soniCane

(A High-Tech version of the long white cane)
microMedic 2013 Contest, Entry #micro13SL251

Introduction

In the USA Network drama series "Covert Affairs," Christopher Gorman plays August Anderson, an ex-Army officer blinded while on a mission in Iraq.

Even though he is still grieving his injury, he doesn't let it slow him down. Auggie cruises the fictional halls of CIA headquarters with the aid of a high-tech laser cane. Alas, Auggie's cane is Hollywood magic with a guestimated cost of 5-10 thousand dollars.

Read on to see if a hobbyist with a microMedic Inspiration Kit can duplicate the features of Auggie's cane without breaking the bank.

Try this Auggie!

Concept

The blind man's cane is used to detect objects so that the operator can avoid a collision. The typical white cane is constructed chest high (55 inches) and is held in front of you. It is moved back and forth to detect objects, walls, curbs, etc. An alternative to the wooden cane is a collapsible cane. The collapsible cane can be stored more easily but is heavier and shorter than the standard cane.

The fields of robotics and automation have been trying to accomplish similar goals for years. Without a human in the loop, how can a machine detect an object and avoid it? A range of sensing systems (see table below) have been developed for object detection. They all have their advantages and disadvantages.

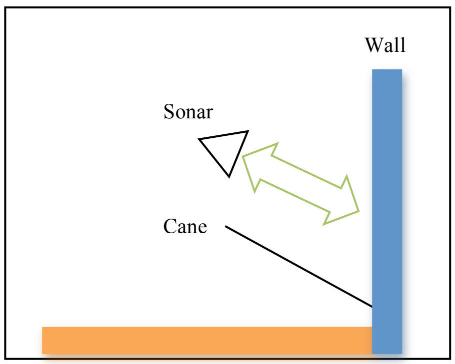
Sensor Technology	**Range**	**Cost**	**Comment**
IR	4"-30"	$10	Beware of bright light
Parallax Ping Sonar	1"-10'	$25	22mm x 46mm
Maxbotix Sonar	6"-10'	$50	22mm square, 2xParallax cost
Laser	6"-48"	$100	Expensive
uWave	8'-30'	$30	High power consumption

Object Detection Technologies

Shooting for low cost and low complexity, I came down to IR and sonar. Sonar has better range and won't have trouble operating outside in direct sunlight.

The white cane uses ~5' of wood to reach out and find an object by running into it. My sonar sensor will reach out with an invisible sound pulse that will run into that same object. (This is the same method bats and submarines use to avoid collisions.) This will make my cane similar to a collapsible cane that can be stored more easily while retaining the lightness and greater effective length of a long cane.

A computer circuit uses the sonar sensor to determine the distance to objects. As with a cane, the operator is responsible for sweeping the sensor back and forth to detect objects. When the cane strikes an object, the user feels the impact. To duplicate this effect, the computer will provide feedback when an object is electronically detected. The computer will sound a tone and cause a physical vibration so that the operator will know of the upcoming collision.



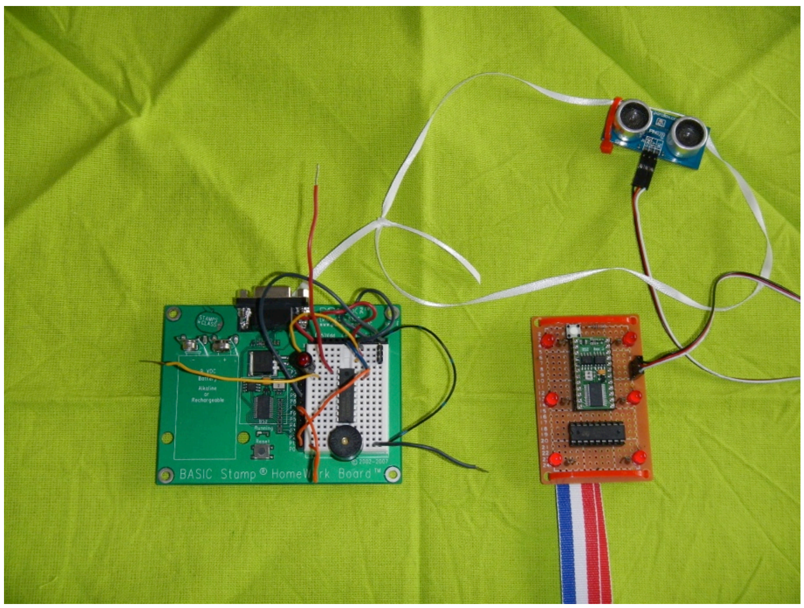
Sonar detection diagram

To help you know where the object is, the tone will vary and the vibration will change based on the proximity of the object.

