Team 522: Vision Impaired Technology

David Alicea, Nicolas Garcia, Madison Jaffe, and Ethan Saffer

Abstract—**Despite countless gadgets have been proposed to assist the visually impaired, most are too expensive compared to the functionality they provide, making many visually impaired hesitant to purchase them. In this paper, we propose a lightweight attachment for the white cane which not only comes at a moderate cost, but should also fulfill various necessities of the visually impaired. The system operates in two distinct modes, one with camera identification and one with ultrasonic sensing. The camera identification was found to function in less than one second when on a laptop, 14 seconds on the mobile unit and highly accurate results, making it a decent option for the design. The ultrasonic sensors' accuracy diminished as distance increased, but as long as the objects were within 2 meters the sensors had an overall precision of more than 90 percent.**

Index Terms—**IEEE, IEEEtran, journal, LaTeX, paper, template.**

I. INTRODUCTION

THE visually impaired community makes up around 285 million people in the world, with 39 million being completely blind [1]. The demographic we are marketing towards are individuals within the United States which includes 1 million completely blind individuals. Upon feedback from a support group for the blind and visually impaired, it was clear that consumers were primarily looking for a product that could help users navigate freely, keep them safe and promote autonomy. To do so, we created HapTac.

Team 522's goal is to improve daily life for the visually impaired. Most depend on family and government support; motivating our mission to aid and expand their independence. Many go through Orientation and Mobility (OM) training to improve agility and motor skills. They employ navigation techniques in new locations, using their senses and typically a white cane. Various products try helping, but most have limited use and high costs. Our design is compatible with their OM training while offering various features to further heighten these skills.

Our solution is HapTac, a product that improves on the standard white cane. HapTac includes sensors that find the distance between objects and the user. Vibrations on the handle relay the interpreted data to the user. HapTac includes 3 vibration motors using varying intensities to guarantee the user can interpret their surroundings. HapTac also includes a camera, which turns on to scan and analyze objects. A speaker or earpiece, depending on user preference, relays the name of the object to the user. This allows the user to identify common items at places like the grocery store or in their pantry. HapTac has a database full of diverse reference images. Users may ask Team 522 to add specific objects into the database.

HapTac's housing attaches onto the top of a white cane as if it were a new handle, thus allowing users to feel the cane's vibrations. The assembly, including the white cane, is under 3 pounds. This ensures comfort for the user's wrist and hand. HapTac's battery is long-lasting and rechargeable; ensuring the user will reach their destination and move around freely. We seek to erase the need for other products, thanks to our competitive price for the market, and HapTac being easy to integrate into daily routines.

A. Basic Operation

Operation is divided into two primary sections, the walking mode with ultrasonic sensors and the image recognition mode. During sensing mode, we assume the user will be either stationary or walking at a fairly constant cadence. While being on, the device will start emitting ultrasonic sound waves directly in front of the user, as well as 15 degrees left and right. This should enable the user to detect what is in front of them at a moderate range. When the sensors detect an object of any kind within

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specific ranges, they trigger vibration motors near the handle, thus alerting the user of the object. Image recognition mode is activated at the hit of a button, which turns on the camera and initiates a convolutional neural network. The camera takes the image directly in front of it, and runs it through the identification system. Once the object is identified, the audio output emits the object's name in the data base. If one were to find a jersey, the speaker would use Text-To-Speech to say ”Jersey”.

II. Design Embodiment

To adequately assist the visually impaired, we designed a lightweight assembly while successfully completing the functions needed. As such, the housing is made out of 3D printed ABS filament with 25 percent infill. This allowed for quick prototyping, strong parts, and overall light construction. There are three main parts to be considered in this assembly: the main body, the handle, and the electrical components.

A. Main Body

The main body has two internal sections. The bottom portion contains most electronics and wires, while the upper section houses our power source. These two sections are separated by a light shelf, flush on both sides. The front of the main body has four openings: one for the camera near the top, two for the ultrasonic sensors aimed at 15 degrees left and right, and one near the bottom facing forwards. Near the rear of the main body is the coupling extrusion, a rectangular shaft which can be fitted into the handle to united them.

