International Journal of Electrical and Computer Engineering (IJECE)
Vol. 12, No. 5, October 2022, pp. 5543~5552
ISSN: 2088-8708, DOI: 10.11591/ijece.v12i5.pp5543-5552

Design and implementation of smart guided glass for visually impaired people

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Article Info

Article history:

Received Jul 18, 2021
Revised May 26, 2022
Accepted Jun 25, 2022

Keywords:

Audio instruction
Faster region-based convolutional neural network
TensorFlow
Guided glass
Object recognition

ABSTRACT

The objective of this paper is to develop an innovative microprocessor-based sensible glass for those who are square measure visually impaired. Among all existing devices in the market, one can help blind people by giving a buzzer sound when detecting an object. There are no devices that can provide object, hole, and barrier information associated with distance, family member, and safety information in a single device. Our proposed guiding glass provides all that necessary information to the blind person's ears as audio instructions. The proposed system relies on Raspberry pi three model B, Pi camera, and NEO-6M global positioning system (GPS) module. We use TensorFlow and faster region-based convolutional neural network (R-CNN) approach for detection of objects and recognition of family members of the blind man. This system provides voice information through headphones to the ears of the blind person, and facile the blind individual to gain independence and freedom within the indoor and outdoor atmosphere.

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1. INTRODUCTION

The World Health Organization (WHO) reports that about 253 million people suffer from vision impairment; among which 36 million are blind. Most of the people of them are low-income over the eightieth area unit aged fifty years [1]–[3]. Vision impairment humans perpetually rely on the chosen person in their daily life. It is pretty arduous for the blind man to go out without help, find out a house, subway stations, and so on. However, there is not a decent device to help them within the least throughout an inexpensive value. If the visually handicapped person gets a tool form of an addict forever with him and offers essential directions, they go to realize accumulated independence and freedom. With the proposed guiding glass, we can give the visually impaired individual necessary information. Here the guiding glass means pair of eyeglasses that contain the hardware parts of our system. We inserted the hardware part in the glass because it is placed on the eyes whose working principle is similar to the eye.

We found many works that give buzzer vibration, obstacles detection [4], [5], multisensory strategy [6] output when any object comes in front of the blind man. A guiding cane also generate voice instructions for blind individuals [7]. A walker contains an ultrasonic sensor [8], microcontroller integrated circuit (MIC) [9], vibrator which helps blind people during walking [10]. We find not any device that notifies blind people about hole information. In this respect, our contribution is to give a smart device to the blind individual which is very efficient in detecting any hole objects and provides specific audio output. We also integrate global positioning system (GPS) technology into our tool so that it is more helpful for a blind individual. There are lots of methods for detecting obstacles nowadays. Based on the sensing type, it can be laser-based, ultrasonic-based, infrared (IR), and image processing-based [11]. The sonar detector has a drawback; it cannot confirm the precise direction of going forward. Optical lasers are additionally used for impediment recognition for cellular robots [12]. Some strategies use a mono-camera, stereo camera, and red green blue-depth (RGB-D) digital camera [13], [14]. Some methods use deep learning-based object detection [15]. For the image process [16], other ways are exploitation lately with an associate in nursing OpenCV, artificial neural networks (ANN), and support vector machine (SVM).

In this work, we used the TensorFlow [17] and faster region-based convolutional neural network (R-CNN) [18], [19] inception v3 model whose working principle is very similar to the MobileNet model. Inception v3 [20] networks limit the model size and computational cost. Another important feature of our model is location tracking via GPS module. Location tracking is used in an automobile for tracking positions. We can sketch a car anti-theft gadget primarily based on global system for mobile communications (GSM) and GPS modules. The device is developed based totally on the high velocity of a one-chip C8051F120 and became aware of the vehicle [21] stolen to the car owned by using the vibration sensor. The caring role can be completed through the GPS gadget connected to the anti-theft system. Then, the proprietor of the car identifies the robbed car and gets back to his stolen car by using GPS technology.

2. PROPOSED MODEL ARCHITECTURE

The proposed guiding glass architecture of our guiding glass is shown in Figure 1. Given the system design diagram includes a Raspberry pi camera module on the module's catches, the video stream rounds the blind, and it was sent to the processing unit. It also contains a NEO6M GPS module, two ultrasonic sensors angle at ninety and thirty degrees severally. It additionally carries a headphone.

