ultrasonic Sensors**, to give the user a tool to detect obstacles and avoid collisions with objects or other people on the street. We also used a **GPS** module and a **Digital Compass** in order to enable the user to do outdoor navigation through positioning features. The garment is also supplied with 4 **vibrating motors**, that are giving the feedback from the sensors we exposed before. 2 motors are located at the front, advising for obstacles, and 2 motors are located at the back, guiding the user through their path. Everything is controlled by a **Gumstix-Verdex** board through *GPIO* pins (Motors and Ultrasonic sensors), *USART* (GPS module) and I^2C protocol (Digital Compass).

1.4 Results.

We managed to interconnect every module of the system with the Gumstix board. The device successfully detect obstacles with the ultrasonic sensors and give the feedback through the haptic motors. Also, we interfaced both, the GPS module and the Digital Compass, with the motors, using a predetermined path we choose, and the garment is able to guide the user through this path.

2. Design Flow.

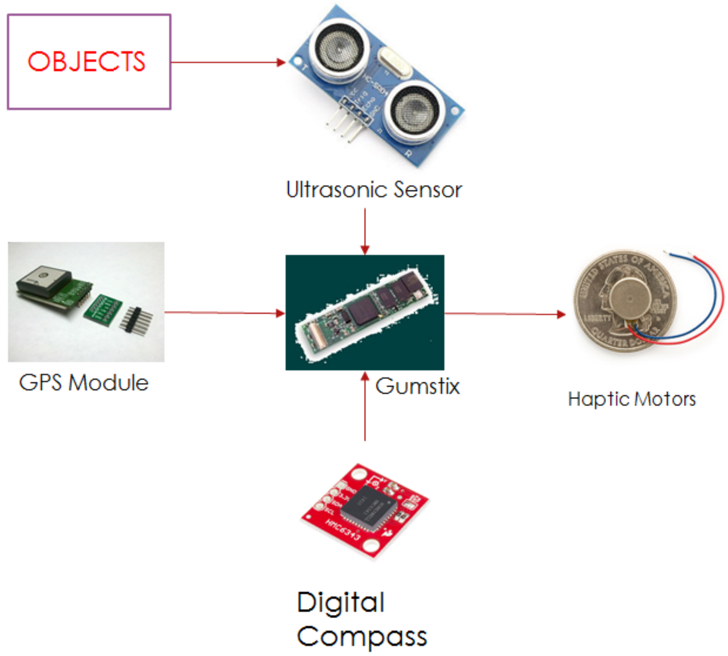

Fig. 1 - Main components of the design

The Gumstix is acting as the central device for this design, controlling the inputs and outputs of every element of the circuit as follows:

The obstacles were detected by the ultrasonic sensors which are sending the information through the GPIO pins. The GPS module gets the coordinates and sends the data through the USART communication port. The digital compass is in charge of sensing the direction accurately, it sends the data to the gumstix through the I^2C protocol. And finally, the feedback to the user is given by the haptic motors, controlled by the Gumstix through 4 GPIO pins.

To successfully implement the basic functionality of our project, we divided the tasks into 3 sub-activities, that were performed for each one of the team members as explained below.

Anurag: Positioning implementation. GPS module and UART communication. Digital Compass and I^2C communication. GPS module data recollection. Kernel module for parsing GPS and digital compass data.

Juan: Hardware design and implementation. Components interconnection. Digital Compass and I^2C communication. GPS module data recollection.

Nirmit: Software implementation. Kernel modules and User level applications to interface ultrasonic sensors and motors with the Gumstix. GPS module data recollection and implementing the GPS-motor algorithm.

3. Project Details

3.1. GPS Module & Digital Compass

GPS Module: We are using the Parallax PAM-7Q GPS module which integrates the uBlox PAM-7Q GPS device and the antenna for the device. The module is shown below:

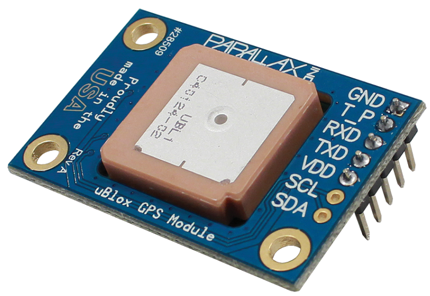

Fig. 2 - Parallax PAM-7Q (GPS Module)

