RESEARCH ARTICLE

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Navigation and Object Identification Aid for the Visually Challenged

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ABSTRACT

The aim of this paper is to develop an affordable consumer device to help the visually impaired people travel independently. The device is an electronic navigation system designed in the shape of a pair of eyeglasses, which utilizes 2 ultrasonic sensors to detect objects up to 400 cm in the front of the device and 2 vibration motors to produce vibro-tactile feedback to inform the wearer about the object's localization. The 2 vibration motors are so calibrated that the wearer can easily comprehend the distance of obstacles surrounding him. Simultaneously an object identification model captures live video from a camera module and recognize objects in the front, informing the wearer about the object detected through earphones, thus assisting the wearer to search any required object. The device uses a 'Raspberry Pi 3B+' microcomputer to process real time data, employing tensorflow for image processing.

Keywords: Camera Module, ERM Vibration Motors, Haptic Feedback, Navigation Aid, Object Detection, Raspberry Pi, Tensorflow, Ultrasonic Sensor, Visual Impairment

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INTRODUCTION

The advent of technology is so unprecedented that it is humanly impossible to keep a track on all the technological advancements taking place every day. Technology has occupied an important place in the modern society since the boom of Industrial Revolution. These technological developments are helping mankind solve basic requirements of many sections of the society. One such contribution is towards the "Visually Challenged" community.

JFMPC (Journal of Family Medicine & Primary Care) estimates that around 253 million people live with vision impairment, out of which 36 million are blind, and 217 million have varying degrees of vision impairment [1]. The official statistics from World Health Organization also reveal that the future generations will experience high chronic blinding conditions such as diabetic retinopathy ageing because of urbanization and lifestyle changes [2]. It has been estimated that if the current trends continue, then the worldwide population of blind people will increase to over 76 million [3].

They are doomed to live with this physical challenge either because of irreparable blindness or humongous costs for surgeries. These visually impaired people face great difficulty in perceiving and interacting with the surroundings, especially those which are unfamiliar.

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There exist many traditional navigational aids to assist the visually impaired and blind people. The most common ones are cane sticks and guide dogs but they possess some limitations in certain circumstances which hampers their reliability. The guide dogs provide an efficient means to help them but the cost makes it hard to be within the reach of masses. On the other hand, cane sticks are ineffective in certain situations where an object's base from the ground is outside the cane's reach as shown in Figure 1. One widely popular navigational aid is long cane stick, which has sensors embedded in them. This has several limitations such as a range limited sensor, typically one pace ahead of the user, difficulties detecting overhanging obstacles, and difficulties storing in public places [4].

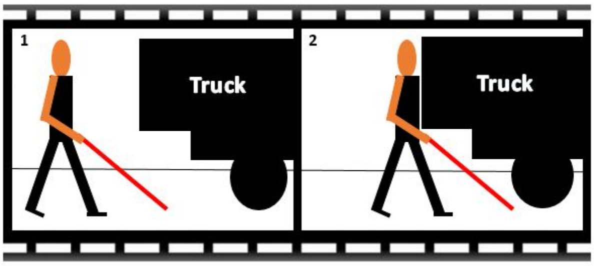

Figure 1: Limitation of Cane Stick

The main requirements for any navigational aid are dependent upon its portability, costing, efficiency and ease of use. Development of a device which can be consumer friendly in terms of both budget and efficiency has been proposed in this paper. The device proposed is an ETA (Electronic Travel Aid) which can help better the lives of the visually challenged people by providing more information about the surroundings by integrating multiple electronic sensors [5].

The proposed device makes use of ultrasonic sensors along with a camera module to help map the surrounding environment. The mapping is communicated to the wearer using haptic feedback and earphones. All the processing of the data is done by the Raspberry Pi 3B+ micro-computer.

Description of the Device

Overview

The device components and their use as a sensor or an actuator has been shown with the help of "I/P" (Input) and "O/P" (Output) in Figure 2.

