A comprehensive assistive solution for visually impaired persons

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***Abstract*— People with vision loss need to make their lives more independent. The proposed system is capable to provide multi solutions in a single package with the ability to switch their algorithm from online to offline. The proposed work provides the indoor Navigation system with Object detection, object recognition and distance depth calculation. The system is also able to generate audio for object positions and object recognition using Text to Speech technology (TTS), and also take audio input from users to find out the objects using Speech Recognition technology. The proposed system consists of a Processing unit, Camera (depth Camera Kinect V2) for object detection and recognition using the YOLO V3 (You Only Look Once) Algorithm, headphones for audio input from a user and audio output from the system and power supply in case of free movement it would be batteries. The camera is mounted on the chest (can be mounted on the head), so whenever the VIP wants to search for anything the system guides them about the position of the object, and if VIP wants to move, the system assists in avoiding obstacles as well as wayfinding in the form of audio. The average accuracy of performance is 93%.**

Keywords*— *visually impaired person, Audio supervision, Depth Calculation, Kinect V2, Raspberry Pi, Pi Cam, Object recognition

I. INTRODUCTION

According to the report of IAPB (International Agency for the prevention of Blindness), the number of visually impaired persons in 2020 was 253 million among them 36 million are blind [1]. The reasons for the increasing number are cataracts, Uncorrected refractive error, Glaucoma, Age factor, Diabetic retinopathy, etc. This number increases as time passes, so need for such a system that is affordable and can assist them in moving freely. Blindness is a disability that cannot have any replacement like other disabilities, such as deafness can be reduced up to some extent using a cochlear prosthesis, disability due to legs can be overcome with the help of artificial legs or motorized wheelchair and so on.

A lot of numbers of blind people use a white cane for their movements, which is a very common and cheap navigation solution. It is not able to provide the complete solution of navigation such as object and person recognition and also not detect obstacles at a certain height, such as low branches of the tree. Even white cane cannot be used for searching things, so white cane cannot pick out all the essential information such as distance and feedback volume, however, by adding some sensors, RIDAR, SONAR, INFRARED and LIDAR makes it more useful which was proposed by many researchers. The guided dogs are also used by blind persons for navigation. However, the guided Dogs need a lot of training sessions and it is also an expensive solution that is not affordable for many blinds and also does not provide information about the obstacles with some height. Compared to these solutions, the ETA (Electronic travel Aid) can provide more information about the surrounding by adding more sensors.

The mature system GPS (Global Positioning System) is used for an outdoor navigation system with minimum accuracy error. GPS cannot be used for an indoor navigation system as a line of sight cannot be done for satellite signals inside or signal strength issues. The replacement of GPS in the case of indoor has been done by pre-installed different devices in buildings, that can be able to provide indoor navigation for VIPs. The advancement in Sensors, and wireless communication, Wi-Fi, RFID (radio frequency identification) readers, and tags, vision-based wayfinding (route finding) are all the replacements of GPS for indoor navigation. The requirements for indoor navigation systems are sometimes too high and required pre-installation. However, some of them are not recommended in certain buildings such as hospitals, where special requirements are needed for electromagnetic communication. The existing solution for indoor navigations can be categorized as Sensors based Navigation system (Ultrasonic, Infrared, RFID, Radar, LIDAR, etc), Wireless based Navigation system (GNSS, UWB, Zigbee, Pseudo satellite, IBeacon, etc), cellular-based Navigation system (GSM), Bluetooth Based Navigation (Bluetooth Beacons) and Wi-Fi-based Navigation System all have some pros and cons.

The major focus of the proposed work is to make a comprehensive system, which is independent of the pre-installation of any device. So that it can be helpful in those buildings which are not equipped with sensors, wireless modules, or indoor navigation systems and also capable of switching online to the offline algorithm in absence of the internet. This proposed system ensures the VIP to navigate to their destination and can also find the surrounding objects with distance estimation. The system is designed in such a way that if VIP wants to move in known or unknown buildings he/she is informed about the obstacles in front of him with estimated distance with the help of an RGB depth camera (Kinect V2) shown in figure 1. The proposed system is capable to recognize the objects and faces and be able in finding the objects inside of a room with audio feedback.

