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SEEMORE: The Haptic Cane.

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***Abstract*— This paper describes an ultrasonic system that can be easily attach to existing canes for the blind. A haptic signal would be transmitted to the user by vibrating motors. Traditional blind canes help visually impaired people to travel and interact with their surroundings. With the SEEMORE device, we are aiming to use ultrasonic sensors to transmit a more accurate representation of the environment.**

I. Introduction

In today's USA, 51.2 million of people experience some level of disability, which represents 18% of the population [1]. Around 6 to 8 million Americans are blind or have some visually impaired condition [2]. Studies suggest that 40% of the visually impaired suffer head level accidents at least once a month, and 30% trip and suffer a fall accident at least once a month [3].

In order to cope with these disabilities, visually impaired individuals used aid methods to perform their daily tasks, among the most popular are, the white cane, guide dogs, and Electronic Travel Aids (ETA). There are limitations to each the methods, some of these are: price, portability, durability and maintenance. Unfortunately none of the methods is perfect, so it is up to the user to discover which aid will better fit his lifestyle and accommodate to the device limitations.

Guiding dogs can help you avoid overhead or waist high objects; they go around objects that the cane would usually hit; they often learn the routes that you take most often and they are a company. On the other hand, guide dogs take up room in your house and car; some people are allergic to them; they have a short work life; they are expensive and it could be hard to find a good match between the life style of the user and the requirements of the dog.

White canes are easy to carry, do not require much maintenance, they are easy to use in crowded areas and they are used to distinguish visually impaired people. On the other hand, blind canes can get stuck in small places; the user could experience strain after long period of continuous use; it does not detect low hanging objects and an invasive form of feedback.

Over the last 50 years, the developing of ETAs has been closely watched. They generally are composed of two elements, the sensor and the display. The sensor can use lasers or sonar waves to range how far the elements might be. The display will present spatial information to the blind traveler to avoid the obstacles. Sound and vibration are the most common form of display or feedback system.

II. Background

Previous experiments have demonstrated that the use of sensors can improve the mobility of visually impaired people. Some of these experiments consist in adding ultrasonic sensors to blind canes (HALO) [4], GPS-based shoes (Le Chal) [5], ultrasonic gloves (Cane 2.0) [6] and infrared GPS vibrator systems installed on the back of a user [7].

So far there is not such thing as a silver bullet for visually impaired people. The devices previously mentioned have incorporated innovating concepts but also have major flaws. The Halo can be heavy and only provide feedback for low hanging objects. On the other side it can be easily incorporated into existing canes.

The Le Chal shoe relies too much on current GPS technology which we know sometimes is not 100% accurate; also there is no backup system if the shoe brakes and there is no easy way to distinguish who is visually impaired using this technology. Looking at the bright side, the user will blend with the crowd and will have both hands free.

The Cane 2.0 looks very fragile, there is no backup system if the device breaks and after holding your hand in the air for long time, it can hurt. The glove is a nice and simple idea if you want to interact with your immediate environment, like in the library or the park but it is not a long-term mobility solution.

The wearable back GPS system is big, bulky and not easy to take off in situations where is not necessary. This system introduces an innovating idea of using other parts of your body to provide feedback.

III. Design

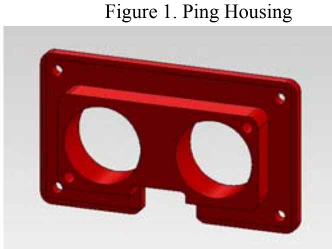
As discussed above, it is certain that ETA's and guide dogs can be economically unaffordable. With that said the use of the white cane for this experiment should be of great economic advantage as well as a failsafe mechanism in case the haptic device does experiences technical problems. We developed the SEEMORE to detect objects in front, on the sides, and above the device. This design allows the users to detect objects before the cane physically hits the object. It detects low hanging objects that cannot normally be detected and the cause of numerous injuries to the visually impaired population.

SEEMORE works by sending a continuous vibration pulse administered at the hand, where the subject holds the cane. We choose the hand because in addition to be extremely sensitive, it has enough surface area to place 4 vibrators corresponding to each of the sensors. The vibrators will be placed in the same hand as the holding cane hand, with the purpose of the subject having the same reference coordinates as the cane.

The vibration pulses are trigged as a result of the sensors detecting any obstacle in any of the sensing directions. There are several sensors that can be used to detect obstacles. Among these are laser triangulation sensors, infrared emitter detectors and ultrasonic sensors. Laser triangulation sensors determine the positions of a target measuring reflected signals from the target's surface [8]. The use of these devices is highly recommended but due to price limitations these solutions were not explored further. Infra-red devices contain small, dark windows called IR ports. Inside these ports, transceivers (a combination of a receiver and transmitter) send and receive data using an IR frequency.[9] The use of IR sensors was highly considered however since the cane will be used outdoors the IR spectrum will be compromised with sunlight. Finally we decided to use ultrasonic sensors which work by emitting sonic pulses and then waiting for the returned echo reflecting off an object. The time between the sent pulse and the returned echo is used to calculate distance.