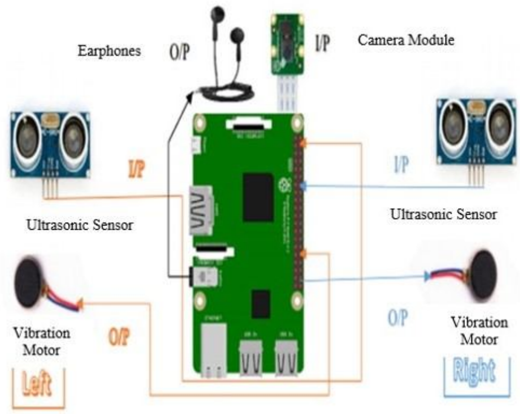

Figure 2: Hardware Configuration of the Device

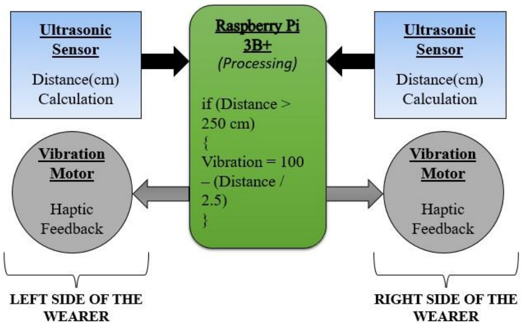

Figure 3: Block Diagram for Navigation

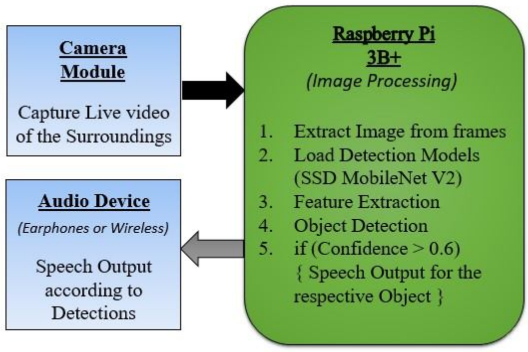

Figure 4: Block Diagram for Object Detection

Figure 3 and Figure 4 presents the block diagram for navigation and object detection respectively. The device uses 2 ultrasonic sensors and 2 vibration motors for both the right and left side of the wearer. The motor used is a coin type ERM (Eccentric Rotating Mass) vibration motor which is a tiny and power efficient component, best for haptic purposes. The camera is aligned to capture live video of the front and the camera input is processed by the Raspberry Pi for object identification. The speech output of this identification is given through the earphones.

The GPIO (General Purpose Input Output) pins, CSI (Camera Serial Interface) and the audio port has been used in the micro-computer. The Raspberry Pi 3B+ comes with inbuilt Wi-Fi and Bluetooth, and hence any wireless audio device can also be used instead of the earphones.

Design

The proposed project is a wearable designed in the form of goggles which are comfortable and easy to use. Two Ultrasonic sensors have been employed so that they can offer a maximum effective detection range of 120 degrees in front of the wearer.

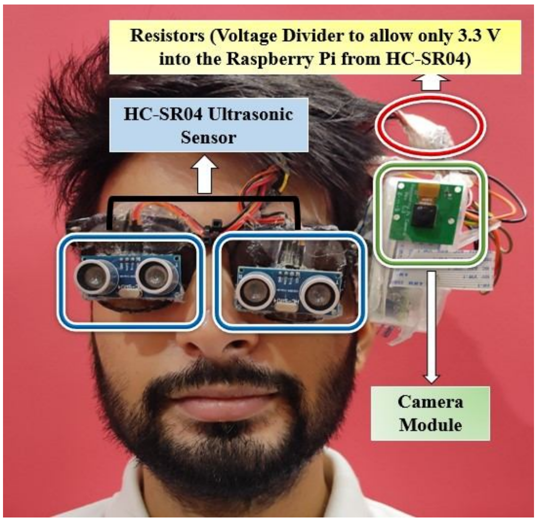

Figure 5: Complete Hardware Model Look with the Wearer

The shown model in Figure 5 is designed so as to maintain portability of the device allowing the goggles to be folded and stored without any strain. Figure 6 shows the placement of the 5MP camera which helps to capture a major part of the surroundings in front of the wearer.

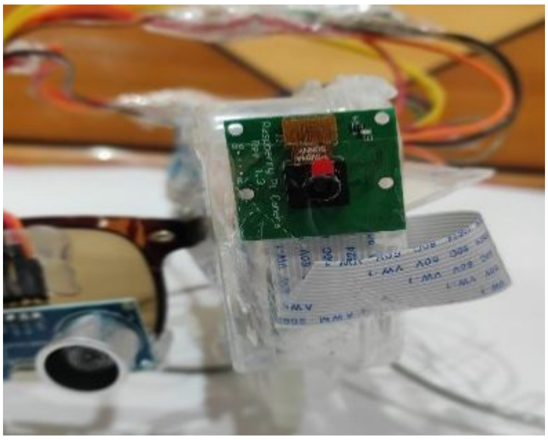

Figure 6: Placement of the Camera Module

Figure 7 presents the placement of vibration motor. The ERM Vibration motor is placed on the arm of the goggles before the temple tip so that the haptic feedback is efficiently given to the wearer. The haptic feedback's intensity is dependent upon the distance of any obstacle in front of the ultrasonic sensors.