The rest of this paper is ordered as follows: Section II shows the Literature Review, Section III provides Methodology, Section IV shows the Final Results of the work, and Section V is based on the conclusion.

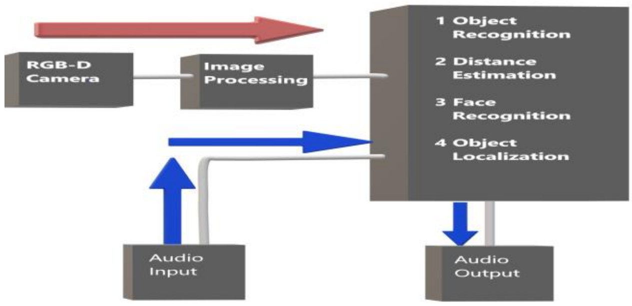

Fig 1. The Block Diagram of the Proposed system

II. Literature Review

A. Sensor-Based Navigation System

The enhancement in the white cane is done by adding sensors along with it. The Augmented cane with magnet reader, metallic trial, and different magnet points was installed in a different location for VIP to move independently [2]. The smart cane with the infrared sensor is used for static obstacles avoidance [3]. The UASISI system was introduced for indoor Navigation systems by using SONAR which is more cost-effective than RADAR and LIDAR [4]. The issue with sensor-based Navigation system is that VIP cannot exactly recognize the desired objects, the second thing is the sensors have a limited view of the angel so for full obstacle avoidance (Lower position, Middle Position, and Upper position of VIP) multi-sensors have to installed on the different parts of the body.

B. Wireless Network Based Navigation System

For the outdoor localization, the Global Navigation Satellite System (GNSS) can be used, on the other hand for Indoor localization due to signal attenuation, or blockage of signal GNSS cannot be used. For those sake different technologies Cellular Network, Pseudo-Satellite [5], Zigbee [6], Ultra Wide Band (UWB) [7], RFID [8], IR [9], Ultrasonic Sensor, iBeacon [10], SONAR LIDAR and RADAR are used. The continuous maintenance services required for all these wireless Navigation devices for the accurate result makes again dependent of the visually impaired person on others. Secondly, these devices are not cost-effective for long-range which is out of approach for poor people. The installation of these sensors in many more indoor regions is not feasible for developing countries.

C. Vision Bases Navigation System

Federica Barontini et al. proposed a wearable Haptic and Obstacle avoidance system for a visually impaired person with the help RGB-D camera for color image and depth image, the processing unit (Laptop) for image processing (corner detection) for obstacles avoidance, and a wearable fabric-based device known as CUFF (clenching upper-limb force feedback) that is mounted on the arm, provides normal and tangential force to arm on detected obstacles with the help of two DC motors [11]. The system is not powered efficiently in case of battery backup as the motor was proposed for instructions which more power.

Sreeraj M et al. proposed VIZIYON a devised based on IoT for object identification [12]. The proposed system will output audio for identifying objects and distance calculation between a blind person and obstacles with the help of an ultrasonic sensor. The component used in this system is Raspberry Pi (image processing), Pi cam (5mp), Arduino (for distance calculation from obstacles from the ultrasonic sensor), Ultrasonic (HC-SR04). The proposed system is bulky because they used two different processing units one is Raspberry pi (Microcomputer) and Arduino (Microcontroller), which is also not powered efficiently. The object identified by a cam and ultrasonic signal for the particular identified object is difficult to align, so the distance for the identified object is not possible in this way.

Imene OUALI et al. proposed architecture for text and object recognition (drugs recognition and pills counting and informing a blind person about remaining pills) using AR (Augmented Reality)[13]. VUFORIA AR software development kits are used for data storing (Pills Name data) and for accessibility.

