Automated Walking Guide for Visually Challenged Individuals to Improve their Mobility

[1]CH.Santhi rani, [2]K.Manoj Kamal, [3]D.Mahesh, [4]S.Bhavana, [5]M.Kranthi
[1,2,3,4,5] *Department of Electronics and Communication Engineering, Usha Rama college of engineering and technology, Telaprolu-521 109, JNTUK, Kakinada, AP*

***Abstract*— This paper has enforced a spectacle model to assist visually impaired individuals with safe and economical walking within the surroundings. The walking guide uses 3 items of ultrasonic sensors to spot the obstacle in each direction, together with front, left, and right. additionally, the system will observe potholes on the paved surface victimization Associate in Nursing ultrasonic sensing element and convolutional neural network (CNN). The CNN runs on an Associate in Nursing embedded controller to spot obstacles on the surface of the road. pictures are to be trained at the start by employing a CNN on a laptop and square measure then classified on the embedded controller in a period of time. The experimental analysis reveals that the planned system has 98.2% accuracy for the front sensing element with a mistake (error) rate of 1.8% once the obstacle is at a 50 cm distance. additionally, the proposed system obtains the accuracy and loss severally for image classification. The experimental study additionally demonstrates that the developed device outperforms outstanding existing works.**

Index Terms: **Obstacle Detection, Pothole Detection, Visually Impaired People, Convolutional Neural Network, Ultrasonic Sensor.**

INTRODUCTION

One of the foremost daily issues encountered by visually impaired individuals is unsafe quality. They fail to find and avoid obstacles in their path, therefore inflicting their emotional suffering, undercutting their independence, and exposing them to injuries. A recent World Health Organization (WHO) statistic shows that their area unit some 253 million individuals around the world who are visually impaired. There are 217 million people with vision impairment, while 36 million individuals are blind.

People with Vision impaired individuals and vision ailments want help to perform regular tasks, like walking and exploring unfamiliar environments. Vision impaired individuals want help to perform their daily schedule, particularly in navigation. once people with vision impairment area unit in new or unfamiliar environments, they need to identify obstacles and alternative interferences to permit secure navigation. the analysis is that specializes in this downside to develop supporting devices or assistants for people with visual impairment. Some navigation devices and systems are presently offered for blind and visually impaired people. Seeing-eye dogs and white canes area unit the foremost important devices. However, their performance is proscribed in terms of speed, coverage, and skill that area unit typically available for individuals with actual eyes [1][2]. A cane can only detect obstacles at knee level and can't find head-level obstructions [3]. additionally, it will solely find an obstacle within a short-range (1 m).

Most walking assistants are developed with feedback signals supported obstacle detection. on-the-market devices for these people are in various forms like smart canes, smart glasses, hand-held tools, and completely different wearable formats. However, the acceptance rate of the on-the-market devices among these people is comparatively low, because of their sophisticated use, big size, excessive price, and heavyweight. The walking assistants that are developed with a mixture of many electronic sensors are shown to be correct in enhancing the vision-impaired individual’s daily activities. to boost the quality of the visually impaired folks, we have earlier introduced strategies like obstacle detection in the front direction and paved surface smoothness detection the system developed in [4] was ready to identify potholes however was solely sculpturesque within the simulation.

In this paper, we have a tendency to introduce a spectacle image capable of detecting obstacles ahead, left, and right of a user. In addition, we have a tendency to show an associate approach for police work potholes victimization image process. A CNN is employed together with a sonar sensing element for classifying road surfaces to seek out potential obstructions.

LITERATURE SURVEY

Several assistants were developed to guide people with visual impairments to navigate safely. For an extended time, many organizations are working to develop cost-effectively supportive devices for the people. The work associated with this area is shortly described as follows.

Obstacle detection:

Several sensors are used to accustomed develop varied kinds of supportive devices to supply obstacle detection and avoidance services. ultrasonic sensors square measure normally used among available sensors like infrared sensors, laser sensors, and dynamic vision sensors for obstacle detection. Most walking guides are developed using ultrasonic sensors for visually impaired individuals. Some assistant devices square measure introduced supported completely different sensor-based ways like infrared sensors, laser sensors, dynamic vision sensors, wave radar, and camera-based ways. The systems, which were developed for obstacle detection and/or avoidance, are outlined shortly as follows.