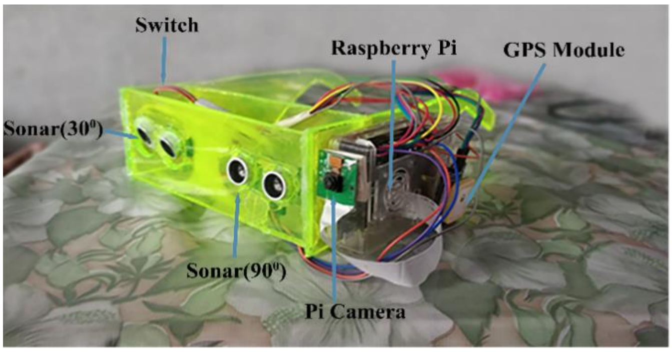


Figure 1. Hardware structure of the proposed smart guided glass

The calculations of hole and obstacle distance are shown in Figure 2. Here the distance is calculated using an ultrasonic device sloping at 30 degrees along with the frame. The first measurement was done for a person whose height was 64 inches (165 cm). The sonar sensor to ground distance was Y=165cos30 (143 cm), and the blind man-to-hole distance was X=165tan30 (6 cm). When the distance was more than 145 cm, our proposed system sent audio instruction that a hole in front of the blind man about 95 cm to the ears. When the distance was 140 cm or less than 140 cm, then the smart glass had notified the blind man of a barrier in front of you. It observed 2 cm to any deeper before the visually impaired individual. An equivalent ultrasonic detector angle at 30 degrees had observed any style of a barrier. Its detection precision was very high. We experimented with different people of different heights in Table 1 and tested the efficiency of the device. It worked correctly in most situations. The general expression of barrier and hole detection is shown in (1):

$$Y = X cos\theta \tag{1}$$

where Y is the distance sonar to the ground, and X is the height of the blind man. Here θ is kept constant at 30 degrees. As we measured any type of holes and barrier distance by using 30 degrees angled sonar sensor, it is also important to calculate the obstacles in front of the visually impaired person. 90 degree angled sonar sensor calculates the distance parallel to the ground. Our system was effective for a distance of about 300 cm.

So, it could notify the blind individual as "An obstacle in front of you about *d* cm". Then object recognition process recognized the object. Table 1 represents the change of distance to the sonar and sensor to ground associated with different height person.

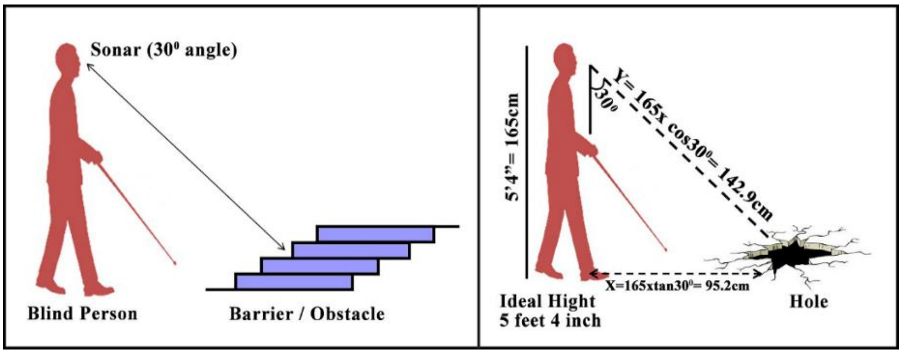


Figure 2. Sketch representation of hole and barrier detection

Table 1. Represents different heights associated sonar to hole and barrier minimum distance

Sl #	Height (cm) (X)	Sonar to ground distance (cm) (Y)	Sonar to hole distance (cm)	Sonar to barrier distance (cm)
1	182.88 (6')	158	>160	<156
2	177.69 (5'10'')	154	>156	<152
3	165.45 (5'4'')	143	>145	<140
4	157.58 (5'2')	136	>138	<134
5	152.4 (5')	132	>134	<130
6	142.32 (4'8'')	123	>125	<121

Another important feature is object recognition and provides associated audio information to the blind man's ears. In our proposed work, the TensorFlow framework was employed to acknowledge all types of objects [22]. TensorFlow is an open-source and American Standard Code for Information Interchange (ASCII) textual content file software program gadget library for dataflow and differentiable programming tasks. Here, the inception network was used for object recognition in TensorFlow. Inception network strategy is to avoid bottlenecks and directly allowing information flow through the network. It gives vital frameworks for neural network configuration. During these frameworks, ANN are described by procedure graphs. For beholding, 1st initialized the pi camera, and it took concerning one minute to initialize. Then the grabbed video frame compares with the TensorFlow library info. Google TensorFlow library info contains one million object data. It had obstacle size, shape, length, and specific feature data. When our module collected a picture of the obstacles, then the Raspberry pi 3 modules were compared with the TensorFlow library info and predicted what object before the blind person. The object recognition algorithmic program is shown in Figure 3.