Parallax PAM-7Q is a very capable device having an accuracy of less than 2 meters, the worst case being 2.5 meters. It uses the UART protocol to send 0183 NMEA sentences with a frequency of 1 Hz to 10 Hz where 1 Hz is the default. NMEA is an acronym for National Marine Electronics Association which specifies the standard for all GPS receivers. Our GPS receiver sends not only the position fix, but also the time when the position fix was taken, the number of satellites in view, altitude in meters above the sea - level and other relevant information pertaining to navigation. An example of the NMEA sentence format is given below:

$GPGSV,1,1,04,05,34,214,26,10,78,117,32,12,42,265,21,17,25,131,33*71
$GPGLL,4222.94367,N,07107.23368,W,161838.00,A,A*7A
$GPRMC,161839.00,A,4222.94326,N,07107.23337,W,0.746,,101114,,,A*6C
$GPVTG,,T,,M,0.746,N,1.382,K,A*2E
$GPGGA,161839.00,4222.94326,N,07107.23337,W,1,03,2.60,65.1,M,-33.1,M,,*58
$GPGSA,A,2,05,10,12,,,,,,,,,,2.79,2.60,1.00*0D

The module sends this type of information to the Gumstix controller every 1 Hz in our project. As you can see we have to parse this information to get the latitude and the longitude fix. The data has a number of identifiers after the ‘$’ sign that specify the information contained after that identifier. For instance GPGLL gives us detailed information about the geographic position, the time the fix was taken and whether or not the data is valid or void. In the example above the first characters after the GLL identifier and before the ‘N’ character gives us the latitude information. In this case the latitude is 42 degrees 22.94367 min N. The next entry gives us the longitude information 71 degrees 07.23368 min W. Further parsing of the data reveals the time the fix was taken and whether the data is valid. The flag A indicates the data is valid and the characters after this flag gives us the checksum information. The control characters that terminate the above string which are not visible and can only be viewed by an hex editor are '\r' and '\n'. Thus, we decode only the GLL field in the program and extract the latitude and longitude data. To make sure if the data is valid we check the 'A' flag every time we extract information. The PAM 7-Q module transmits data at a predefined baud rate of 9600 and includes 1 stop bit, 8 data bits and no parity bit. As this module uses UART communication protocol we have to set up the Gumstix controller to receive characters from this module as per its standard. One peculiarity of this module is that it transmits strings containing the ',' character when it is not receiving the correct data and when it does receive the correct data the LED on the board starts blinking. This provides a good feedback of the time to start collecting the GPS data as we don't want garbled information. An example of bad data is: $GPGLL,,,,,161710.00,V,N*4A. Notice the V flag in this data. This indicates that the data is invalid. This module can also communicate using the I^2C communication protocol but we save the I^2C function pins for the digital compass which is discussed next.

3.2. Digital Compass

We are using the HMC6352 digital compass to obtain orientation information. A picture of the digital compass is as:

Fig. 3 - HMC6352 (Digital Compass)

The digital compass uses the I^2C communication protocol or the two wire interface to communicate with the Gumstix. The digital compass transmits at a fix baud rate of 100 kHz. The two-wire interface is very convenient for this device as the compass transmits orientation information in tenths of degrees from 0 to 3599 in two bytes, most significant byte first. We use the Gumstix in the master mode and this device becomes the slave. The Gumstix issues commands and generates the clock and this device acknowledges the commands issued by the gumstix and then transmits appropriate information. To initiate communication with this device we use its 7 bit slave address and the read or write bit to indicate whether we are reading from or writing to it. The default address for the write is 0x42 (write = 0) and the address for the read is 0x43 (read=1). The gumstix transmits the command for obtaining the offset from the true north in degrees every time the application demands and this device acknowledges the request and transmits back its readings in two bytes. This device has a number of modes and we make use of only a select few modes. Before describing the modes, the commands to configure the modes that are used are described:

- Command byte 0x77 writes to the EEPROM of the digital compass. This is used in conjunction with the address of the EEPROM and the data byte to be written to this address. The data byte is usually the operation mode of the compass.

- Command byte 0x41 gets the data in two bytes transmitted over the SDA line. This byte is extensively used as we want the orientation of the person on demand by the application.

The byte that is written to the EEPROM address byte is to set the operational mode.