Lee et al. [5] used a camera and ultrasonic sensors to design a tool mounted on a combination of glasses for individuals with disabilities. The developed system recognized certain color-coded markers inside a 15m vary employing a recognition algorithm. ultrasonic sensors square measure employed in the front left, and right directions to spot obstacles.

Jiang et al. [6] developed a wearable tool to help people with disabilities using binocular vision sensors. the photographs square measure captured and sent to the cloud for computing from the real-world atmosphere. the information are processed using CNN and therefore the results are came to the users that can facilitate them in navigation. The system will find around ten objects.

Pothole:

There is a recommendation from specialists on orientation and quality that there's a scarcity of devices to differentiate between potholes and rough pitches that limit secure quality. The systems that are developed for pothole detection is outlined as follows.

Madli et al. [7] provided a theme for autonomous vehicles for automatic pothole and hump detection. The proposed theme used GPS to require the potholes and humps' geographic position coordinates that embody the potholes and humps' depth and height. The perceived knowledge is warehoused in cloud storage. The road knowledge remains hold on in an exceedingly info for a selected place. once observation on the road, an award notification is shipped to the driver employing a smartphone application. The user expertise of the system isn't well enough because it isn't integrated with Google maps.

Pan et al. [8] introduced a hollow and crack detection theme for asphalt pavement for the transportation systems. during this theme, multispectral pavement pictures are wont to find the pavement with potholes mistreatment machine learning algorithms. the info from the real-world atmosphere is collected utilizing remote-controlled aerial vehicles (UAV). However, the system cannot capture the cracks wherever the dimension is lesser than 13.54 millimetres.

Hari Krishnan et al. [9] enforced a road surveillance theme capable of detecting the potholes and humps on the paved surface. The vibration of the autonomous vehicle is collected through the accelerometer of the smartphone. The hindrances are known with the assistance of x-z filtering. The scheme conjointly determined the depth and altitude of the humps and potholes. This system cannot determine growth joints and holes.

Proposed work:

In the projected system, real-world knowledge is collected using ultrasonic sensors and a photographic camera. Then the information from sensors are processed in an embedded controller for obstacle detection and also the pictures from the camera square measure compared with the pertained model for potholes classification. the general system design of the developed prototype is shown in Fig. 1. The system sends an audio feedback signal to the user. The system is comprised of 2 modules that are represented as follows.

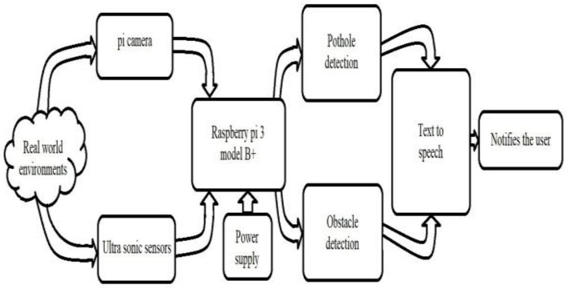


Fig. 1. Overall architecture of the proposed walking guide for the visually impaired individuals.

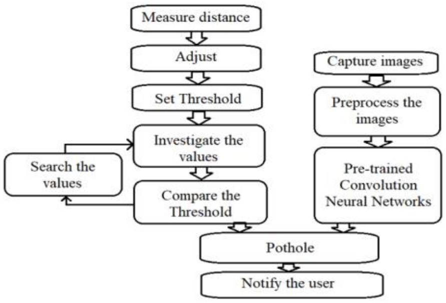


Fig. 2. Pothole detection procedure of the proposed walking guide for the visually impaired individuals.

Obstacle detection:

Three ultrasonic sensors square measure used for obstacle detection to help the individuals with vision impairment within the proposed system. These sensors find obstacles to the left, front, and right directions severally. the gap between the hindrance to the person is measured.