Our guiding glass can transfer location information to the family member when needed. A NEO6M GPS module can detect the latitude and longitude value and send it to the specific mail. We attached a switched beside the guiding glass and when the blind individual felt that he/she wanted to send position information to the family member, then pressed the button. A mail was sent to a specific person, and it carried out latitude and longitude values. Then family members could identify the blind individual position via Google map. It can detect area coordinates from four satellites.

Figure 4 represents the schematic layout of four satellites and the GPS receiver system. The GPS measurement is associated with 4 equations with 4 unknowns x, y, z, and t_c [23]. Where t_c is the time correction, x, y, z is the receiver's coordinates acquired from GP. The equations are given in (2):

$$\begin{aligned} d_1 &= c(t_{t1} - t_{r1} + t_c) = \sqrt{(x-x_1)^2 + (y-y_1)^2 + (z-z_1)^2} \\ d_2 &= c(t_{t2} - t_{r2} + t_c) = \sqrt{(x-x_2)^2 + (y-y_2)^2 + (z-z_2)^2} \\ d_3 &= c(t_{t3} - t_{r3} + t_c) = \sqrt{(x-x_3)^2 + (y-y_3)^2 + (z-z_3)^2} \\ d_4 &= c(t_{t4} - t_{r4} + t_c) = \sqrt{(x-x_4)^2 + (y-y_4)^2 + (z-z_4)^2} \end{aligned} \quad (2)$$

where c is known as the speed of light, i.e., 3×10^8 *m/s*. t_{t1}, t_{t2}, t_{t3}, t_{t4} times that GPS satellites 1, 2, 3, and 4, respectively, transmitted their signals (these times are provided to the receiver as part of the information is sent). t_{r1}, t_{r2}, t_{r3}, t_{r4} times when signals are received from GPS satellites one, two, three, and four. x_1, y_1, z_1 GPS coordinates directly from satellites. The receiver of the GPS module solves these equations concurrently to found out the value of x, y, z, and t_c.

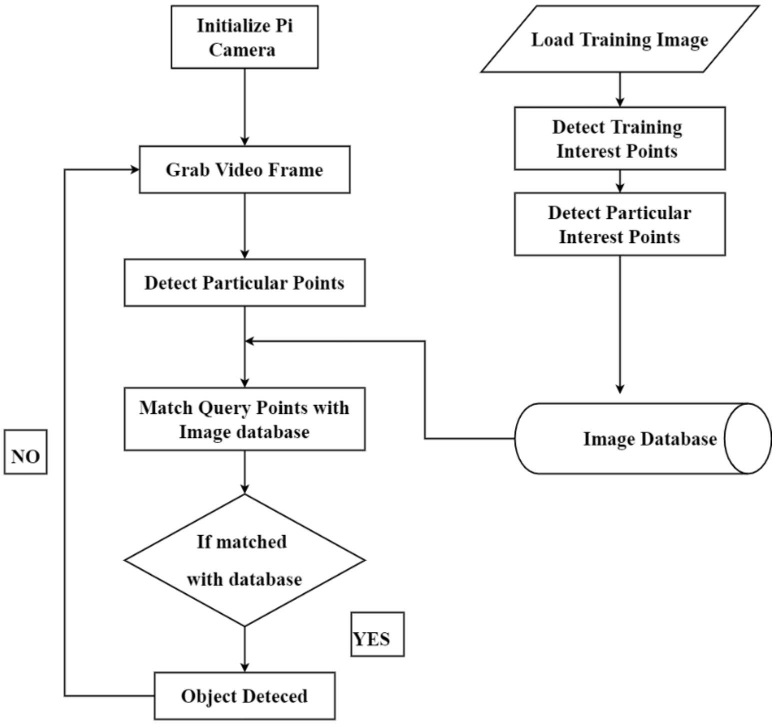


Figure 3. Proposed algorithm for object recognition

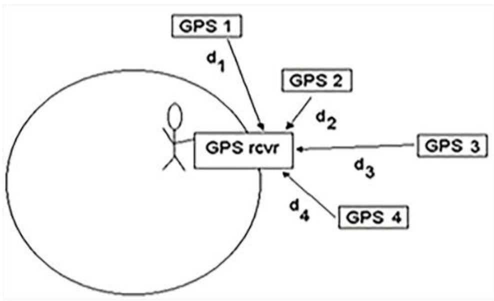


Figure 4. Schematic representation of four satellites and the GPS receiver system

This section represents the family member recognition procedure of our proposed guided glass system. We used the faster R-CNN method for the recognition process faster region recognition then applies a CNN which makes the recognition process high accuracy. Figure 5 represents the training and real-time family member recognition method of our proposed system.