The HMC6352 has three operational modes: 1) Continuous mode, 2) Query mode and 3) Standby mode. The standby mode is the default and we use that as well in our project. We planned on using query mode where we don't have to issue commands to the digital compass and issue reads on the fly. There is a caveat to this mode as we won't get accurate measurements because the digital compass performs a measurement soon after it finishes transmitting the previous measurement. We thus went for the standby mode. The continuous mode performs continuous sensor measurements at rates of 1 Hz, 5 Hz, 10 Hz and 20 Hz. We decided against going for this mode as it would be consuming a lot of power and updating its internal registers with the measurements even when the application was no longer using it. Hence we selected the standby mode after taking into account all these considerations.

The Gumstix uses polling instead of interrupts to communicate with the digital compass, making use of its sophisticated I^2C interface. As the data rate of the I^2C protocol is 100 kHz and the baud rate of the UART is only 9600 and we need to append the data at the end only after getting the valid coordinates we use polling instead of an interrupt-driven mechanism. The gumstix issues appropriate commands and waits for the acknowledgement from the slave (device), after getting the acknowledgement the slave performs the sensor measurements and transmits the data to the master (gumstix).

3.3 Motors and Ultrasonic sensors

Ultrasonic sensors (also known as transceivers when they both send and receive, but more generally called transducers) work on a principle similar to radar or sonar which evaluate attributes of a target by interpreting the echoes from radio or sound waves respectively. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object.

A motor is the mechanism by which a control system acts upon an environment. The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), or a human or other agent.

Implementation of Motor in Our Project:

- Providing haptic feedback on the event of object detection by the ultrasonic sound sensor.
- Customization of Vibration intensity as per the needs of the users by varying the motor speed.
- Reducing the weight of the device to make it convenient while also increasing its wearability.
- Syncs with GPS module to show direction and position.

Here, is the algorithm which we used for ultrasonic sensors and motors. We used two PWM pins to configure them motor for different speed. The table below explains the motor algorithm.

Object Distance(in inch)	Pulse width(us) (147*Object Dist)	Motor Intensity(On the Shoulders)
1-7	809-1000	Very High
7-18.	1029-2646	Very High
18-37	2646-5439	High
37-50	5439-7350	Medium
50-78	7350-11466	Low
>78	>11466	Motor Off

