Orbit : Hands-Free support for the Visually-Impaired

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Project 25

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Introduction

Objective

We propose to make daily life easier for the visually impaired by creating a device that enables them to sense their environment via ultrasonic sensors. In order to make the project appropriate for ECE 445, we think that it should be hands-free, allow 360 degree obstacle detection, and be as non-invasive as possible. In the event that our subsystem PCB design is not sufficient for ECE 445, we will use an off-the-shelf microcontroller for testing, but design our own peripherals and solder the microcontroller chip onto it after we are certain that the microcontroller meets our requirements.

This device will be secured onto a vest, allowing friendly use. The user will then be able to know which direction the nearest object is through an audio subsystem feedback. This requires using a pair of open-ear headphones and circuitry that will be able to create a tone that gives meaningful information to the user regarding the how far he or she is from objects and people, as well as the elevation.

Background

According to the World Health Organization there are roughly 253 million people in the world who are visually impaired, of which 36 million are blind [1]. The most commonly used aid is the walking cane, but it has its limitations. The cane keeps one arm engaged and has a limited range. It can also be tiring to carry and may not provide extensive information about the objects in the user's path. The cane only signals the user that an object, usually near the ground, is present. But it does not provide information about objects above ground or people behind the user. Previously people have come up with solutions to this problem in this class.

Our proposed solution is to use ultrasonic sensors mounted on a vest to allow a blind person to detect objects nearby and ground elevation. Since we are placing the sensors on the front side and back side of the vest, the sensing range will not be quiet 360 degrees. The device will, however, alert the user of the presence of objects in front and behind the user. The feedback mechanism we are pursuing is open-ear headphones. We will create the circuitry necessary to create the audio tones with an intuitive protocol indicating to the user how far objects are. Currently we are thinking that if we encode information about distance onto the amplitude of the audio signal (louder tone as people get closer/user moves closer to objects and vice versa). We must make the audio directional in order for the audio controller to perform its job correctly. We must design an audio controller that receives sensor echo data from the microcontroller (through a DAC) and amplify it, filter it, and implement a stereo sound such that what the user hears gives him or her a sense of direction of the obstacle.

Our project combines some of the most notable features of the previously designed solutions. Specifically the idea of using an audio circuit in project "Blind Eye" and the idea of using ultrasonic sensors and a vest from "Ultrasonic Spatial Awareness Device for the Visually Impaired". This gives us the chance of reducing the weight and size of the vest by using audio circuits and microcontrollers instead of haptic feedback.

High-level requirements

If successful, the device should enable the user to maneuver around objects in any direction without the need and use of sight. The device should detect objects around the user, providing roughly a 360° view, and the detection range error should not exceed 5 inches. At the moment we are planning to detect objects within a 1-2 meter radius of the user. Considering that there is a tradeoff between continuously notifying the user about objects that aren't in vicinity and safety, we will perform extensive tests to fix the range. For now we want it to detect objects within a 1-2 m range.

- Detection Range Error < 5 inches
- Effectively covers front and back views (120 degrees horizontal on each side)
- Detect objects within a 1-2 meters range