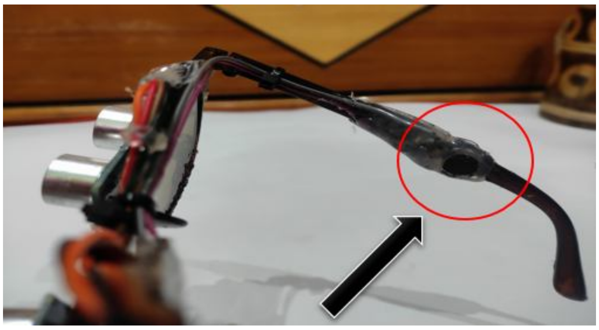

Figure 7: Placement of the Vibration Motor

The brain of the device i.e. the Raspberry Pi micro-computer is fixed in a case on the left side of the goggles as shown in Figure 8.

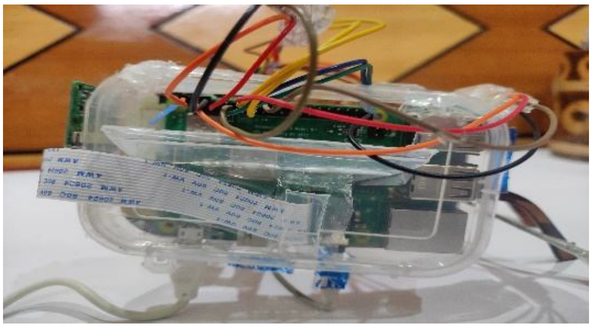

Figure 8: Placement of Raspberry Pi (Micro-computer)

Working of The Device

The device's working has been divided into 2 portions for simplicity. The 2 portions are as follows:

Navigation

The purpose of this part is to precisely calculate the distance of obstacles in the path of the wearer and give haptic feedback according to the distance. It will help the wearer to get an approximation of distance from the obstacles around. If the wearer gets too close to an obstacle, the feedback is a high vibration indicating very close distance and hence guiding away from the obstacle. It deploys 2 ultrasonic distance sensors to calculate the distance and 2 vibration motors to give haptic feedback according to the distance. The left and right side vibration motors are calibrated to the respective ultrasonic sensors. The ultrasonic sensor works on the principle of SONAR which is used to determine the distance to an object. An ultrasonic sensor generates the high frequency sound (ultrasound) waves. When this ultrasound hits the object, it reflects as an echo which is sensed by the receiver. The Logic implemented here is that, as the distance gets below 2.5 meters, the vibration intensity from the motor gets increased. Hence this variation in vibrations can act as the perfect output which can be used to communicate dangers to the user.

The equation for haptic feedback for the navigation purpose is:

$$Vibration\, Intensity = 100 - \frac{distance(cm)}{2.5} \quad (1)$$

where, vibration Intensity remains within the domain (0, 100). The intensity is varied using the Pulse Width Modulation (PMW). An intensity of 100 represents the maximum vibration while 0 represents no vibration. The vibration intensity produced can reach a maximum of 1G which is comfortable to the wearer even during long usages.

The distance of the obstacles is calculated using the following equation:

$$D = \frac{Ev}{2} \quad (2)$$

where,
D = Distance from the obstacle in cm
E = High time of the Echo Pulse Width in seconds
v = Velocity of sound in cm/s

The sensors are efficient enough to work in environments like fog, smog and even in dark environments. Hence provide accurate navigation to the wearer in these conditions.

Object Identification

This part aims to employ the camera module and machine learning models to identify certain objects in the surroundings and accordingly give speech output to the wearer through the earphones. It would ease the wearer's search for an item as well as help him identify the surroundings. It uses a single camera module to capture live video and sends it to the microcomputer for processing and identification. After the object is identified, the controller sends a speech output to the wearer through the earphones. The microcomputer deploys pre-trained AI networks which then compares the coming image data with the existing object models and gives speech output on higher matching rates, here inferred as the confidence.