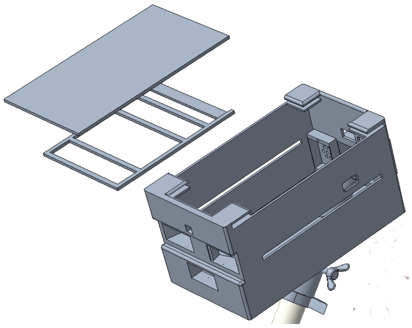

Fig. 1. Main Body

B. Handle

The handle of the assembly has two main sections: the grip and the coupler. The grip section was modelled after a knife grip to ensure the user's grip with make the device face forwards while remaining comfortable. Near the coupler, there is a thumb groove for the user to place their thumb. This section contains an opening for the button to be placed. This button is what enables camera use, so the user only needs to shift their thumb to enable the camera.

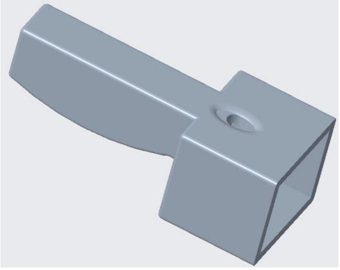

Fig. 2. Handle

C. Electrical Components

To construct and develop the HapTac, the associated electrical components were centered around the Raspberry Pi, which was used as the internal processing system. We chose the Raspberry Pi 4 Model B with 8 gigabytes of RAM. This size was necessary to be able to download all of the associated packages and programs to accomplish our device. The Raspberry Pi itself does not sell the necessary components needed for our device, so we supplemented it with the GrovePi+ which was a modular system for hardware hacking with the Raspberry Pi. The GrovePi+ attached directly to the Raspberry Pi and has the necessary attachments needed for our device. The hardware components attached to the GrovePi+ include:
(3) Ultrasonic Distance Sensors The ultrasonic distance sensors are ultrasonic transducers that utilizes ultrasonic waves to measures distance. It can measure from 3cm to 350cm with the accuracy up to 2mm [3]. These sensors have a pre-calibrated speed of sound of 340 m/s. The speed of sound is dependent on the temperature of the medium, but this source of error is negligible due to the minute difference it would cause.

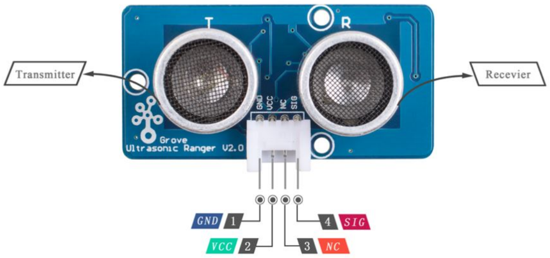

Fig. 3. Grove Ultrasonic Distance Sensor

(3) Grove Vibration Motors Grove - Vibration Motor consists of one coin type motor which is a permanent magnet coreless DC motor. It vibrates when the input logic is HIGH which can be used to notify the user. This makes it possible to attach the motors to varying places within our device without the uses of soldering [4].

Fig. 4. Grove Vibration Motor

(1) Grove Speaker Plus The speaker used in our device was the Grove Speaker Plus. It is consisted of a powerful amplifier driver board and an independent high-quality speaker [5]. The name of that object that is being identified through the camera, is relayed through the speaker. The raspberry pi also has to ability to connect a standard pair of headphones into the 3mm audio jack.

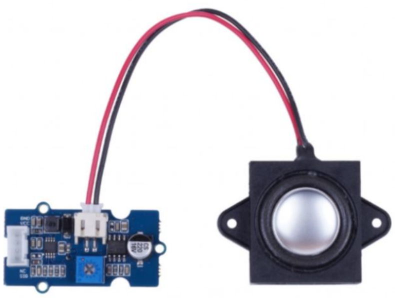

Fig. 5. Grove Speaker Plus

(1) Grove Button The Grove Button is a momentary push button. It contains one independent ”momentary on/off” button. “Momentary” means that the button rebounds on its own after it is released. The button outputs a HIGH signal when pressed, and LOW when released [6]. This button is used when using the object identifying function our device has. The button will be pressed which will take a picture of the object in front of it.