Fig. 4 - Algorithm table

3.4. Circuitry

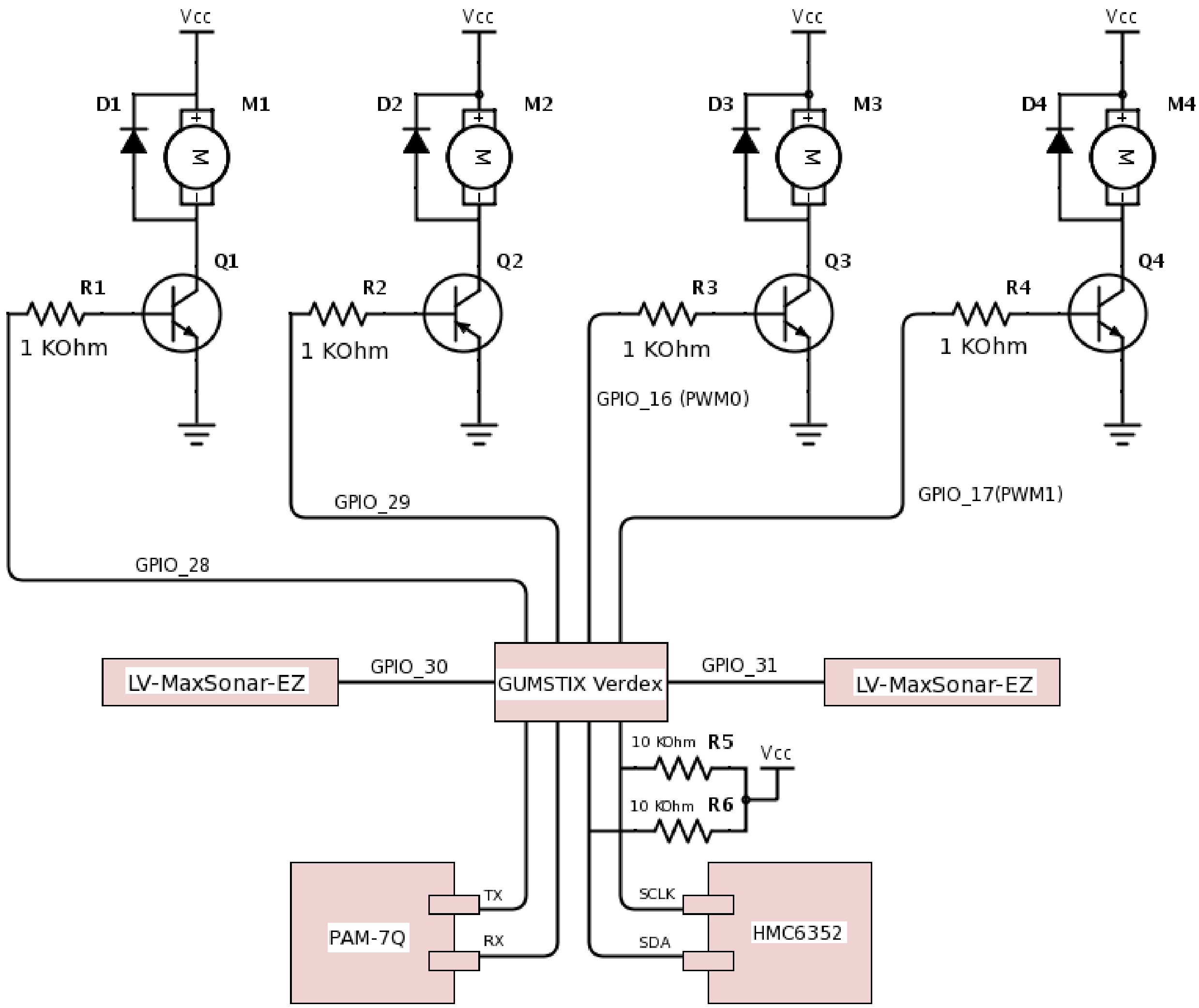

Fig. 5 - Hardware Schematics

The hardware is connected as shown above. All the motors are interface by 4 BJT transistors, acting as switches, to avoid the damage on the Gumstix pins because of overcurrent. Also, clamp diodes were implemented, in order to avoid damage for an inverse current coming out of the motors.

Out of the 4 motors, 2 are going at the back of the user, to give the feedback coming from the positioning modules. These motors are controlled by the Gumstix through GPIO pins 28 and 29. The other motors are positioned at the front of the user, giving the feedback from the ultrasonic sensors. These motors are controlled by the PWM signals from the gumstix (PWM0 & PWM1).

The ultrasonic sensors build a PWM signal, proportional to the distance of the object detected. We measure the pulse width of this signal using interrupts, and then convert this to distance through the code. The signal goes into the Gumstix through GPIO pins 30 (left sensor) and 31 (right sensor).

The GPS module, is providing the positioning coordinates, and we interfaced it through the USART module available at the Gumstix. TX from the PAM-7Q module goes into GPIO_46 at Gumstix (RX) and RX from the PAM-7Q module goes into GPIO_47 at Gumstix (TX).

The digital compass was implemented to give support to the GPS module, having a better and more accurate position information. Also, we need to handle the how many degrees should the user turn when it faces a corner for example, and it need to turn to the left or right. We achieve this precision with the digital compass. SCL from the HMC6352 module goes into GPIO_117 at Gumstix and SDA from the HMC6352 module goes into GPIO_118 at Gumstix.

Once the whole system was assembled, we implemented a 9 volts battery with a voltage regulator of 5VDC (LM7805), to be able to use the garment without AC outlet connection.

3.5 Algorithms

The algorithms are explained as comments in the source codes. (see mygpio.c, nirmit_mygpio.c for further details)

4. Summary

After interconnecting all the components and interfacing them with the Gumstix, we started to do the testing part. The first part of the testing was the obstacle detection. When the device encounters an obstacle on the right side of the user, the right motor is going to vibrate proportionally to the distance of the obstacle. We achieved to do this for both sides of the garment.

Once we had this done, we started getting data points with the GPS and the digital compass outdoors. We picked a fixed path for testing, and we took all the data points possible within that path, to compare it later with the real-time measurements. We also managed to get this task ready to use.

Our final milestone for this project, at this stage, was putting everything that have been done together. At the end, we basically read the real time-data at the moment of using and we compare this data, with the fixed path we previously set. The device is able to follow the path with an accuracy of approximately 3 meters.