SEEMORE has four components: ultrasonic sensors, a microcontroller, vibration motors, all made by Parallax Inc., and the cane. The vibrators were flat coin motors that allow minimal intrusion on the users' skin. The first step was to attach the sensors to the cane, after considering many options we created a simple minimalistic design. Each ping was contained inside a protective housing which was design using SolidWorks and manufactured with a 3D printer. (Figure 1) We decided to place each ping individually to avoid creating big momentum forces with respect to the hand of the user.

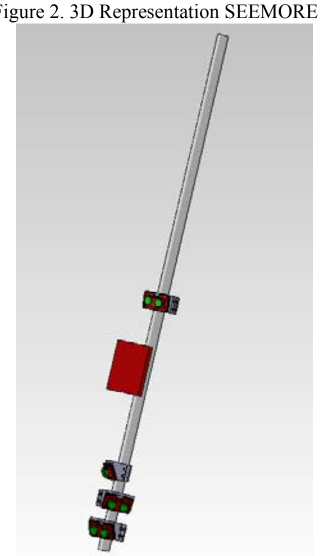
Figure 1. Ping Housing



To attach the cane and the Ping housing, we decided to use a simple "clap design" with one inch wood rectangles having the same dimensions as the Ping housing. This clap design will ensure the position of the ping and will also give us the freedom to relocate the pings if necessary or desired by the user. Noting that one of SEEMORE's needed features is an ability to detect objects at an angle of inclination with respect to the floor. This project was made with the assumption that most visually impaired use the cane with a 45 degree inclination angle but a larger degree would be useful.

In order to ensure that the Pings will detect obstacles in the users' path, we added a 30-degree inclination with respect to the cane for right, left and forward Ping sensors. By adding this inclination we kept the Ping parallel to the ground. The Ping sensor for low hanging obstacles was designed differently. We used approximately 10 degree angle with respect to the cane. These angle fixtures allowed SEEMORE to detect objects in front of the user torso and head instead of ground obstacles. Figure 2 shows the final location of the sensors.

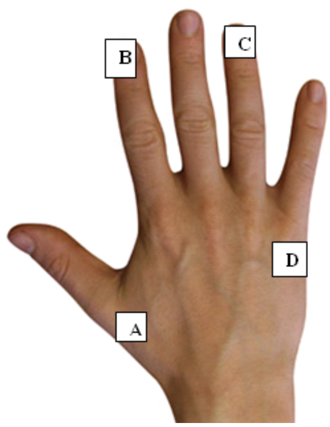
Figure 2. 3D Representation SEEMORE



The microcontroller uses four Mosfet (metal–oxide–semiconductor field-effect) transistors; each transistor controls a single motor. The microcontroller rated for 5V did not provided enough current to activate the 3V vibration motor which led to the use of additional components and an additional battery. The Mosfet transistor acts like an on/off switch. When a sensor is activated, a signal of HIGH is sent by the microcontroller to a specific PIN. This HIGH signal then becomes the ON signal, which closes the circuit on the Mosfet transistor and completes the loop by allowing the motor to vibrate.

After running several tests we learned that having the vibration motors on the cane was creating confusion among the vibration directions. We decide to explore the use of a wristband; this would allow easy of removability as well as sufficient surface area to allow the motors placement to be 90 degrees apart on the wrist. However, due to the fragility of the motors, placing them on the wristband created a direct exposure, leading to the collapse of the motors from the wristband. We solved this issue by using a glove. Thus, learning that the placement of the motors was critical we designed the motors placement schematic as shown in figure 3.

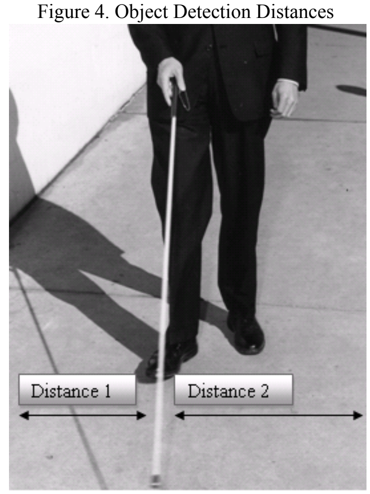
Figure 3. Glove Vibrating Motor Placement