We use the inception v3 model in training. The model was fine-tuned by the dataset. In faster R-CNN [24], [25], the very first thing was region proposal network (RPN). In the beginning, it found out the face within the image then apply CNN classification to it. So, for the train of the network, we used 2,280 images with 5 different categories. Among the images 452 images were the happy face, 402 images were the sad face, 432 images were the worried face, 502 images were the surprised face and 492 images were the neutral face. The ratio of training, testing, and validation were 4:1:1. Figure 6 represents our used training images with xml file. The xml file, containing the level mapping information as name, height, the width of a picture. Figure 7 represents the total loss of the training process. After about 20,000 iterations the loss was less than 0.02. So, our training was good as its normal standard is 0.05.

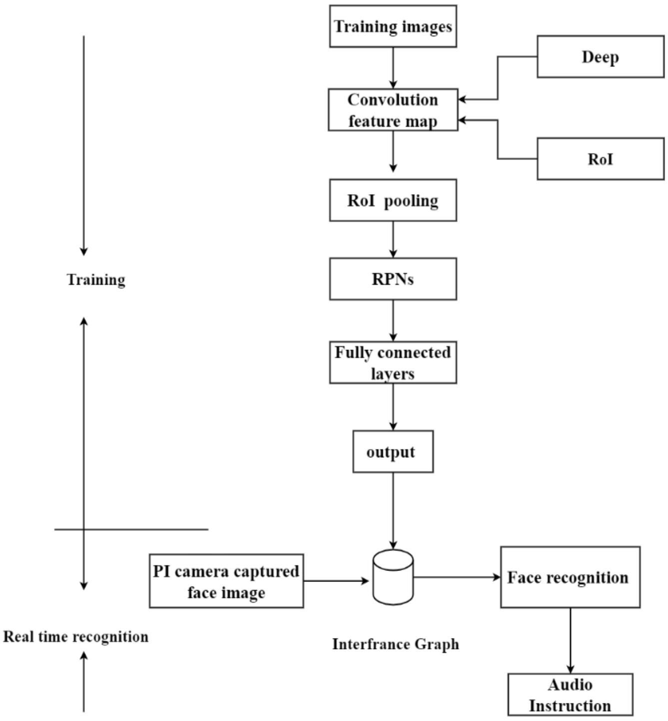


Figure 5. Flow chart of real-time recognition of family members

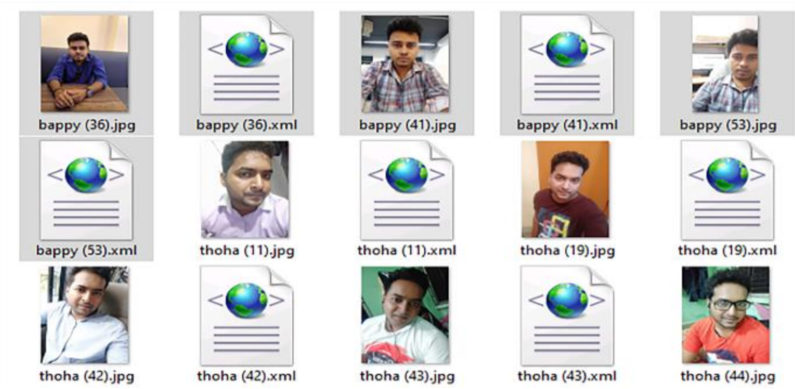


Figure 6. Represents training images with the xml file

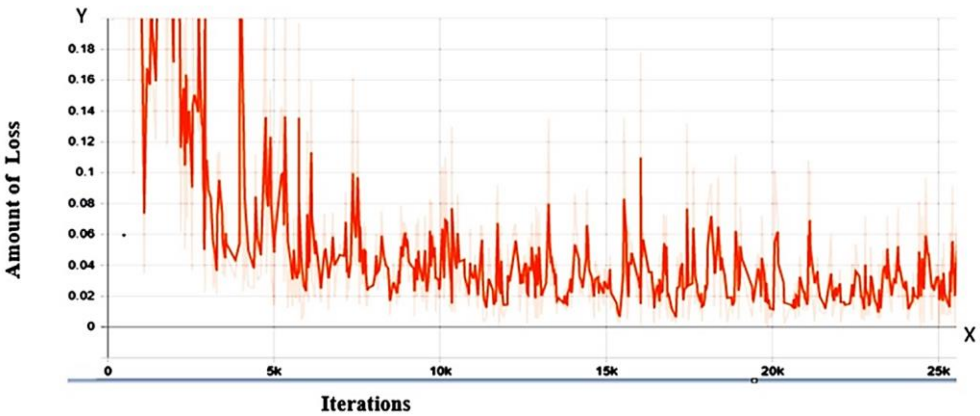


Figure 7. Total loss during the training, where the X-axis represents the number of iterations and the Y-axis represents the amount of loss

3. RESULTS AND DISCUSSION

Our smart glass successfully detected the barrier and notified the blind man as shown in Figures 8. Here, Figure 8(a) represents plane surface and Figure 8(b) barrier in front of the man. It was found that 2 cm to any deep and barricades ahead of the visually handicapped person. We showed that our guiding glass found objects before the blind person within a distance of 2 to 400 cm. When our system found a car about 200 cm in front of it, then it automatically recognized the car and sent audio instruction "an object in front of you about 2 meters distance, and it is a car" to the ears of the visually impaired people. Object identification are shown in Figure 9, where Figures 9(a) to 9(c) represents practically object recognition at different places by using our module.