Rapid Prototype

Based on the design concept, I created a quick prototype to try it out. Sorry Auggie, no high tech laser ranger ☹. While cool and glitzy, a laser range finder is bigger and more expensive than a sonar ranging system. One of the contest goals is to do things less expensively, so I chose sonar.

For a quick and easy first round of development I used a Parallax Basic Stamp BS2. (Insert shameless plug for one of the contest sponsors☺.) The Stamp connects to a sonar ranging system to determine the distance to an object. Based on the distance, an audio tone changes pitch and beeps faster as the object gets closer. In conjunction with the tone, the device begins vibrating when an object is detected. The vibration becomes more violent as the object gets closer. Computer software allows me to adjust the object detection range and the reaction (sound & vibration) of the sensor.



Rapid prototype version 1 and durable breadboard versions of my soniCane.

Mission accomplished for step 1. I can close my eyes and use the prototype circuit to navigate around my house.

Smaller, Cheaper, Better

With a proof of concept behind of me, it's time to refine my project and package it for use.

I'll address three categories as I refine my soniCane. The circuit, as you can see in the photo of the prototype, is not a customer friendly device. Just bump one wire out of place and the circuit will stop working.

The packaging of the prototype, well there isn't any. It needs to be mounted inside of something.

Once I have a portable and durable device, I can address the user's end of the product. I can refine how it provides feedback and how it is operated.

I envisioned a small handheld device for the final version of my soniCane. A small tube that is held in the hand would allow it to be used like a traditional cane, it just doesn't stick out several feet in front of you, and it fits in your pocket for storage.

I also experimented with mounting the device on a belt buckle and a hat. Look ma, no hands!

Alternate Packaging (cane, belt, hat)

I could work with each form factor. Head mounted was fun but required a dorky hat. Belt mounted required your body to move but was still hands free. The form was going to dictate packaging and component selection, so I had to pick one. I went with the cane to duplicate Auggie's Hollywood prop.

Packaging

One of the judging criteria is execution, evaluating how well your prototype is built. This called for some thought into how to package my device. A cool looking final product would be better than a clunky breadboard.

My idea for packaging has always been a hand held tube of some kind. The plastic pipe worked, but it didn't look very nice. Following that line of thought, I stuffed my parts inside an old Maglite handle. Now that looked cool and felt good in my hand. With an assembly plant, the size and shape of the tube could be reduced to something a bit smaller, but for an inexpensive demonstration, I was constrained by what was easily (and cheaply) available.

Circuit

The choice of a handheld cane directed the component selection and circuit design.

The prototype provided a proof of concept, but it's too big to hold in my hand. Additionally, the sonar sensor is awkward for a handheld device. (It worked great on a hat or belt buckle, though.) I replaced the sensor with something smaller. The new sensor could be used in any of the 3 forms though it costs twice as much as the original sensor.

The rapid prototype used a Parallax Basic Stamp (BS2.) Its size was fine for a belt buckle but didn't really fit inside my "tube." At this point, any microprocessor could be wired in and programmed to work. To avoid a total redesign, I tried the Stamp's little brother, the BS1. The little stamp is smaller and cheaper and runs similar software. A quick experiment showed that the baby stamp would work just fine and even have a little leftover capacity.

User Experience

When I started working on the user's interface, the first thing I looked at was the feedback from my cane; how can it tell me there is an obstacle in the way?

The best feedback I found was sound, an audio tone. As soon as the cane "sees" an obstacle, the cane makes noise. The sonar sensor is good for 6 inches to 21 feet. The microprocessor allows the detection range to be adjusted, which I did, because I'm not worried about something 20 feet away.

As I get closer to collision, the tone sounds faster (beep-beep-beep), and it gets higher in frequency. By sweeping the cane back and forth, I can tell the hallway from the walls. Silence means clear ahead. Beep-Beep means there is a wall there. Simple software changes can fine tune the detection distance and the franticness of the response to an imminent collision.

Wanting to mimic a wooden cane, I tried to add tactile feedback to my soniCane. The original idea was to repeat what I did with the tone, a variable feedback based on distance. This failed miserably☹. But, hopefully, I can learn from the experience and fix the problem.

To provide the feedback, I pulled the buzzer out of an old cell phone. Your phone vibrates by running a small motor that has a weight attached. The motor is unbalanced, so that when it runs, it shakes. You feel this shake and know that your phone is ringing.