Md Wahidur Rahman et al. proposed an architectural design for the assistance of blind persons with the help of deep learning and IOT [14]. The proposed system is classified into three portions. In the first portion, IOT based smart white cane is used for wayfinding and also real-time observation with the help of the cloud. The second one is the use of Deep learning for the detection of surrounding objects for the blind. The third one is Architecture design for virtual assistance. The system will be failed in the buildings with no pre-installed Wi-Fi and Bluetooth.

Jinhui Zhu et al. proposed a fog computing framework for a guided dog robot for the blind person the system is known as PEN (Phone + Embedded board + Neural Compute Stick) [15]. Their proposed guided dog system contains Visual function (that identify the surrounding obstacles and recognize obstacles and moving vehicles while crossing the road using SSD), Natural Language processing function, Decision function (the robot will not work on the command of a blind person if there are vehicles) and Motion function (the robot can move autonomously). The system is integrated lot of sensors cameras, motors, a processing unit that increases its cost, and still the area without the network like cloud or fog the system is failed to work properly.

Ningbo Long et al. presented work about object detection and object recognition for visually impaired persons [16]. Object Recognition was done with the help of SSD Network and R-CNN network. On comparison of SSD and R-CNN it was concluded that SSD is faster with time 100ms/frame but less accurate on other hand R-CNN takes a longer time of 2000ms/ Frame but is accurate in recognition. Both are trained on COCO Dataset. Object Detection was done by using the MeanShift Algorithm with the help of depth differences from depth images. The different ranges and angles of Obstacles (Object) were found with the help of MMW-Radar.

Shiwei Chen et al. Proposed system for visually impaired persons. The Major Objective of this paper is to find the right People, Identify the Common Objects and read Paper text. Hardware used are Raspberry Pi (local processor), Micro

Camera, Ultrasonic Sensor (for object detection), Infrared sensor (for Human detection) [17], connecting to the cloud via Wi-Fi or 4G. The server's recognition result will be transmitted to the client and then converted to voice feedback to the user through TTS (Text To Speech) technology. Aliyun, Baidu Cloud, and Tencent Cloud have their recognition Algorithms. Due to the lack of restriction and accuracy of Baidu AI, the Baidu cloud server is finally chosen If a captured image has some error like light effect, not contain a full face, the face is covered and so on then error code is generated and corresponding sound is produced for correction.LFW database is used for face recognition and the PASCAL VOC2007 dataset is used for object recognition. The recognition accuracy is 88% to 90%.

Adwitiya Arora et al. proposed a system in which Single Shot detection and MobileNet(which was further improved using PASCAL VOC) were used for detection and processing Raspberry Pi and COCO dataset for training were used [18]. In this proposed system the Camera is mounted on the cap, whenever the blind person focuses on an object the system will respond in recognition of the object and category of an object through voice.

Natal Henrique Cordeiro and Emerson Carlos Pedrino presented a work that provides the comparison of four techniques (Pattern Recognition (PR), Farneback Optical Flow (FOF), Background Subtraction (BS), and Continuously Adaptive MeanShift (CamShift)) for dynamic object detection (DTDO) [19].

A vision system with 3D Audio feedback for Navigation for visually impaired persons is proposed by Aakash Krishna GSaet al[20]. The deviation in the sound intensity of headphones facilitates a natural and spontaneous awareness of the relative location of objects in a way. The proposed system is comprised of three modules: depth calculation (with the help of stereoscopic vision), Object detection with help of CNN (Convolution Neural Network), and 3D audio generation. The Hardware used is Raspberry Pi, Pi Cam, and earphones. They concluded that the system is robust for indoor and outdoor and also for different light intensity, and the system depends on the remote server for object detection.

A wearable assistive device for VIP was proposed by Jinqiang Bai et al. that can navigate in strange places as well as used for Object recognition for indoor and outdoor locations [21]. The device consists of an RGB depth Camera, and IMU (Inertial Measurement Unit), which are installed on spectacles and smartphones. The device takes the ground height link among neighboring image frames to section the ground exactly and quickly and then searches the moving way according to the ground. A lightweight Convolution Neural Network (CNN)-based object recognition system is developed and implemented on the Smartphone to increase the awareness ability of VIPs and endorse the navigation system. It can provide semantic information of environments such as categories, locations, and orientations of objects.