(a) (b)

Figure 8. Represents barrier and hole detection performance analysis of our module (a) on the plane surface (not any audio instructions) and (b) barrier in front of the man ("a barrier in front of you" instruction)

(a) (b) (c)

Figure 9. Real-time object detection by using proposed glass module at different places (a) "a car in front of you" audio instructions, (b) "a chair in front of you" audio instructions, and (c) "a dustbin in front of you" audio instruction

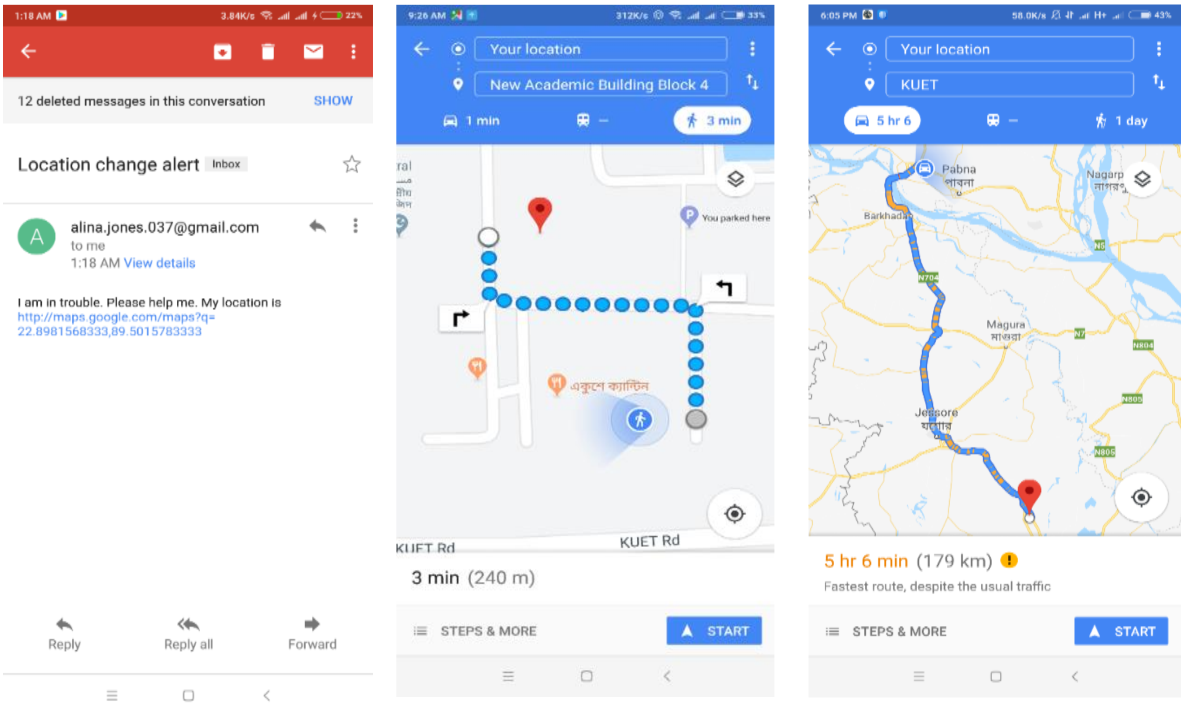
Table 2 represents object identification in various places on the university campus. Here we give some real-time recognition data with associated distance information. Mail information was "I am in trouble; please help me. My location is 22.09829T89.50255". The mail represented the longitude and latitude value, and family members found out the blind individual within a second by using Google Maps. The mail can be shown as in Figures 10. Here, Figure 10(a) represents snapshot of email information, Figures 10(b) and 10(c) also represents different location information of the blind individual which was sent to the family member. Using Google Map, the family member could also know the distance in meters and way distance in time by walk, train, bus.