Pothole detection:

For pothole detection, a hybrid approach with the combination of sensing element and CNN is employed. The pothole sensing element facing toward the bottom is connected to the spectacle prototype. The camera captures the pictures and checks with a pertained model that has already been developed during a host laptop. The pothole detection procedure of the developed system is shown in Fig. 2

(i) Pothole Detection using Threshold Values:

The sonar sensor measures the distance from the spectacle to the bottom. A threshold value is ready and compared with the current distance. If it exceeds the threshold, it's considered a pothole. the threshold value calculation procedure considers the various situations of wearing the prototype. The setting of the threshold value could also be misguided by a single value. Hence, a sequence of values is noted in different directions ahead of the pothole. we have considered 10 values to set the threshold. the typical value for setting the threshold is calculated by (1).

$$Avg = \sum_{i=1}^{n} \mathit{distance}_i / n \qquad (1)$$

where n is the variety of distances. the threshold value is ready by repeating the method multiple times and also the average value that is recorded most times is set because the threshold is shown in (2).

$$Threshold = Maximum(Avg) \qquad (2)$$

(ii)Pothole detection using CNN:

By considering the datasets containing each non-pothole [10] and pothole pictures [11]. the dimensions of the retrieved non-pothole pictures are 1242×375. However, the hole images square measure of various sizes. to gather the information from the real-world atmosphere, we have a tendency to use a Raspberry Pi (RPi) camera with a resolution of 3280×2464 pixels. Data augmentation techniques are applied so as to prevent the network from overfitting. knowledge augmentation could be a way to generate new knowledge by rotating the image, moving the left/right/top/bottom image by a definite quantity, flipping the image horizontally or vertically, cutting or zooming the image, cropping, padding, scaling, and translating. The dataset square measure is divided into (80-20) % training-testing segments. The collected knowledge square measured in several resolutions, shapes, and sizes. Hence, pre-processing is completed on the collected knowledge to bring them to an equivalent format that produces it simple to fit into CNN. At last, all pictures square measure resized into 32×32 dimensions for correct input.

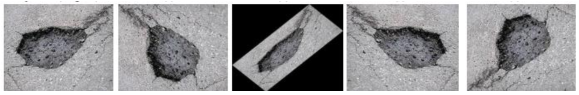
CNN:

The convolutional neural network structure used 2 convolution layers and 2 subsampling layers every succeeding just one convolution layer for hollow classification. Fig. 5 shows the CNN structure for pothole classification thought of during this work.

(a) (b) (c) (d)

Fig. 3. Sample images from the dataset: (a) Dataset non-pothole (b) Non-pothole collected using camera (c) Dataset pothole (d) Pothole collected using camera.

Plane (original) (a) (b) (c) (d)



Pothole (original) (a) (b) (c) (d)

Fig. 4. Images after applying data augmentation technique. (a), (e). 90-degree rotation (b), (f). 45-degree rotation (c), (g). Flip left to right (d), (h). Transpose.

The kernel size remains fixed for each convolution layer and is 5×5 whereas the dimensions of the pooling space are 2×2 in each subsampling layer. the pictures of the input area unit 32×32 that are thought of as 1024 linear nodes on that the convolution process is to be accomplished. Convolution operation with kernel spatial dimension five converts 32 spatial dimensions to 28 (32-5+1) spatial dimension wherever the dimensions of the image are 32×32 and also the size of the kernel is 5×5. Hence, the convolutional layer (C1) with a kernel size of 5×5 and 16 kernels offer an associate degree output of 28×28 within the initial convolution. The max-pooling procedure is employed with the dimensions of 2×2 and we used ReLU as associate degree activation operate. The feature maps of size 28×28 area unit subsampled by a 2×2 window and 16 feature maps with size 14×14 area unit achieved in subsampling layer S1. The output knowledge from S2 is convoluted with 32 filters of size 5×5 in convolution layer C2. The output data in C3 area unit 32 feature maps of size 10×10. The output knowledge from the past layer is subsampled by a 2×2 window to come up with 32 new feature maps with a size of 5×5 within the subsampling layer S2. Lastly, hidden layer nodes area unit connected to the 2 output layer neurons to classify pictures into 2 categories. within the output layer, the sigmoid classification is employed. Potholes within the output layer area unit were determined from a selected somatic cell and non-potholes from another somatic cell area unit were determined. When the value of the pothole neurons generates 1, the worth of alternative neurons becomes 0. The kernels area unit is updated at the side of the hidden-output weights whereas the training proceeds with 200 epochs.

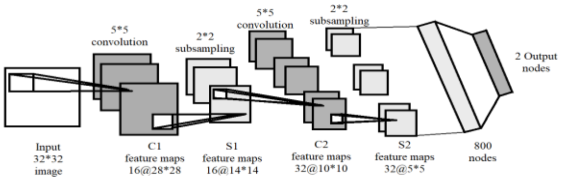


Fig. 5. CNN structure for pothole classification.