I connected the motor the same way that I connected the speaker. When an obstacle appeared, the motor shook. But unlike the audio tone that seemed to give me a good perception of the range, the tactile feedback from the motor was not very good. Sure I could feel it vibrating, but I wasn't able to perceive distance with it.

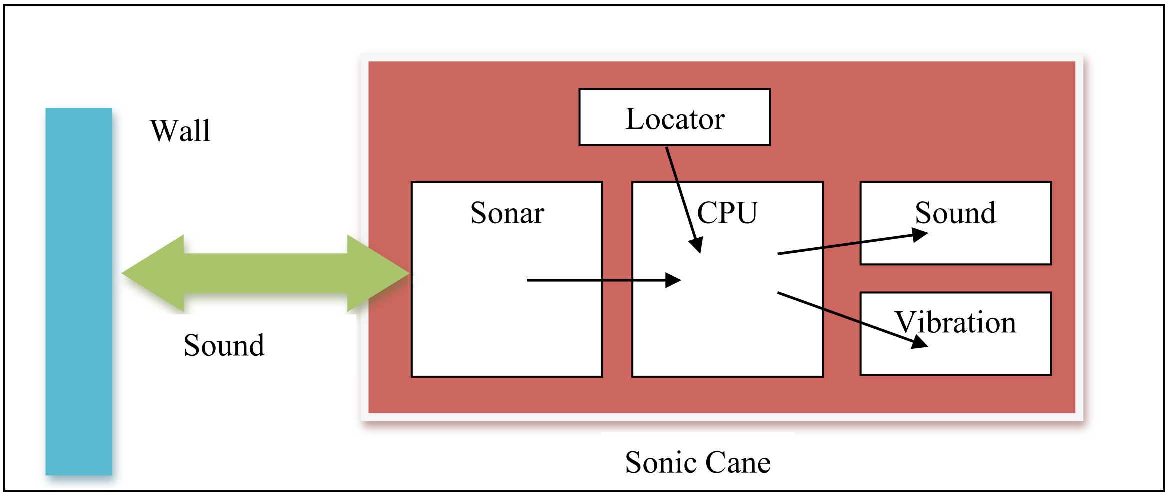
Ok, now what? Well, a wooden cane doesn't really measure distance, you just know that it hit something. Maybe I can work with that. Instead of trying to modulate the motor based on distance, what if I just turn it on when something is as close as the length of a cane! That seemed to work well. Now when the cane points at a close obstacle, it vibrates. Sweep until the vibration is gone, that is the hallway. If it starts shaking, the dog is coming down the hall to greet you. I now have a simulated white cane that fits in my pocket and allows me to navigate my home.

What happens if I lose my cane? Since it makes noise, I can find it by listening. Clap loudly once, and the cane will sound its collision alert. Reach for the sound, and you have it back.

This simple user interface seems to cover everything I need and nothing I don't. As they say, "Keep it Simple!"

Hardware

The hardware for my soniCane consists of a sonar range finder, a processor, and two feedback devices.



Block diagram

The sonar sensor is either a Parallax Ping sensor or a MaxBotix EZ4, depending on the physical size of the device and the purchase price. Both sensors return a pulse that is directly proportional to the distance between the sensor and its nearest obstacle. By measuring the pulse, the CPU can tell how far away an object is.

When I added the option of the more compact MaxBotix sensor, I choose a narrow beam width thinking that would be better. In reality the 40 degree beam width of the Parallax Ping sensor seems to perform a better job of detecting obstacles. The MaxBotix EZ2 sensor more closely resembles the Ping, so would be a better choice for future versions of soniCane.

The CPU is a computer processing element that ties the project together. A wide variety of processors could fill the requirements here. I choose the Parallax Basic Stamp because it is available as a functional module (not a chip I need to wire up), it's small in size, and it is quickly and easily programmed in BASIC, allowing for the quick creation of my prototype.

A locator can help you recover your cane if you drop it. The locator is a Sound Impact Sensor. When the sensor hears a loud sound, it outputs a signal to the CPU that can be used to generate a lost cane alert tone.

Two types of feedback are provided to the user, sound and vibration. Sound is supplied by a small piezo speaker. Vibration is supplied by a pager motor. Simple drive circuits connect the output devices to the CPU.