This part makes use of Google's tensorflow 2.0, which is an end-to-end open source platform for machine learning. The COCO (Common Objects in Context) image dataset is employed, using which 80 common objects of day to day importance can be recognized by the device.

Results and Discussion

Results

The device has been tested for any anomaly on both component specific level and integrated level as a whole. The HC-SR04 sensors in the testing have shown accurate results in the navigation portion. The vibration sensors also worked good enough to provide distance information through the haptic feedback. Hence, the navigation portion stood very well on the standalone tests.

The Object identification portion takes up to 3-5 seconds to load all the required resources and datasets, thereby creating a slight delay in the initial working. However once initialized, the device can work non-stop for long hours without difficulties.

These 2 parts together work to provide both navigational and object identification features. Both the objectives aim to fulfill the project's motive which is to help the visually challenged better cater to their environments on their own without external human help.

The project has been successful in meeting its objectives. The project is able to sense the distance of obstacles with an accuracy of 3 mm and 15 degrees of measuring angle. The sensors continuously work to give the real-time distance.

The accuracy can be inferred from the working results given in a dedicated manner for the 2 parts:

- Figure 9(a) & 9(b): Only Object Detection is employed
  - The project runs smoother with 50% faster fps than both the parts being run simultaneously. The device does not heat easily.
  - Average FPS is 3.35
- Figure 10: Whole of the Project, that is both Navigation and Object Identification employed

- The Project does more work and hence the processing speed is reduced. More heat is dissipated and battery is drained faster.
- Average FPS is 1.50

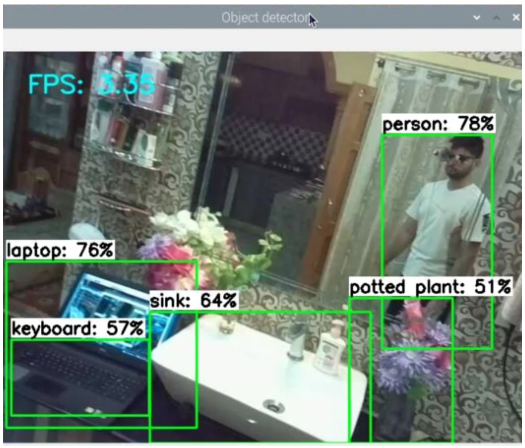

Figure 9(a): Results with Only Object Identification Employed

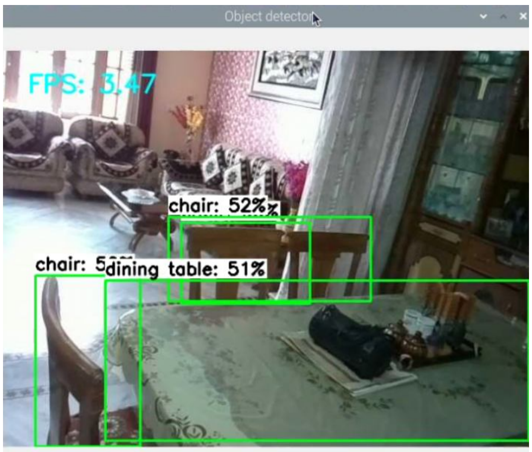

Figure 9(b): Results with Only Object Identification Employed

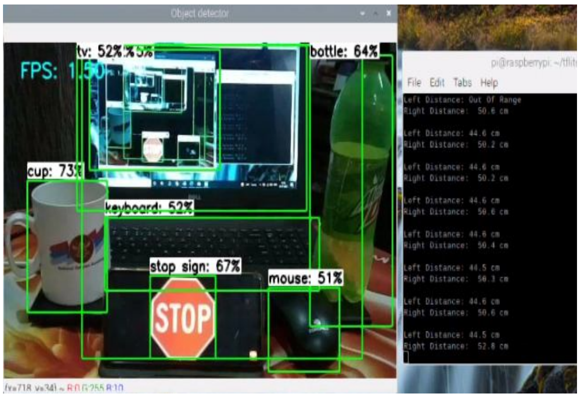

Figure 10: Final Results with Both Navigation and Object Identification Employed (Original Working of the Project)

Findings

The device fulfils the objectives set out for it. It has been helpful in its testing in indoor environments, especially the navigation portion as it helped as a reliable guide in moving from one place to another, providing collision warnings through a high vibration feedback. More training with the device has helped the subjects to even map the surroundings. This has been possible due to the right and left calibration of the ultrasonic sensors and the vibration actuators. The speech messages on object identification also helped the subjects to find the required items in less time when compared with the time required to search without the device.