Implementation details:

We have used a pc powered by Intel Core i5 with eight GB RAM for developing the CNN model for pothole detection. additionally, Scikit-learn is employed in python's programming language as an associate degree open-source machine learning library. the general system was run in Raspberry Pi 3 Model B+. The careful description of the implementation section is printed as follows.

Prototype construction:

This design was made with Fusion 360 (student version). As a starting point, we used a rectangle shape with a length of 150-60mm. Then, using the Extrude command, the 2d rectangle is turned to 3d up to 150mm. We then used the Extrude Remove Material command to remove material to achieve the desired shape. Then we cut a 0.8cm circle out of the material and removed it. The sensors will be easier to place if the circle shape is removed. We made a square with 1cm sides for the camera positioning. Both the right and left support go through the same procedure. Sharp edges are rounded off with the Fillet and Chamfer commands in R20. As a result, the required design is completed, converted, and saved in .stl file format for 3d printing.

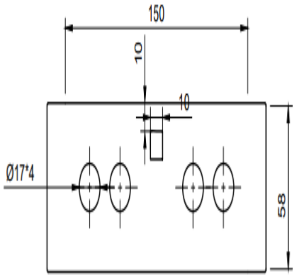


Fig. 6. (a) Front view

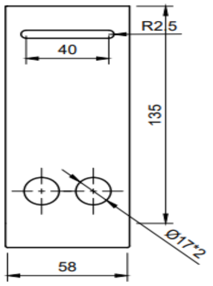


Fig. 6. (b) Side view

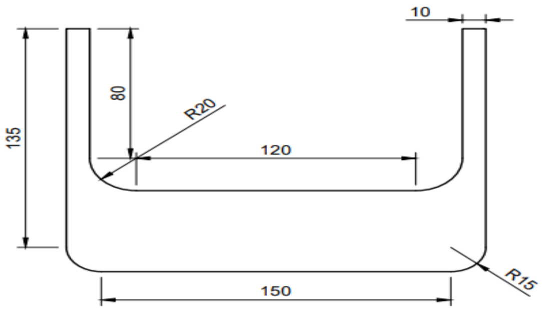


Fig. 6 (c) Top view

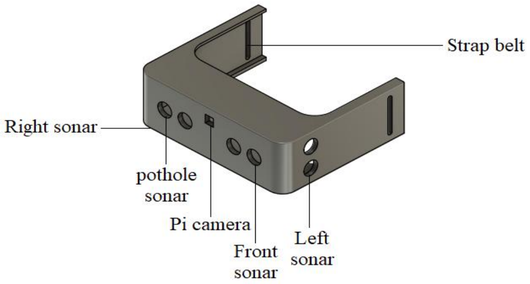


Fig.6. (d) Schematic diagram of the developed walking guide

Fig. 7. Prototype of the developed walking guide

SYSTEM IMPLEMENTATION

The walking guide was enforced within the sort of a spectacle example within which four ultrasonic sensors, an RPi camera, RPi controller, battery, and headphones are used. From Fig. 7, it is often shown that 3 ultrasonic sensors are used to notice obstacles in the front, left and right directions, and therefore the remaining one is employed for pothole detection facing toward the bottom. The RPi camera is found at the centre point of the prototype.

The communication between the users and therefore the example is administrated employing an earpiece that transmits the audio a message with the presence of obstacles on the way to walk. The module, Text to Speech (TTS) is employed for generating audio messages from the text. completely different styles of audio messages, that are played as feedback, are shown in Table I. If there's no obstacle found in any direction then any direction is often used for the navigation by the users. In this scenario, we've got disabled the text input for “No obstacle” that indicates that no hindrances are currently within the approach of walking; users will move in any direction. The projected system suggests the users' free path in which direction to move.