Software

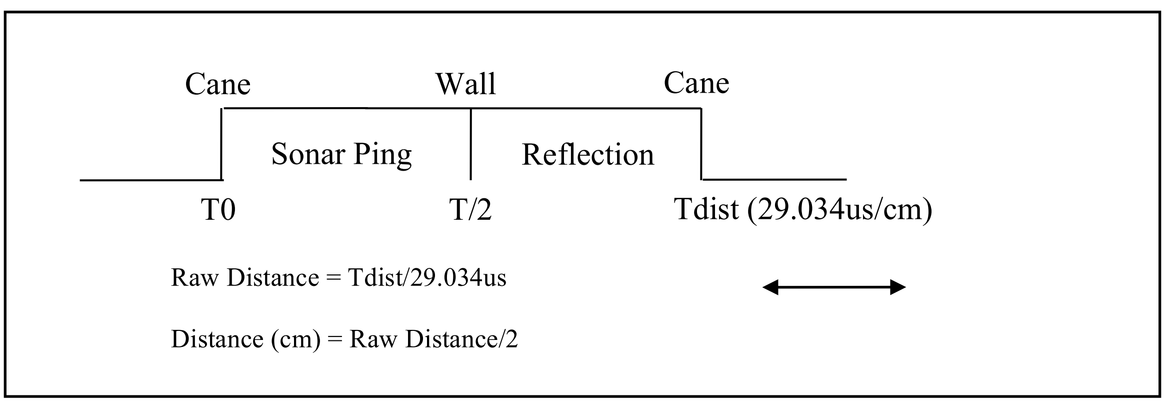
Let’s look at the software that controls my soniCane. The software fires a sonar ranging pulse, converts the pulse to distance, and provides feedback as to the distance to an object.

```
Main:
  DO
    GOSUB Get_Sonar                 ' get sensor value
    inches = rawDist ** RawToIn     ' convert to inches
    cm = rawDist ** RawToCm         ' convert to centimeters

    GOSUB Locate_Unit:              ' where are you sonic device?

    GOSUB Loop_Leveling:            ' save power

    GOSUB Play_Tone:                ' make a sound for range
    GOSUB Play_Buzz:                ' make a vibration for range
  LOOP
  END
```

Main Program Flow

The sonar sensor pulse is converted to distance first by measuring the sound pulse and second by applying physics to convert the pulse to distance.

The speed of sound is roughly 1130 feet per second. This yields a pulse time of 73.746us per inch or 29.034us per centimeter. Since the sound goes from the cane to the wall and back, the actual distance to the object is half the pulse. It’s true that environmental parameters such as temperature and humidity will affect the speed of sound and produce an error in the distance, but it doesn’t change the fact that you are going to run into something. The temperature effect would only be a fraction of an inch and could be compensated for by upgrading the sonar sensor to the next price point where environmental compensation is included.



Sound to distance conversion formula

The audio alert changes from 500hz for something far away to 4000hz for a collision. The tone’s frequency changes linearly between those two frequencies, and the tone gets shorter as the object gets closer. The audio alert tone is fed to a speaker.

Testing showed that fine resolution was not possible using tactile feedback. So, when the object gets within the distance of a typical cane, the vibration motor starts running.

Additional software can help you locate a lost cane by activating the collision alert when you need help.

Battery power is saved by putting the system to sleep when there are no objects around.

In Practice

The rubber hits the road, or the cane hits the wall. How does my sonic cane perform in actual use? I drop the cane on the floor, clap my hands, and locate it by following its noise. I spin in a circle to disorient myself, pull out the cane, and safely navigate the hallway. It looks like a success!

Sorry Auggie, still no laser beam, but I can always add an old laser pointer for Hollywood effects.

Believe it or not…

Believe it or not, the soniCane builds on a project I called Seeing Eye For a Dog.

Lest we forget our four footed friends and furry soldiers, I set out years ago to create an anti-collision device for a friend's elderly and vision impaired Maltese.

The blind have used guide dogs since the 16^{th} century. That's a heck of a debt owed to "man's best friend." To help repay that debt, I created a twist on the seeing eye dog by creating The Seeing Eye for a Dog. I adopted the technology that helps robots avoid collisions into a puppy mounted system.

The microMedic contest energized me to continue the work I began. The first prototype can now be mounted on a dog. The trick is to train the dog to act on the tone and vibrations that precede collisions.

A stunt double modeling the Seeing Eye

Resources

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Parallax, Inc., Sound Impact Sensor (#29132) v1.0, Oct 27, 2009.

Parallax, Inc., BASIC Stamp Help Version 2.5.2, Mar 11, 2011.