Fig. 6. Grove Button

The following electrical components were not purchased for the Grove adapter.
(1) Raspberry Pi Camera Board The camera used for this device is an 8 megapixel camera capable of capturing 1080p video and 3280 x 2464 pixel static images [7]. This makes it possible for the camera to capture high quality images that make it possible for the coordinated convolutional neural network to be as accurate as possible when identifying items.
(1) Belkin Boost Charge Power Bank The power bank used for this device was picked due to its high capacity and ability to be recharged quickly. The Belkin battery has 20,000 mAh capacity and is capable of delivering 12 watts of power to the Raspberry Pi. At full capacity, the battery life will last roughly 4.8 hours. The raspberry pi can connect directly to the power bank through a USB Type C cable.

D. Assembly

The assembly of HapTac consists of mounting the ultrasonic sensor and cameras using machine screws on their respective mounting holes. Once these are placed, the Raspberry Pi 4 is placed near the bottom of the housing. The handle can them be placed onto the main housing, and the vibration motors are then placed and wired. The shelf can now be slid into place. The battery is then placed and connected to the USB cable on the Raspberry

Pi, and the lid can be place overhead to seal the assembly.

III. EVALUATION

A. Procedure

1) Ultrasonic Sensors: To evaluate the performance of the design, the two specific modes were evaluated separately as they will not be functioning in tandem. To evaluate the precision of the ultrasonic sensors, an object is placed at set distances. Since our sensors operate in centimeters, we will be testing the precision at intervals of fifty centimeters. By finding the discrepancy between the true value compared to the experimental value, we can find the loss of precision as a function of distance. This allows us to know at what point our sensors stop working optimally and become unreliable, denoting our ideal sensing range.

2) Camera Accuracy: For the camera identification, two different methods were employed. First, the accuracy of the image identification was tested on various household items. We chose to test 7 general household items: a cellular telephone, a medicine chest, an iron, a hand blower, lotion, a Band-Aid, and a plastic bag containing items (in this case a bag of flour). These will be placed individually in front of the camera in both well-lit and dimly-lit scenarios, and the image will be recorded. Success is defined as having the item in frame being analyzed and emitted from the program. Once final accuracy test may be performed by placing various of these items in the same frame and activating the camera. In this case, three distinct items were placed: an iron, a hand blower, and lotion. This defines the area of priority for the camera.

3) Camera Time Response: Secondly, the time response for the software will be tested by trying various items and recording how long it takes the system to identify the image.

B. Results

1) Ultrasonic Sensors: The ultrasonic testing was performed within a confined environment and the results are as follows.

Ultrasonic Sensor Reading (cm)		
Actual Distance	Recorded Distance	Percent Error
5	5	0
10	9	10
15	14	6.67
20	19	5
25	24	4
30	28	6.67
50	48	4
100	96	4
150	145	3.33
200	193	3.5
250	242	3.2

2) Camera Accuracy: When run directly from the computer, the 7 images were taken (the six others in the Appendix).

Fig. 7. Cellular Telephone

Under normal light conditions, Alexnet was able to swiftly analyze objects in front of the camera and display their name. In the case of lower light conditions, Alexnet began showing partial hesitation towards objects with less distinct shapes; however, it was able to identify each one of the objects swiftly and remained accurate.

Fig. 8. Cellular Telephone

When tested with a variety of objects, location was the determining factor for identification. Objects placed in the center of the screen were analyzed. In the case of the iron, hand blower, and lotion, only the object directly in the center of the screen would be analyzed and emitted from Alexnet.

Fig. 9. Test with three objects

This center-line bias remains standard despite low-light conditions.