TABLE I. AUDIO FEEDBACK SIGNALS

Obstacle Situation	Audio Message
Obstacle located on right	Move front or left direction
Obstacle located on left	Move front or right direction
Obstacle located in front	Move left or right direction
Obstacle located on left and right	Move front direction
Obstacle located in front and right	Move left direction
Obstacle located in front and left	Move right direction
Obstacle located in front, left and right	Stop. All directions are blocked
Pothole detected	Pothole

EXPERIMENTAL RESULTS ANALYSIS

The developed system was evaluated both for obstacle and pothole detection. every part of the example is evaluated individually and therefore the overall system is tested once assembling all the elements. The experiment was performed in an exceedingly real environment to judge the performance of the system. We considered the outside environment because it contains each obstacle and potholes. The 3 obstacles area unit used as hindrances in 3 directions specifically front, left, and right severally. To conduct the experiment, we have a tendency to mark four regions on the front side, and these regions also are repeated in the left and right directions. The initial region is marked at 50 cm and therefore the final region is at 200 cm having a 50 cm interval between the regions.

The obstacles were positioned at variable lengths ranging from region one to region four in every direction. In every case, the data area unit is collected from the developed example. To analyse potholes, we have a tendency to consider a paved surface that contains four potholes on the surface that are of circular and rectangular shapes. it's noted that the potholes are created nearly. Afterward, the experiment was done with the ultrasonicsensor and camera module used for pothole detection and the camera module that continuously captured pictures and sent them to CNN for checking the presence of potholes

TABLE II. REAL TIME DATA COLLECTED USING FRONT ULTRASONIC SENSOR

Actual distance (cm)	Observed Distance (cm)					Average (cm)	Accuracy (%)	Error (%)	Standard Deviation	Variance
	1	2	3	4	5					
50	49.2	49.5	48.1	49.2	49.5	49.1	98.2	1.8	0.57	0.33
100	98.2	97.9	98.5	98.1	97.8	98.1	98.1	1.9	0.27	0.07
150	146.3	145.7	147.1	145.2	146.2	146.1	97.4	2.6	0.71	0.505
200	194.6	195.3	194.2	194.2	194.4	194.54	97.27	2.73	0.45	0.208

TABLE III. REAL TIME DATA COLLECTED USING LEFT ULTRASONIC SENSOR

Actual distance (cm)	Observed Distance (cm)					Average (cm)	Accuracy (%)	Error (%)	Standard Deviation	Variance
	1	2	3	4	5					
50	49.2	49.5	48.7	48.9	49.9	49.24	98.48	1.52	0.47	0.22
100	97.2	97.9	99.1	98.5	98.2	98.18	98.18	1.82	0.7	0.49
150	146.2	147.4	145.7	145.9	146.4	146.32	97.54	2.46	0.66	0.43
200	194.4	194.3	195.1	195.3	194.2	194.66	97.33	2.67	0.5	0.25

TABLE IV. REAL TIME DATA COLLECTED USING RIGHT ULTRASONIC SENSOR

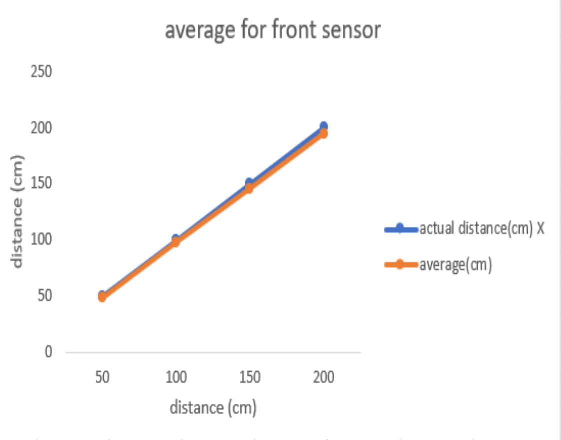
Actual distance (cm)	Observed Distance (cm)					Average (cm)	Accuracy (%)	Error (%)	Standard Deviation	Variance
	1	2	3	4	5					
50	49.1	48.3	49.8	48.9	49.7	49.16	98.32	1.68	0.61	0.37
100	98.1	98.3	98.9	97.1	97.5	97.98	97.98	2.02	0.7	0.49
150	145.2	146.3	148.2	145.1	148.8	146.12	97.41	2.59	0.8	0.64
200	195.2	195.5	194.4	194.1	194.2	194.68	97.34	2.66	0.63	0.39

A.Obstacle Detection:

The data are collected for the front, left, and right ultrasonic sensors by positioning obstacles in numerous orientations. For each interval, we've got taken data 5 times and calculated the average value of those data. we've got additionally estimated the accuracy, error rate, standard deviation, and variance of observed data. The collected knowledge from each sensor is represented in Table II, Table III, and Table IV. The comparison between actual distance and observed distance for front, left and right sensors are represented in Fig. 7(a), Fig. 7(b) and Fig. 7(c) respectively. These representations demonstrate the distortion of the observed distance to the real distance. The deformity is shown to be not severe, and also the observed distance is appropriate.