Block Diagram

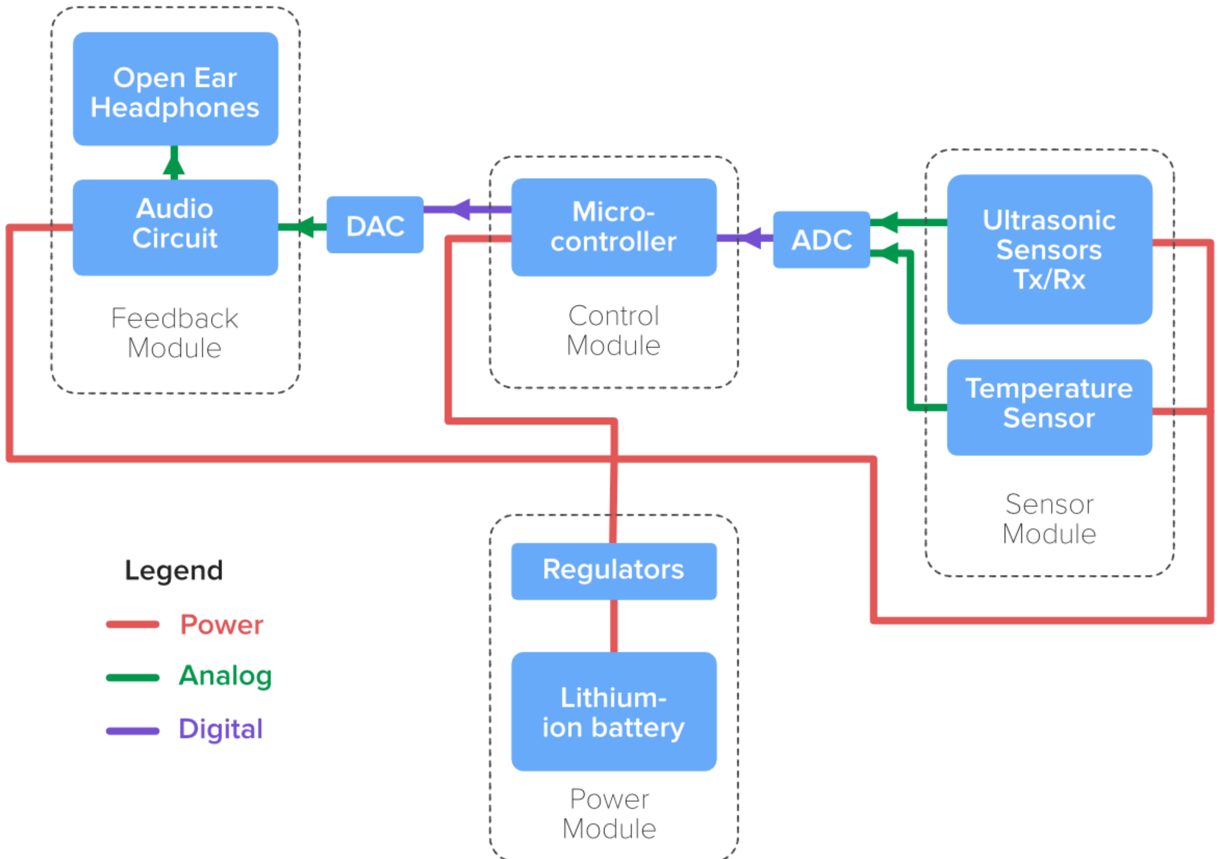

Figure 1: Block Diagram of the Project

To turn on the device and use it, the sensors must calibrate first. For this purpose, the system will include a calibration routine that can be triggered by a button. This routine will be able to calibrate each sensor (on the order of 40 ms per sensor, may need to calibrate serially to avoid interference) using the microcontroller. Additionally, the microcontroller will be responsible for sending the trigger voltage signals to the sensors in the correct sequence for sensor ranging. The decision on the particular method will be discussed. Once the sensors send their pulses and receive the echo, the data will be sent to the ADC chip and then to the microcontroller where the digital signal processing can take place. Using mathematical formulas we can determine the distance from the object. Additionally, we will add a temperature sensor to the system so that the microcontroller can receive the temperature data and re-calculate the speed of sound more accurately.

Our current idea for creating directional tones is to program the microcontroller so that Once the distance has been calculated in the microcontroller, it would then send information about distance and direction to the audio circuit. We will need to determine how exactly the audio controller would create such directional tones.

An efficient method for the sensor ranging process would be to dedicate two separate state machines to each set of sensors; one set at the front and one set at the back since there will be no significant interference between the two sets unless the user is in a very tight, closed space. If that is the case, we could implement an algorithm that detects this situation and starts the ranging process serially between all of the sensors.