Fig. 10. Test with three objects, dim light

3) Camera Time Response: When analyzing objects directly from the mobile unit with the Raspberry Pi 4, identification times increased from less than a second to roughly 14 seconds (Assuming a preview period being nearly instantaneously).

IV. DISCUSSION

1) Ultrasonic Sensors: The ultrasonic sensors displayed great accuracy at both the close and long range, only reaching a percent error greater than 10 at moments in which distances were so low that even the slightest deviation would lead to high error values. It should be noted that the group limited testing to 250cm as these would ensure that the design would work. That stated, the design was made so that even larger deviations were usable with our vibration motors; however, if we have such a high precision, we could implement a more sophisticated solution to the haptic feedback.

2) Camera Accuracy: The camera displayed incredible accuracy when employed from a laptop despite light conditions. This would indicate that the neural network Alexnet is a more than suitable candidate for object identification. With such high precision, Alexnet would allow users to accurate scan objects and get the information relayed back to them. The only predominant issue would be the lack of reference material causes biases, such as with scanning plastic bags.

3) Camera Time Response: The camera response time was found to be roughly 14 seconds without including any extraneous processes, which is roughly twice as long as we would have wanted. The team aimed for roughly 7 seconds overall as a relative metric, but this was based on a person bias.

If the device were to be used for low-risk actions, then the 14 second delay would be more than acceptable. As our device would be particularly useful in the scenario of shopping for basic needs, one could assume that the user is in low-risk, no rush circumstances. While that might be acceptable, the team wishes to avoid having the user spend so much extra time when scanning objects. This could be fixed by upgrading the processing unit by either having more RAM available, or by changing the Raspberry Pi 4 for a custom assembly with a high focus on processing speed and power.

V. CONCLUSION

Through the experimental procedure we were able to validate both hardware and software to determine whether it was adequate for street use. The identification software proved to be somewhat slow on mobile applications with the Raspberry Pi 4;however, the accuracy of the results despite light conditions and cluttering of objects may outweigh this negative factor. The ultrasonic sensors were proven to be highly accurate near the sensor while having slight deviations. Since our applications simply need a rough estimate of the location of objects, this inaccuracy is determined to be acceptable. As such, the design proves to be functional with various limitations. Were this design be revised in the future, more funding should go into the processor and the ultrasonic sensors to make the device function at the desired performance.

APPENDIX

Fig. 11. Medicine Chest

Fig. 12. Iron

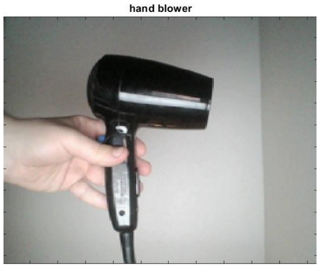

Fig. 13. Hand Blower

Fig. 14. Lotion

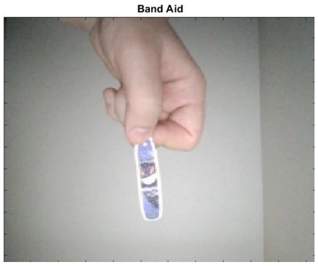

Fig. 15. Band-Aid

Fig. 16. Plastic Bag

Fig. 17. Medicine Chest

Fig. 18. Iron

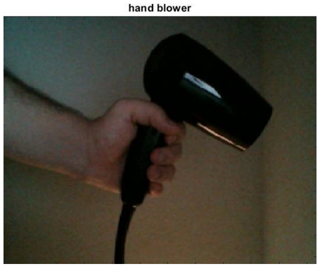

Fig. 19. Hand Blower

Fig. 20. Lotion

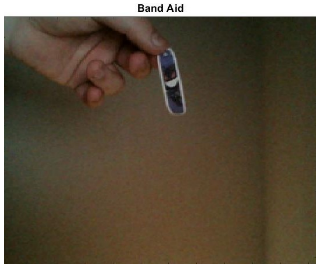

Fig. 21. Band-Aid

Fig. 22. Plastic Bag

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