The Uasisi (which means bat) system was proposed by J. Antonio Garcia-Macias et al. The working principle is an echolocation system using SONAR (Sound Navigation and Ranging) to position surrounding objects, the way like used by bats and dolphins [22]. The proposed system is modular and also can be integrated with other existing systems. The proposed system was categorized in levels, in level1 wearable modules (such as knee pad, bracelets), in level2 WBAN and cloud support (smartphone with BLE), in level3 smart environment(the presence of smart objects with semantic communication), and in level4 Recognition (using Machine learning technique for the awareness of blind persons about nearby persons or site of interest).

III. METHODOLOGY

The system is wearable, and it can be easily used by VIPs in any indoor building as shown in figure 2. The data from Kinect V2 is fed to the processing unit for getting RGB (Red Green Blue) information and Depth information (the estimated distance calculations of Objects) with the help of an Algorithm. Object recognition, face recognition done by algorithms YOLO V3 and LB.

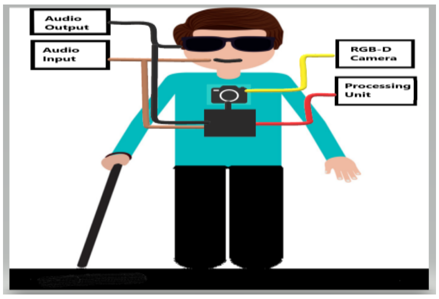

Fig. 2. A wearable System

The 4th important proposed solution is to find the location of the desired object which was done by using CONTOUR phenomena. The video display is not important for VIPs so that the Audio is fed back to them. With the help of audio, the impaired persons will decide independently moving forward with avoidance of obstacles. The text to speech (TTS) engine can be installed by installing Espeak in OpenCV Python [23]. The results of a proposed system assure the complete navigation system with avoidance of obstacles, information about surrounding objects, information about the distance between obstacles and the system, and information about the persons.

IV. SYSTEM IMPLEMENTATION

A. The Depth Calculation

The depth calculation is used to find the estimated distance of obstacles at front VIPs so that the user can change its direction accordingly. The Kinect V2 is used that outputs the color (RGB) image (Figure 3a) and the depth image (Figure 3b). The depth sensor helps find the position, shape, and dimension of an object. The field of interest parameter is the position of an object.

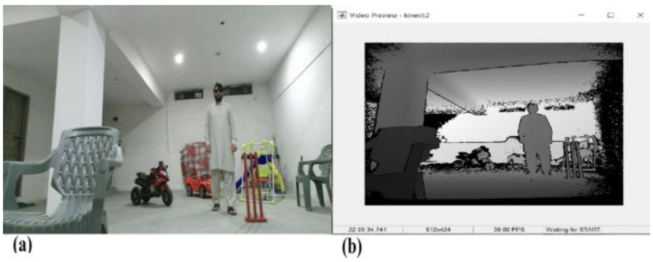

Fig.3. (a) Color Image, (b) Depth Image

The object can be any sort of obstacle that becomes a hurdle in the independent movement of VIPs. The system is capable in finding the three-dimensional view that is X-axis, Y-axis, and Z-axis. The Z-axis from the 3-dimensional depth image of Kinect gives the estimated distance of an object from the camera as shown in figure 4. In the below figure the four objects are placed, the chair is closer to the camera, then the wicket, then swings and then a toy, and at the end wall. The distance ode ac object is clear from 3-dimensional figure 4. Table 1 shows the depth estimated distance of each object in meters.