The GPS data was taken using the proposed guiding glass in various locations. The information was taken from the new academic building blocks (Newacd-blocks). GPS information in the new academic building of our guiding glass and google actual values are given in Table 3 and displayed in Figures 11, where Figure 11(a) represents actual location value plot and Figure 11(b) actual and module location information of vision impairment individual. GPS information from our proposed guiding glass has a little different than the actual location found on the Google map. Our A, B, C, D blocks locations have about 3 m, 55 m, 79 m, and 38 m values different from the actual location. We found a percentage error of about 0.0009% to 0.004% during A, B, C, D blocks.

Our system successfully recognized the person in front of the glass. Using faster R-CNN its recognition accuracy was very high compared to SVM, R-CNN, KNN CNN, and Fast R-CNN. For family member recognition, the system accuracy was 98.89%. Figure 12 represents family member recognition with name information in Figures 12(a) and 12(b) known faces with name information. Figure 12(c) an unknown marked face that was not present in the module database. These recognition results were produced audio information like “Thoha’ in front of you”. In this way, the blind individual knew who was in front of him or her.

Table 2. Represents different object detection associated with audio instructions

SL#	Original → identified object	Obstacle distance (cm)	Voice instruction
01	Laptop →Laptop	300	The object in front of you is about “3” meters and it is a “laptop”
02	Table →Chair	208	--- “2 “meters and it is “chair”
03	Mobile →Cell phone	300	--- “3 “meters and it is “cell phone”
04	Desktop →Monitor	200	--- “2 “meters and it is “monitor”
05	Fan →Electric fan	300	--- “3 “meters and it is “electric fan”
06	Book →Book	360	--- “3 and a half meter” and it is “book”
07	Bottle→ Water bottle	400	--- “4 “meters and it is “water bottle”
08	mouse →Mouse	230	--- “2 “meters and it is “mouse”
09	Pen →Fountain pen	100	--- “1“meters and it is “fountain pen”
10	Lighter →Lighter	400	--- “4“meters it is “lighter”

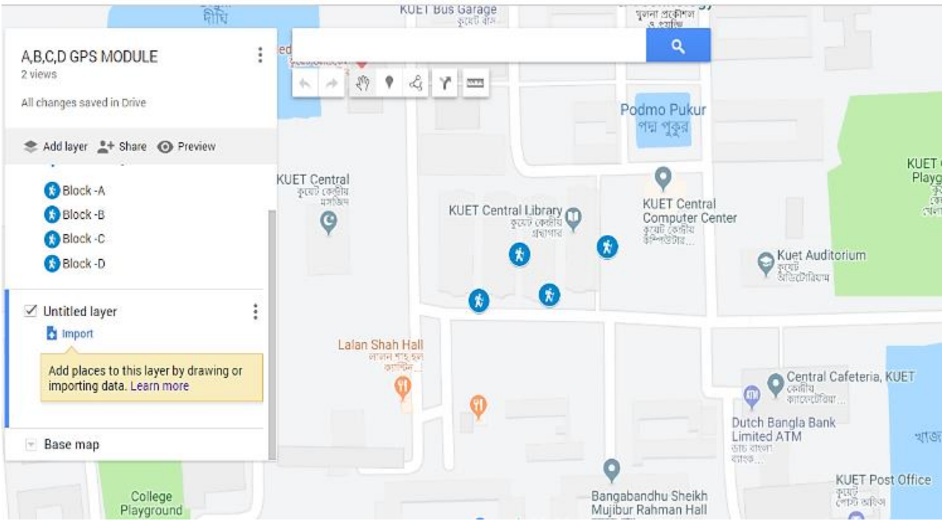


(a) (b) (c)

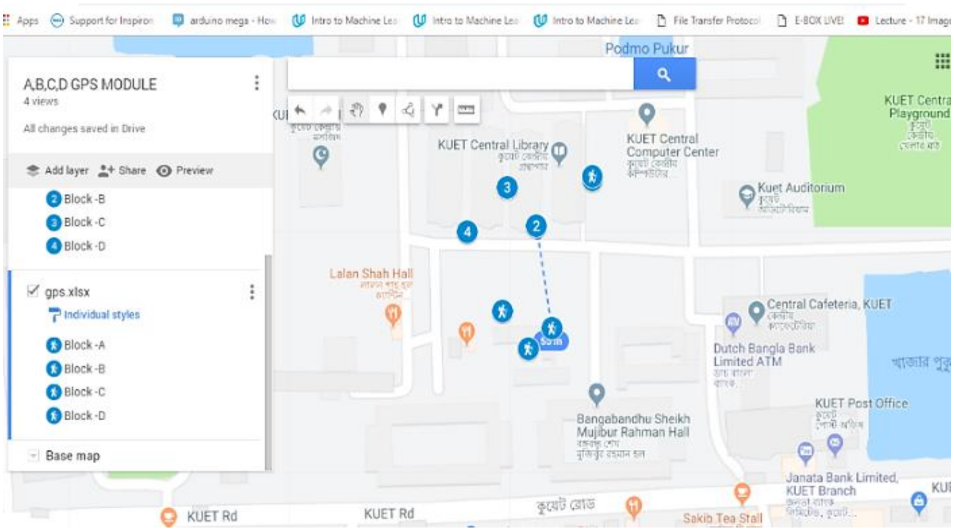
Figure 10. Performance analysis of GPS features of our proposed blind glass module (a) snapshot of email information, (b) and (c) snapshots of location information of the blind man which was sent to the family member