Following the results, these are the advantages of the device made:

- The device was made under 4500 ($34) which is impressive considering the features it provides. Hence, can be a good substitute over the costly methods introduced in the beginning.
- The device can easily detect over a range of items and can also be customized to detect certain objects like medicines, personalized items, etc.
- The device provides a trustworthy system which can help the visually challenged navigate freely.
- The device with more training time can help the user to virtually map any surrounding with the haptic feedback.
- The device can work in fog and misty conditions (only for navigation).
- The device employs ultrasonic waves and hence can even work in the dark and thereby providing extra accessibility to the user.
- The feature of object identification will make the visually challenged self-sufficient especially in indoor environments.

There are some areas in which the device can be further improved. These areas along with the solution to the lacunas are as follows:

- The device offers an average FPS of 1.50 during its operation which is way below the real-time standards. This makes its utility less efficient for all environments. Any further upgrade in the hardware can help it achieve a level of near perfect usefulness.
- The device's weight distribution is not perfect and hence the aid slips during long intervals of usage. This can be solved by either shifting the whole system on a peripheral place or by balancing

the weight of the system with a suitable battery on the opposite side.

- The Ultrasonic Sensors fails to detect pointy and edgy surfaces as the rays gets deviated in orthogonal planes rather than returning back. This has been minimized with the usage of 2 sensors placed in different places and different angles.
- The hardware has another limitation of heating up which decreases its efficiency during long usages. This can be solved by adding a CPU heat sink or a fan over the ARM chip.

In spite of these demerits, still the project has fairly reasonable utility especially in the indoors. However the device lacks computational power to feasibly carry out object identification as the fps rates are much lower than the real-time standards. These drop further during long usages as the CPU heats up. Thus it can be inferred that currently the feasibility is still limited to navigation but in later versions it can be improved to cater the real time needs.

Future Scope

The device has a huge potential in revolutionizing dependence of the visually challenged society. The device as discussed has some limitations which will definitely get resolved in the future owing to the advancements in technology. The hardware features an ARM Mobile processor which is a SoC (System on Chip). This technology was not much discussed into the computational world until the tech giant Apple itself started launching its products based on this sort of chipset. The Apple's M1 chip provides world class computational power in the same resources and does not heat at all even in its peak output. Thus Moore's law keeps the window open for such applications.

Apart from the computational advancements, the other areas in which the future seems bright for such devices is Internet of Things. The hardware has the capacity to link itself with IoT devices with the help of Bluetooth and Wi-Fi. Just this capability can have numerous applications such as health tracking, emergency alerts, panic messages, surveillance from distances, medication benefits, control over home appliances, etc.

Conclusion

This paper presents a device which is capable of providing feasible navigational guidance along with a feature of object identification, that too under an affordable cost of 4500 ($34). The findings reveal that the device can successfully help a visually challenged person navigate and interact with the surroundings in a better manner. Also the future for the device seems bright as it provides visionary customizations. This provides endless ways to help the visually challenged. The technology used however poses some limits on the usage of the device but numerous advancements await which will surely make the life of the visually challenged easier without having a high toll on their pockets.

References

[1] Vignesh D, Gupta N, Kalaivani M, Goswami AK, Nongkynrih B, Gupta SK. Prevalence of visual impairment and its association with vision-related quality of life among elderly persons in a resettlement colony of Delhi. J Family Med Prim Care 2019;8:1432-9

[2] Shripad S. Bhatlawande, Jayant Mukhopadhyay, and Manjunatha Mahadevappa, "Ultrasonic Spectacles and Waist-belt for Visually Impaired and Blind Person," 2012 National Conference on Communications (NCC), Kharagpur, India, 3-5 Feb. 2012.

[3] A. Dodds, D. Clark-Carter, and C. Howarth, "The sonic PathFinder: an evaluation," Journal of Visual Impairment and Blindness, vol. 78, no. 5, pp. 206–207, 1984.

[4] Y.J. Kim, C.H. Kim, and B.K. Kim, "Design of auditory guidance system for the blind with signal transformation from stereo ultrasonic to binaural sound," in Proc. Int. Sym. Robotics, 19-21 April 2001.

[5] A. Aladrén, G. López-Nicolás, L. Puig and J. J. Guerrero, "Navigation assistance for the visually impaired using RGB-D sensor with range expansion," IEEE Systems J., vol. 10, no. 3, pp. 922-932, Sept. 2016.