SEEMORE was design to be customizable according to the users preferred hand. The prototype built was made for the use of a right hand subject. After carefully examining the way subjects held the cane, we decided to use the following layout for the motors (Figure 3). Where the A label points to a "low hanging objects" sensor, B for front-of-cane sensing, C refers to left-of-cane sensing and D for the sensing to the right of cane. This setup allowed noticeable sensation on each location allowing a sound distinguishing of the haptic feedback for each motor. Upon completing the glove setup the SEEMORE does not use a traditional blind cane instead it uses a traditional wood walking cane. Similarly the device is not used like a blind cane due to its extensive weight. SEEMORE is pushed forward with the aid of a tennis ball at the end, to reduce friction. Since the prototype was built for right hand users the sensors needed to be calibrated; the device is not symmetric. As seen in figure 4, for right hand users', distance-1 will scan a smaller surface than distance-2 and vice versa for left-hand users. After careful calibration the final optimal distances are: 60 inches for the top sensor since it has to detect objects above the head, 12 inches on the right, left 36 inches and front 24 inches.

Correspondingly, as we tested SEEMORE we learned there was a slight confusion created among the locations of the vibrations simply because the brain was not train to understand which vibration defined each direction. We solved this by creating an introducing a loop. This loop would vibrate as following: forward, pause, front, pause, left, pause, right. This allowed the user to become familiar with the device and reduce the source of error.

Figure 4. Object Detection Distances



IV. Experiment

Human subjects were used to evaluate the effectiveness of SEEMORE, a total of 12 subjects aged from 18-60 were recruited for the study, 6 males and 6 females. Six of the subjects were familiar with haptic devices the rest was never exposed to any. The experiment was to introduce a brief explanation of how the device worked, sequentially randomly applied 12 stimuli and recorded where the subject thought the stimulus was applied. Upon completion of the random stimulus, subjects navigated an obstacle course with the purpose of completing it with the help of SEEMORE to avoid collisions.

Our 1st subject showed confusion with the vibration effect. His feedback included to first explain how the device worked with eyes open so the subject could make a connection between the vibration and the location of the feedback. His results were inconclusive and discarded from the results however his feedback was applied to all other participants.

V. Results

Unfortunately, we were only able to test 2 users with an obstacle course due to space/time limitation. Subject 1 completed the course, without any collisions however his completion time was relatively slow. Subject 2 successfully completed the obstacle course without any collisions but his completion time was significantly faster than subject 1. We believed the reason for this was the familiarity that subject 2 gained with SEEMORE after subject's 1 feedback was added to the experiment.

Subject 3 showed the same trend as subject 1, his answers were consistent with thinking that the forward vibration was the upward vibration, after discussing his results he admitted the confusion. Subjects 3 results were also discarded from the study.

As seen in table 1, all other subjects were 100% successful in completing the experiment. After subjects' 1 feedback was applied, all subjects were able to distinguish the feedback with the adequate sensor. Since not all participants were able to complete the obstacle course an ANOVA was not completed. Nevertheless all participants provided significant feedback which will be discussed in the next section.

Table 1. Right VS Wrong Stimulus

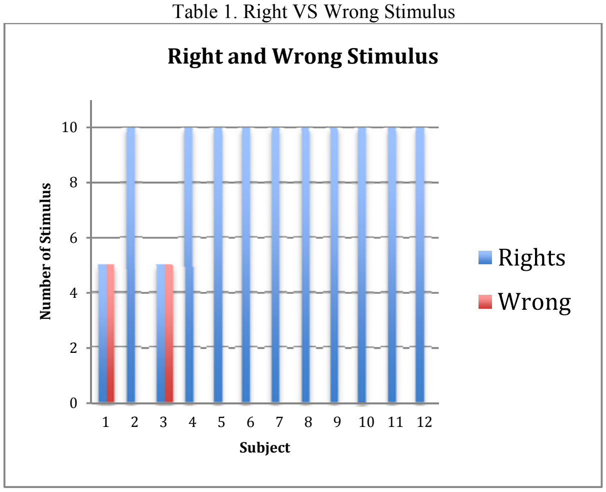
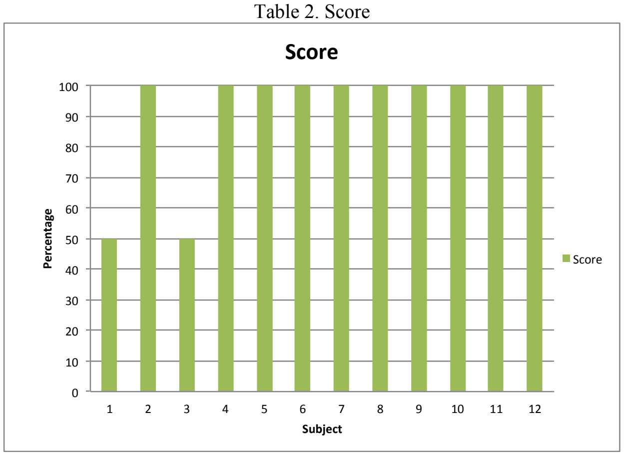


Table 2 shows the percentage each subject completed. In order to assure SEEMORE's effectiveness participants had to score above 85 percent.