The accuracy and error rate at the side of the gap for all sensors are shown in Fig. 8 and Fig. 9 severally. From in Fig. 8, it will be noted that the best accuracy of 98.2% is achieved by the front sensing element once the particular distance is 50 cm. additionally, the best accuracy obtained by the left and right sensors is 98.48% and 98.32% severally at an equivalent distance. The accuracy is decreased with the rise in the distance. the best error rate was found at the particular distance of 200 cm which is concerning 2.66% for the correct sensor. The front and left sensors acquire the best error rate of 2.73% and 2.67% respectively at an equivalent distance (200 cm). From Fig. 9, it can be observed that with the rise in the distance, the error rate becomes high.

Standard deviation and variance are two closely associated measures of deviation. The lower worth standard deviation depicts the narrower deviation from the average. The variance measures the common unit to that every value varies from the mean. The larger value of the variance represents the greater data aim the system. the standard deviation and variance of the info collected by the developed system are illustrated in Fig. 10 and Fig. 11.



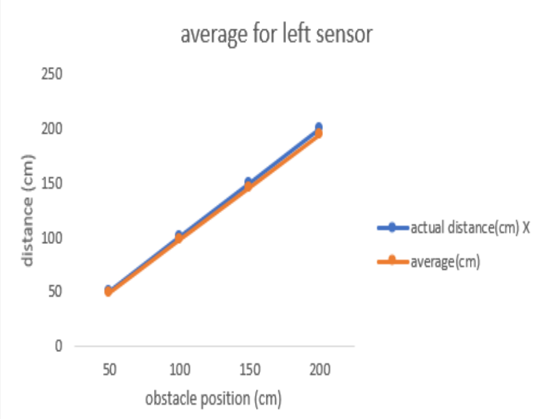
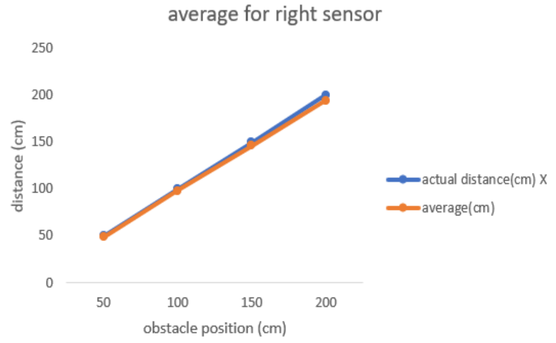


Fig. 7. (a)Fig. 7. (b)



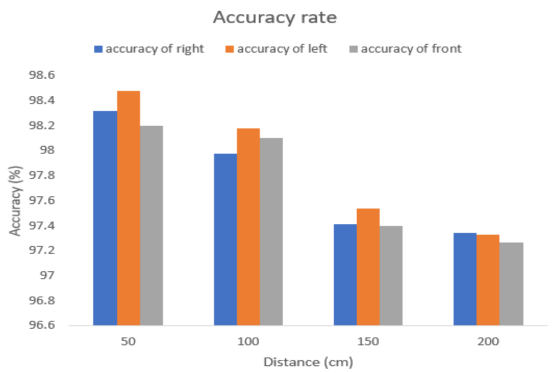
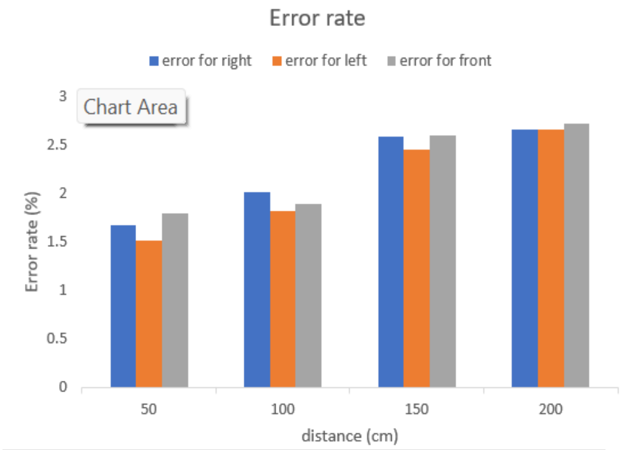