Table 3. Module accuracy identification in the academic building (Newacd-blocks)

Location	Module GPS values		Actual GPS values from Google map		Percentage error
	Latitude	Longitude	Latitude	Longitude	
Newacd -A	22.89923	89.50200	22.89922	89.50200	0.0009%
Newacd-B	22.89899	89.50166	22.89845	89.5016	0.002%
Newacd -C	22.89917	89.50146	22.89834	89.5015	0.004%
Newacd -D	22.89893	89.50120	22.89854	89.5015	0.002%



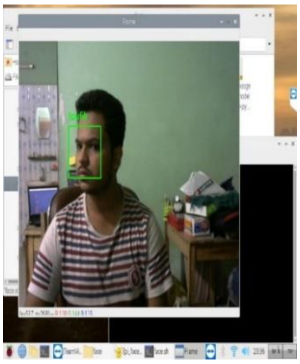
(a)



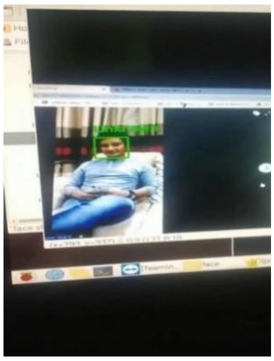
(b)

Figure 11. Represents snapshots of A, B, C, D block GPS location (a) actual location and (b) actual location and module GPS location plot information of vision impairment individual

(a)



(b)



(c)

Figure 12. Represents real-time face recognition by using a PI camera after completing the training during software build-up section (a) known face “Thoha”, (b) known face Toufik, and (c) face was not present in the database so recognized by unknown face

4. CONCLUSION

We introduced a smart guiding glass that can provide necessary information to visually impaired people. Using a machine-learning algorithm, the smart guiding glass can quickly identify all types of objects, and the person who was in front of them. The audio instructions were effectively sent to the ears of the visually impaired individual. We hope that our proposed guiding glass would be much helpful for blind individuals. In addition, the location tracking would also be beneficial for the blind individual indoors and outdoors atmosphere. We believe that the government or high-tech company will build this product commercially for blind people.

REFERENCES

[1] E. Ferreyra and A. Balantani, "Understanding visual impairment: a CA-CV approach for cognitive computer vision," in *2018 14th International Conference on Intelligent Environments (IE)*, 2018, pp. 99–102.

[2] J. Bai, S. Lian, Z. Liu, K. Wang, and D. Liu, "Virtual-blind-road following-based wearable navigation device for blind people," *IEEE Transactions on Consumer Electronics*, vol. 64, no. 1, pp. 136–143, Feb. 2018, doi: 10.1109/TCE.2018.2812498.

[3] E. Brady, M. R. Morris, Y. Zhong, S. White, and J. P. Bigham, "Visual challenges in the everyday lives of blind people," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Apr. 2013, pp. 2117–2126, doi: 10.1145/2470654.2481291.

[4] N. Rachburee and W. Punlumjeak, "An assistive model of obstacle detection based on deep learning: YOLOv3 for visually impaired people," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 11, no. 4, pp. 3434–3442, Aug. 2021, doi: 10.11591/ijece.v11i4.pp3434-3442.

[5] E. E. O'Brien, A. A. Mohtar, L. E. Diment, and K. J. Reynolds, "A detachable electronic device for use with a long white cane to assist with mobility," *Assistive Technology*, vol. 26, no. 4, pp. 219–226, Oct. 2014, doi: 10.1080/10400435.2014.926468.

[6] B. Ando, "A smart multisensor approach to assist blind people in specific urban navigation tasks," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 16, no. 6, pp. 592–594, Dec. 2008, doi: 10.1109/TNSRE.2008.2003374.

[7] E. C. Guevarra, M. I. R. Camama, and G. V. Cruzado, "Development of guiding cane with voice notification for visually impaired individuals," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 8, no. 1, pp. 104–112, Feb. 2018, doi: 10.11591/ijece.v8i1.pp104-112.

[8] M. Kelemen *et al.*, "Distance measurement via using of ultrasonic sensor," *Journal of Automation and Control*, vol. 3, no. 3, pp. 71–74, 2015.