For the next steps we would like to interface the system with a well established navigation system, like Google Maps, so instead of following the path of fixed addresses, we could set different directions, and the garment would be able to get you there.
Also, we would change some of the components in order to get a better accuracy of the measurement. The GPS module, only gives us an accuracy of 2-3 meters, we might find a different module with a smaller range of precision. And for the Digital Compass we used, the HMC6352, we can replace it with another digital compass with tilt compensation, because, despite we getting very accurate readings from this sensor, if it is not parallel to the ground, thus the readings are not very precise.

Hardware Challenges

- Limiting the measuring angle of the sensor and controlling it.
- Our device has a drawback of overlapping ultrasonic detection region of the left and the right sensor. If this is not solved, the detection range will be full of ambiguity and result in inaccurate detection and blind spots.
- Hence it is imperative to solve this by orienting the sensors in different directions and then testing the device.
- Weather limitations of the sensor.
- In all terms, the ultrasonic sensor beats the conventional sensors like IR, and laser by the virtue of it being robust, cost effective.However, we still have to test the strength of the ultrasonic sensor in extreme environmental conditions.
- Battery.
- In order to make our device lightweight and long lasting, we have to explore different power supply options and test it on our circuit.

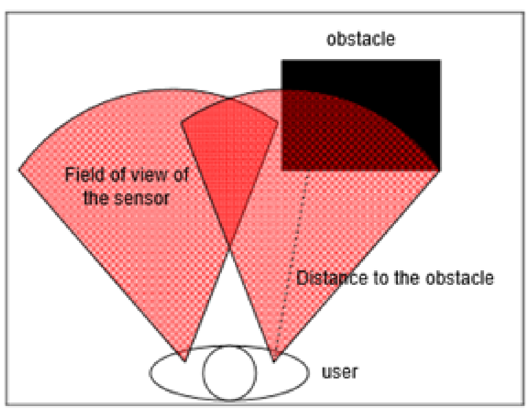

Fig. 7 - Overlapping scheme

Software Challenges

- Eliminating the doorway conundrum.
- One of the major drawbacks of our device is that it will vibrate vigorously while the user is passing through a doorway.

- Introducing Energy Saving Algorithms and Sleep mode.
- For the device to last longer than two hours of continuous operation we need to effectively incorporate the sleep mode into the program.

5. References

1. Intel PXA27x Processor Family Developer's Manual, October 2004.https://learn.bu.edu/bbcswebdav/pid-2683404-dt-content-rid-8893066_1/courses/14fallengec535_a1/Intel_XScale_PXA27x_Developer_manual.pdf
2. PAM-7Q GPS Module (#28509), http://www.parallax.com/sites/default/files/downloads/28509-PAM-7Q-GPS-Module-Product-Guide-v1.0_1.pdf
3. Honeywell Digital Compass Solution HMC6352, https://www.sparkfun.com/datasheets/Components/HMC6352.pdf
4. http://www.robotica-up.org/PDF/Wearable4Blind.pdf
5. http://www.cs.cmu.edu/~iwan/papers/guidecane.pdf
6. http://www.ee.hacettepe.edu.tr/~alkar/ELE414/dirz2005/wpic%5B2005%5Dprint.pdf
7. Microsoft Word - Wearable-Velazquez2 - Wearable4Blind.pdf
8. Ultrasonic ensor - ultrasonic-sensors.pdf
9. Vex Ultrasonic Sensor Interfacing and Programming Vex Ultrasonic_Tutorial_Rev3.pdf
10. HC-SR04 Datasheet
11. Microsoft Word - Wearable-Velazquez2 - Wearable4Blind.pdf
12. http://www.futurlec.com/TR40-16OA00.shtml
13. http://www.ultracane.com/ultracanecat
14. Obstacle Detection Gadget for Visually Impaired Peoples.pdf
15. http://research.microsoft.com/pubs/180050/chi2013-vizwiz.pdf
16. http://www.cim.mcgill.ca/~haptic/pub/VL-CIM-TR-05.pdf
17. http://infoscience.epfl.ch/record/99014/files/haptex05.pdf
18. http://www.designbuzz.com/10-gps-navigation-devices-guide-visually-impaired/
19. http://www.iitd.ac.in/research/Smartcane_Press_release_29_June.pdf