TABLE 1 DEPTH ESTIMATION

No	*Objects*	*Z-Axis Distance in Meter*
1	Chair	2.89m
2	Wicket	3.61m
3	Swing	4.45m
4	Toy	4.91m
5	End Wall	6.854m

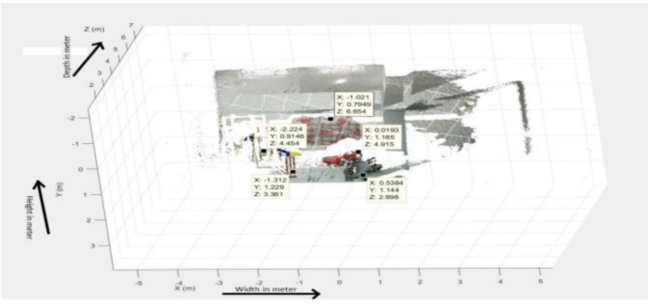

Fig.4. 3-Dimensional image from depth data of Kinect V2 with X-axis shows width, Y-axis shows Height and Z-axis Shows the depth of image

B. *Object Recognition*

The system is capable of recognizing the objects, which helps the VIP to get the awareness of their surroundings. The Deep learning Algorithm YOLO V3 was used for object recognition, with pre-trained models by using weight file, configuration file, and coco names files. After a comparison study of the different algorithms for object recognition, YOLO V3 was finalized due to its fast response. The trained COCO dataset was used. The programming result shown in figure 5, demonstrates the runtime output of the camera with close boxes and labels for recognized objects. The dataset contains limited objects images, which fulfil our requirement, these are mostly from day life using objects, like a cup, laptop, chair, mobile, person, bike, etc. The response was accurate and fast enough so that it can be implemented in any application. This phase of the research helps the VIP to know about the objects surrounding him.

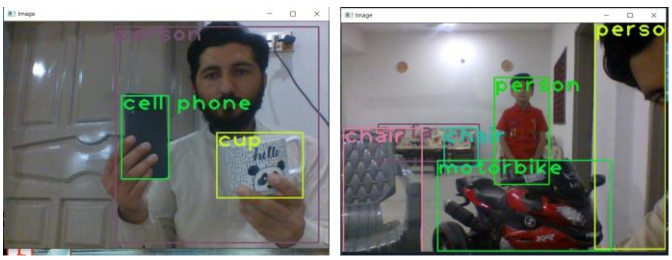

Fig.5. Object recognition using YOLO V3

C. *Object Locality*

The feature added in navigation for the blind persons is that, if the VIP wants to search any object, he will be informed by the system that the object is to the left, middle, or right of him. This process is done by using the Contour detection method. The Contour is the border around objects that has sound clear edges. As the object detected is bounded by boxes, which can be used for the process of contour detection. Figure 6 shows the X-axis and Y-axis dimensions of three trial boxes. The output of each box is X_min, X_center, X_max, Y_ min, Y_center, Y_max are given in table 2. The output axis of bounded boxes shows the location of an object, with the help of these coordinates the VIP is directed by the system to reach the desired object with an estimated approach.

TABLE 2 CONTOUR DETECTION

Coordinates	**Object Boxes**		
	Larger Box	***Smaller Box***	***Medium Box***
X _min	782	466	91
X _max	902	621	295
X Center	841	543	192
Y _min	56	168	106
Y _max	442	430	431
Y Center	248	298	248

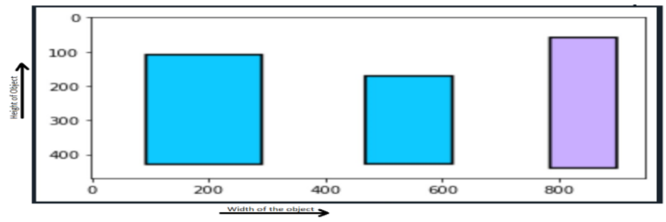

Fig.6. Contour Detection

D. *Face Recognition*

The most cases VIP needs to be recognized by the persons, like in crowded areas, the voice is not much helpful to call someone in such areas. Due to such reasons, face recognition is added in a proposed system, with a limited data set which helps in making a less computational and fast response system. There are many algorithms (Classifiers) for face recognition, among those the selected classifier is LBP (Local binary pattern), due to fast computation, simple, fast training time, robust to illumination and occlusion. The three steps involve training to prediction. At first prepare the training data by adding the images of the concerned person along with labels and detecting the faces along with integral labels, then secondly train face recognizer OpenCV LBPH by feeding the training data, at the end prediction is done by some test images. Figure 7 shows the face detected and recognized successfully. The data folder contains subfolders saved with folder names s1, s2, and so on, that contain the number of pictures of each person that has to be recognized. Each training pictures save with numbers 1,2, 3, etc.