Fig. 7. (c) Fig. 8. Accuracy rate



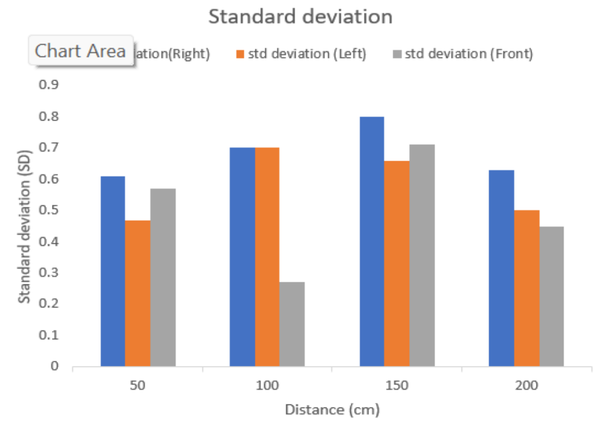


Fig. 9. Error rate Fig. 10. standard deviation

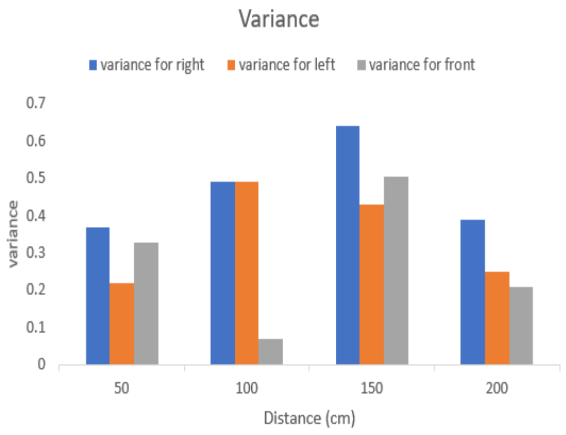


Fig. 11. Variance

POTHOLE DETECTION

As the pothole detection system uses both ultrasonic sensor and camera, the appropriate fusion between them is necessary. For this purpose, the information employing a sensor and also the images employing a camera are continuously taken. Whenever the sensor identifies a pothole signal and CNN additionally returns the same results indicating the pothole, then an audio signal is generated to alert the users. The pothole detection using a sensor uses a generated threshold to flag potholes. the threshold values are set once the device is powered on by averaging the primary ten values from the pothole detection sensor. Table V highlights some trials of threshold values measurement. From Table V, it can be observed that the edge values for 1st, 2nd, and 3rd users are 192.059 cm, 188.001 cm, and 180.984 cm severally. The user's height that's thought-about for the experiment is 165 cm, 160 cm, and 152 cm for 1st, 2nd and 3rd users respectively. The threshold value varies because of the various heights of the users. Any distance bigger than the threshold values depicts the presence of potholes.

TABLE V. MEASUREMENT OF THRESHOLD VALUES

Users	Measurement of threshold values for different users (cm)	Threshold Values (cm)
1	191.10, 191.32, 192.47, 192.31, 193.54, 191.56, 192.11, 191.07, 193.67, 191.44	192.059
2	188.37, 186.97, 189.75, 187.21, 186.93, 188.79, 186.79, 188.16, 188.88, 188.16	188.001
3	179.89, 180.55, 181.13, 180.12, 181.27, 180.29, 181.84, 180.84, 182.34, 181.57	180.984

CNN is trained with the sample pictures on a host pc. The developed model is transferred to Raspberry Pi 3 which predicts the presence of potholes by capturing one image each time. The experimental findings indicate that CNN generates a highly correct pothole detection scheme where 200 epochs are performed. In each epoch, we have evaluated the accuracy and loss of the training and testing phases. the accuracy obtained by the system is 84.44% and overall loss obtained by the system is 15.56% in the training section. the accuracy obtained by the system is 85.00% and the overall loss obtained by the system is 15.00% in the testing section. The performance measure parameters for the testing section are illustrated in Fig. 12, and Fig 13.