Table 2. Score



VI. CONCLUSION AND FUTURE WORK

Based on the result it can be concluded that SEEMORE worked as expected. All Subjects in the study were able to distinguish all the random stimulus, similarly the two subjects that completed the obstacle course did not collide with any of the objects on their paths. The versatility of this device allows being attachment to existing canes, also providing a failsafe mechanism in case any of the components malfunction. Looking back at the motivation to create this project and analyzing our study results, we strongly believe that SEEMORE can help decrease the injuries occurred to the visually impaired, with help of a few improvements.

Nonetheless, the study was modified based on the feedback of Subject 1, which called for teaching the users the layout of the glove with their eyes open. If the main use of the device will be to serve visually impaired the familiarization of SEEMORE with the user must be improved. Other areas that we would like to improve are: decreasing the weight by using a smaller sized microcontroller, replacing the vibrating motors with more durable motors, adding a wheel at the end of the cane allowing it to be used in all surfaces, and finally we would like to improve the glove. We would like to make a custom glove with Velcro that allows the installation of the glove on the user easier and less fragile.

VII. AKNOLEDGEMENTS

We would like to thank Dr. Kyle Reed for all the aid the provided through the project, Louis Melgar for helping us print the Housing Ping, Dr. Daniel Hess for assisting us with the microcontroller programming through his Microcontroller class, and all the subjects that participated in the study that provide feedback to enhance our future work.

VIII. REFERENCES

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IX. Appendix

This is the code that the SEEMORE system uses. Use this for future references or in case that someone wants to continue the project. Please reference the proper source.

```
' David Gomez
' Blind Cane Sensor

' {$STAMP BS2}
' {$PBASIC 2.5}
' Variables
' Units are in inches
cmCons    CON   2260  ' Constant for cm
inCons    CON   890   ' Constant for in
PingU     PIN   15    ' Pin 15 for Up Ping
PingR     PIN   13    ' Pin 14 for Right Ping
PingL     PIN   6     ' Pin 13 for Left Ping
PingF     PIN   2     ' Pin 12 for Forward Ping
SenF     PIN   0    ' Pin 0 for Up Sensor
SenU     PIN   1    ' Pin 1 for Right Sensor
SenL     PIN   8    ' Pin 8 for Left Sensor
SenR     PIN   10   ' Pin 10 for Forward Senor
DistanceU VAR   Word
DistanceR VAR   Word
DistanceL VAR   Word
DistanceF VAR   Word
timeF      VAR   Word
timeL      VAR   Word
timeR      VAR   Word
timeU      VAR   Word
' -----[ Main Loop ]--------------------------------------------------
GOSUB welcome
DO
  GOSUB Pings
  GOSUB Sensors
LOOP
' -----[ Subroutines ]--------------------------------------------------
Pings:
  PULSOUT PingU, 5
  PULSIN PingU, 1, timeU
  DistanceU = inCons ** timeU
  PAUSE 5
  PULSOUT PingR, 5
  PULSIN PingR, 1, timeR
  DistanceR = inCons ** timeR
  PAUSE 5
  PULSOUT PingL, 5
  PULSIN PingL, 1, timeL
  DistanceL = inCons ** timeL
  PAUSE 5
  PULSOUT PingF, 5
  PULSIN PingF, 1, timeF
  DistanceF = inCons ** timeF
  PAUSE 5
RETURN
Sensors:
' if("distance value of ping" < "units in inches")
  IF (DistanceU < 60) THEN
    HIGH SenU
  ELSE

  LOW SenU
  ENDIF
  IF (DistanceR < 12) THEN
    HIGH SenR
  ELSE
    LOW SenR
  ENDIF
  IF (DistanceL < 36) THEN
    HIGH SenL
  ELSE
    LOW SenL
  ENDIF
  IF (DistanceF < 24) THEN
    HIGH SenF
  ELSE
    LOW SenF
  ENDIF
RETURN
welcome:
'F U R L
  PAUSE 3500
  HIGH SenF
  PAUSE 2000
  LOW SenF
  PAUSE 2000
  HIGH SenU
  PAUSE 2000
  LOW SenU
  PAUSE 2000
  HIGH SenR
  PAUSE 2000
  LOW SenR
  PAUSE 2000
  HIGH SenL
  PAUSE 2000
  LOW SenL
PAUSE 2000
RETURN
```