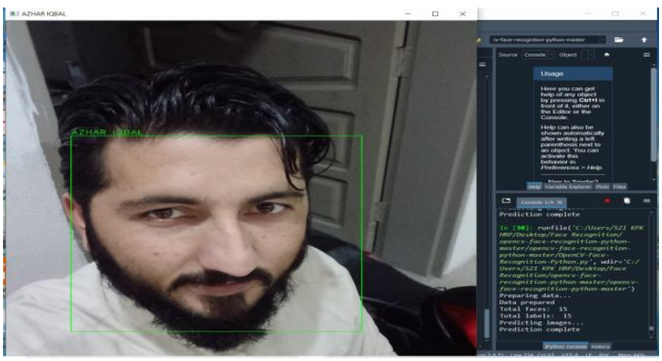

Fig.7. Face Recognition

E. Text to Speech

The text to speech is a key bone of the proposed work, as the instructions convey to VIP after recognition of faces, recognition of objects and obstacle avoidance are in the form of audio. The labels in case of the recognized object and recognized faces are in the form of text which is further converted into speech with the help of using the offline library “pyttsx3”, as the focus of the proposed system is to provide the solution for blind persons which is independent of pre-installed equipment and internet so that the user of the proposed system can exploit it anywhere.

F. Speech Recognition

The proposed system provides the maximum solution for daily life problems of VIPs, from independent movement to recognizing objects, faces, and searching surrounding items. For the sake of searching objects, the contour phenomena of computer vision were used. The bounding boxes around each recognized object are the contour phenomena of computer vision. The audio from VIP is interpreted in text and saved in a variable. Further variable (text) is matched with the labels of recognized objects and output the localization of object, which helps in finding the easy way.

G. Testing

The proposed system was tested in an indoor place and examined all the proposed features of research work. During investigation of object recognition and obstacles avoidance, the system was successfully capable of providing a path that was free of obstacles as shown in figure 8. The process of text to speech helped in issuing the audio commands like “left chair”, “Right table” and in case of no obstacles found the audio command was “follow the path” as shown in figure 8. In case going through stairs, the system was also successfully recognized the stairs which make the user move independently through stairs as well. For the sake of testing depth images, the distance between the user and different objects was successfully conveyed via audio. The person who was added to the dataset was recognized by system and informed the name of the user as audio shown in figure 10.

The important feature of searching items around the VIP was done by using contour application computer vision. The user of the system issued an audio command such as “cup”, “water bottle” or mobile, etc., the system responded to the audio about the position of the desired object like “left”, “right” or “front” to make it easier of reaching to the desired objects. This feature is dependent on the view angle of the camera which is mounted on the chest of the user (VIP). The starting and ending of the X-Coordinates and Y-Coordinates represent the object position as shown in figure 9. From these objects position coordinates, the system is capable of finding the object localization in the image and output the audio commands “left”, “Right” or “Centre” to direct the VIP.

Fig.8. the test results of obstacles detection recognition, wayfinding, depth estimation, and stair detection. All messages convey via audio.

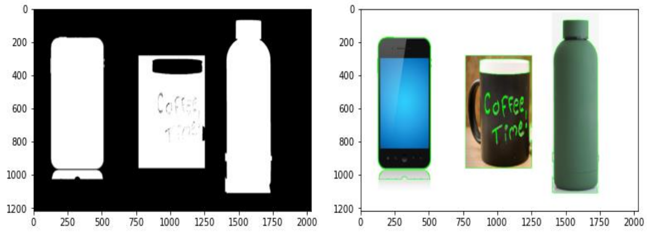

Fig.9. Object Localization using Contour.