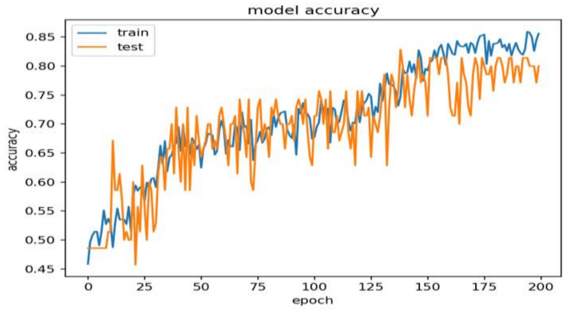


Fig. 12. Accuracy for training and testing phase

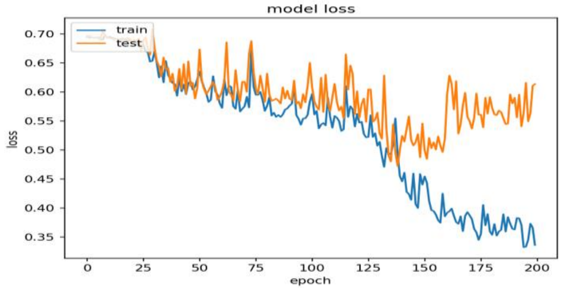


Fig. 13. Loss for training and testing phase

CONCLUSION

The main goal of this paper is to develop a walking guide to help vision-impaired individuals to navigate independently in their environment. The developed system consists of 2 main parts that are an obstacle and pothole detection. The obstacle detection system is meant to point out the presence of obstacles within the front, left, and right directions around the surroundings. The pothole detection system detects the potholes on the paved surface. the general electronic spectacle prototype, which might be used for guiding visually impaired people, is built in this paper. By analysing the data from ultrasonic sensors, the distance between the obstacle and the user is calculated. The pothole images are trained initially employing a convolutional neural network and therefore the potholes are detected by capturing one image every time. The notification to the users is provided with the presence of obstacles and potholes through audio signals by headphones. The developed walking guide could be a supporting aid for vision-impaired individuals.

REFERENCE

[1] S. Mahmud, X. Lin and J. Kim, "Interface for Human Machine Interaction for assistant

devices: A Review," in 2020 10th Annual Computing and Communication Workshop and Conference (CCWC), 2020, pp. 0768-0773.

[2] R. Tapu, B. Mocanu, and T. Zaharia, "Wearable assistive devices for visually impaired: A state of the art survey," Pattern Recognition Letters, 2018.

[3] N. Sahoo, H.-W. Lin, and Y.-H. Chang, "Design and Implementation of a Walking Stick Aid for Visually Challenged People," Sensors, vol. 19, no. 1, 2019.

[4] M. M. Islam and M. S. Sadi, "Path Hole Detection to Assist the Visually Impaired People in Navigation," in 2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT), 2018, pp. 268-273.

[5] C. Lee, P. Chondro, S. Ruan, O. Christen, and E. Naroska, "Improving Mobility for the Visually Impaired: A Wearable Indoor Positioning System Based on Visual Markers," IEEE Consumer Electronics Magazine, vol. 7, no. 3, pp. 12-20, 2018.

[6] B. Jiang, J. Yang, Z. Lv, and H. Song, "Wearable Vision Assistance System Based on Binocular Sensors for Visually Impaired Users," IEEE Internet of Things Journal, vol. 6, no. 2, pp. 1375-1383, 2019.

[7] R. Madli, S. Hebbar, P. Pattar, and V. Golla, "Automatic Detection and Notification of Potholes and Humps on Roads to Aid Drivers," IEEE Sensors Journal, vol. 15, no. 8, pp. 4313-4318, 2015.

[8] Y. Pan, X. Zhang, G. Cervone, and L. Yang, "Detection of Asphalt Pavement Potholes and Cracks Based on the Unmanned Aerial Vehicle Multispectral Imagery," IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 11, no. 10, pp. 3701-3712, 2018.

[9] P. M. Harikrishnan and V. P. Gopi, "Vehicle Vibration Signal Processing for Road Surface Monitoring," IEEE Sensors Journal, vol. 17, no. 16, pp. 5192-5197, 2017.

[10] J. Fritsch, T. Kühnl, and A. Geiger, "A new performance measure and evaluation benchmark for road detection algorithms," in 16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013), 2013, pp. 1693-1700.

[11] Pothole Detection Dataset. [Online]. Available: http://people.etf.unsa.ba/~aakagic/pothole_detection/, accessed on: Dec. 10, 2018.