Physical Design

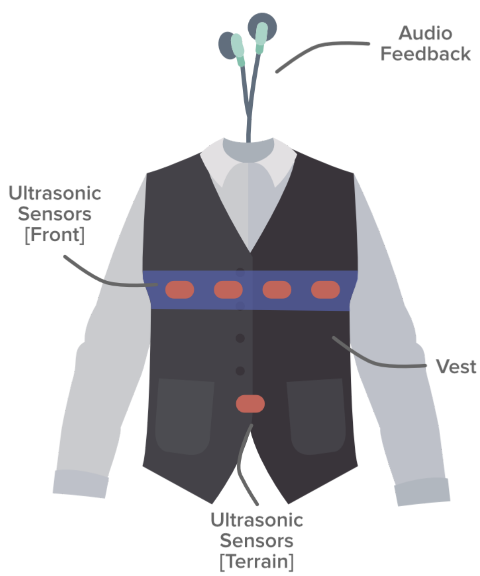

Figure 2: Front Side View

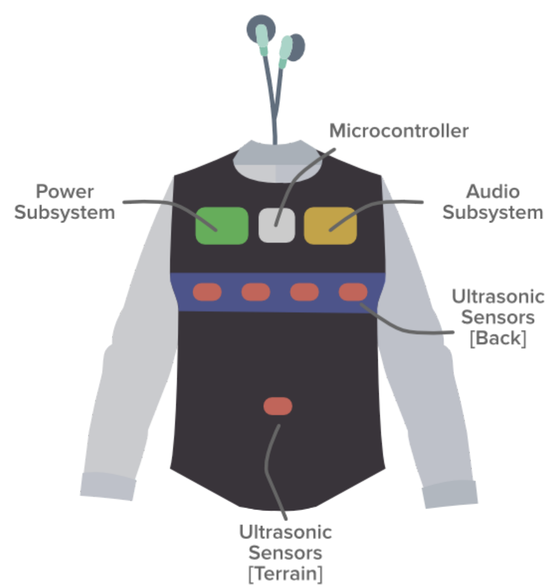

Figure 3: Back Side View

The device would be laid out on a vest as shown in the figure above. The user will wear this like any other vest thus making the process intuitive. The ultrasonic sensors will be mounted on a harness structure. There will be four sensors facing each direction - front and back to provide roughly a 360° view. There will be two more sensors pointing downwards to monitor change in terrain. The power subsystem and the audio subsystem would be installed on the back of the vest. The feedback will be provided through a pair of open-ear headphones.

Functional Overview

Block Requirements:

Ultrasonic Sensors: Each sensor must be able to measure distance from an object within a 30 degree azimuth and be sensitive enough such that the error is in the range of 1-5 inches. Each sensor must be small enough such that nine of them can fit comfortably on a vest.

Temperature Sensor: Must be able to measure ambient temperature within $\pm 1° C$ tolerance. It is crucial to have an accurate measurement of temperature since the error would propagate into the calculations involving the speed of sound, leading to an error in the calculated distance between the sensor and the object.

Microcontroller: The microcontroller must be able to allow analog input for each sensor, interface with a memory system, and transfer data to the audio controller. The microcontroller will need to operate at 3.3V. Overall latency in the system could become a problem in terms of the time where the first ultrasonic pulse is transmitted and the time when the correct directional tone is produced by the audio controller and heard on the headphones. If we divide the maximum detection range of 2 meters by the average human running speed, we find our maximum allowed latency from the very first procedure to the very last. This means that the **minimum** latency should be $(2m)/(12.52m/s) = 0.159\ s\ =\ 159\ ms$. This would be the safest tolerance but realistically a visually impaired person would not be running at the average human speed while on the street or in a crowded place, therefore this relaxes the latency constraints a bit. The average walking speed of 1.4 m/s on the other hand would give a **maximum** latency of

$(2m)/(1.4m/s) = 1.428\ seconds$. This means that our latency should be in the 159 ms - 1,428 ms range.

Audio Controller: We must design an audio circuit that performs the necessary functions for providing the directional sound information to the user. This will involve amplification and filtering of input signals from the ADC. By feeding digital trigger signals from the microcontroller to the audio controller the audio controller can generate its own directional tones and after the required amplifier stages and filtering, it can then output the sound to the headphones.

Power Module: Composed of a set of voltage regulators and a place to insert a standard 9V battery. We think that if we integrate all of the power components onto one PCB design, it will help with modular testing and decrease the chance of failure of other components once the time for integration comes. On the other hand, the trade-off would be that the failing of the power module would disable all other modules and the Nyquist-Johnson noise from longer wires could degrade our audio signals and figures of merit such as power supply rejection for the audio amplifiers.

Risk Analysis

The potential error introduced by the ultrasonic sensors causes the greatest risk. If the error is a few feet, then the user can accidentally walk into objects and harm him or herself. Handling the data through the microcontroller will not be as great of a risk since signal propagation occurs at electronic speeds. The reliability of the ultrasonic sensor data, however, will depend mainly on air temperature and wind speeds, both of which are outside of our control. One way to mitigate this risk would be to use a temperature sensor and re-calculate the speed of sound using the microcontroller.

Ethics and Safety

According to the IEEE Code of Ethics we need to be honest and realistic in stating claims [2]. Our project aims to provide easy and hands-free navigation to the visually impaired and while it is an ethically sound idea, the safety of the user is paramount. Given the short 16 week duration of the project, it is not recommended that the device at this stage be used as a primary means of navigation by the visually impaired.

In addition to that there are notable risks involved with wearable electronic devices that we need to acknowledge. In accordance with the IEEE Code of Ethics we must promptly disclose factors that might endanger the public [2]. Malfunctions of the power subsystem would arguably be biggest risk involved in our project. To make sure that there are no potentially hazardous issues with the power subsystem we will provide liquid Ingress Protection level 3 against spraying water.

References

[1] “Visual impairment and blindness fact sheet,” World Health Organization, Aug. 2014.

[2] “IEEE code of ethics.”