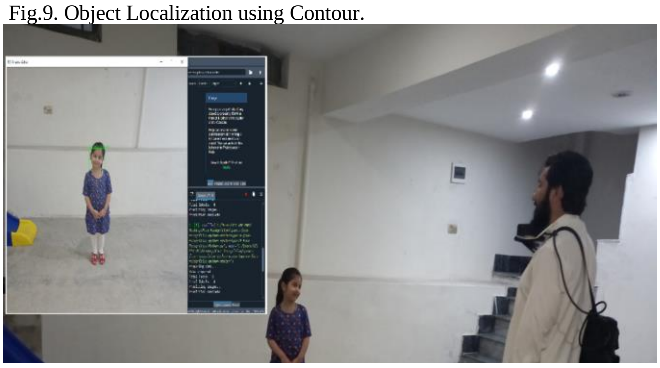

Fig.10. Face recognized with label “Anabi Azhar”

H. Results

The Confusion Matrix of different activities shows the performance of the proposed system. Similarly, table 4 shows the actual distances of different objects and the estimated depth distance from Kinect cam. The approximate distance is close enough to the original distance, as a result, the system successfully generated the right alarm for VIPs.

Object Recognition N=40	Predicted No	Predicted Yes
Actual No	9	1
Actual Yes	2	28

Accuracy=90% Error=10%

Face Recognition N=20	Predicted No	Predicted Yes
Actual No	6	0
Actual Yes	1	13

Accuracy=95% Error=5%

Location Recognition N=30	Predicted No	Predicted Yes
Actual No	7	1
Actual Yes	1	21

Accuracy=93% Error=7%

Text to Speech N=40	Predicted No	Predicted Yes
Actual No	10	0
Actual Yes	0	30

Accuracy=100 Error=0.00%

Speech to Text N=40	Predicted No	Predicted Yes
Actual No	10	2
Actual Yes	3	25

Accuracy=87.5% Error=12.5%

TABLE 4 THE COMPARISON BETWEEN ACTUAL AND ESTIMATED DISTANCE.

No	Objects	Depth Calculation from system	Actual Distance	Error %
1	Chair	2.89m	3m	3.66%
2	Wicket	3.61m	3.8m	5.00%
3	Swing	4.45m	4.6m	3.26%
4	Toy	4.91m	5.1m	3.72%
5	End Wall	6.854m	6.4m	6.95%

V. CONCLUSION

The proposed research work provides indoor multi solutions for the daily life problems, faced by visually impaired persons. One of the advantages of the proposed system is that it can provide independent movement for VIPs by obstacle detection, recognition and generates the audio using Text speech technology which helps them to take decisions accordingly while moving known or unknown buildings without pre-installed equipment. The other importance of the proposed system is that it helps in finding objects inside the room whenever the VIP issues the command in the form of audio for the desired object, this audio is converted into text using speech recognition technology, the text is matched with the labels of the desired object and the system directed the VIP to left, right or front according to the presence of the desired object. The system is capable of finding the estimated distance from the camera which is mounted on the body of the VIP to the object using depth calculation of the image. The system also provides the face recognition facility which makes it the multi-solution provider for making the life of VIPs more independent. The seven different works that make the proposed system complete are as follow.

- Object Detection via cv2.rectangle library of OpenCV.
- Object recognition using deep learning algorithm YOLO V3 (You only look once), which is fast in response as compared to other techniques.
- Face Recognition using LBPH (Local Binary Pattern Histogram), LBP combines with Histogram uses for face images as vector form, which is robust against monotonic grayscale conversion.
- Depth Calculation(RGB & depth image) using KinectV2
- Object Localization using contour application of computer vision.
- Text to Speech (TTS) using pyttsx3 library.
- Speech to text (speech recognition) using speech recognizer library in OpenCV python.

The proposed system almost completes all the basic needs of VIPs. The testing results show that the VIP is capable of moving independently with obstacles avoidance, successfully recognizing objects and faces, and also can successfully find the objects with an average precision of every task is 91.3%.

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