[9] H. Siswono and W. Suwandi, "Glasses for the blind using ping ultrasonic, ATMEGA8535 and ISD25120," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 18, no. 2, pp. 945–952, Apr. 2020, doi: 10.12928/telkomnika.v18i2.12419.

[10] C. Geol Kim, S. Eon Kim, W. Hwan Na, and B. Seop Song, "Development of a Walker with ETA for the visually impaired people," *Indian Journal of Science and Technology*, vol. 9, no. S1, Dec. 2016, doi: 10.17485/ijst/2016/v9iS1/110277.

[11] L. Dunai, G. P. Fajarnes, V. S. Praderas, B. D. Garcia, and I. L. Lengua, "Real-time assistance prototype-A new navigation aid for blind people," in *IECON 2010-36th Annual Conference on IEEE Industrial Electronics Society*, Nov. 2010, pp. 1173–1178, doi: 10.1109/IECON.2010.5675535.

[12] J. Hancock, M. Hebert, and C. Thorpe, "Laser intensity-based obstacle detection," in *Proceedings. 1998 IEEE/RSJ International Conference on Intelligent Robots and Systems. Innovations in Theory, Practice and Applications (Cat. No.98CH36190)*, 1998, vol. 3, pp. 1541–1546, doi: 10.1109/IROS.1998.724817.

[13] J. Bai, S. Lian, Z. Liu, K. Wang, and D. Liu, "Smart guiding glasses for visually impaired people in indoor environment," *IEEE Transactions on Consumer Electronics*, vol. 63, no. 3, pp. 258–266, Aug. 2017, doi: 10.1109/TCE.2017.014980.

[14] J. Ai *et al.*, "Wearable visually assistive device for blind people to appreciate real-world scene and screen image," in *2020 IEEE International Conference on Visual Communications and Image Processing (VCIP)*, Dec. 2020, pp. 258–258, doi: 10.1109/VCIP49819.2020.9301814.

[15] Z. Kadim, M. A. Zulkifley, and N. Hamzah, "Deep-learning based single object tracker for night surveillance," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 4, pp. 3576–3587, Aug. 2020, doi: 10.11591/ijece.v10i4.pp3576-3587.

[16] A. S. Bin Sama, "Enhancement and development of smart glasses system for visually impaired persons by using intelligent system," *International Journal of Computer Science and Mobile Computing*, vol. 9, no. 8, pp. 40–49, 2020.

[17] N. R. Gavai, Y. A. Jakhade, S. A. Tribhuvan, and R. Bhattad, "MobileNets for flower classification using TensorFlow," in *2017 International Conference on Big Data, IoT and Data Science (BID)*, Dec. 2017, pp. 154–158, doi: 10.1109/BID.2017.8336590.

[18] J. Li *et al.*, "Facial expression recognition with faster R-CNN," *Procedia Computer Science*, vol. 107, pp. 135–140, 2017, doi: 10.1016/j.procs.2017.03.069.

[19] H. Jiang and E. Learned-Miller, "Face detection with the faster R-CNN," in *2017 12th IEEE International Conference on Automatic Face and Gesture Recognition (FG 2017)*, May 2017, pp. 650–657, doi: 10.1109/FG.2017.82.

[20] A. E. Tio, "Face shape classification using Inception v3," *Computer Vision and Pattern Recognition*, Nov. 2019

[21] M. T. Islam, M. Ahmad, and A. shingha Bappy, "Development of a microprocessor based smart and safety blind glass system," in *2019 International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering (IC4ME2)*, Jul. 2019, pp. 1–4, doi: 10.1109/IC4ME247184.2019.9036504.

[22] B. N. K. Sai and T. Sasikala, "Object detection and count of objects in image using tensor flow object detection API," in *2019 International Conference on Smart Systems and Inventive Technology (ICSSIT)*, Nov. 2019, pp. 542–546, doi: 10.1109/ICSSIT46314.2019.8987942.

[23] C.-H. Wu, W.-H. Su, and Y.-W. Ho, "A study on GPS GDOP approximation using support-vector machines," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 1, pp. 137–145, Jan. 2011, doi: 10.1109/TIM.2010.2049228.

[24] W. Zhang, S. Wang, S. Thachan, J. Chen, and Y. Qian, "Deconv R-CNN for small object detection on remote sensing images," in *IGARSS 2018-2018 IEEE International Geoscience and Remote Sensing Symposium*, Jul. 2018, pp. 2483–2486, doi: 10.1109/IGARSS.2018.8517436.

[25] X. Chen and A. Gupta, "An implementation of faster RCNN with study for region sampling," *Computer Vision and Pattern Recognition*, Feb. 2017.

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