An assisting model for the visually challenged to detect bus door accurately

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ABSTRACT

Visually impaired individuals are increasing and as per global statistics, around 39 million are blind, and 246 million are affected by low vision. Even in India, as per the recent reviews, over 5 million visually challenged people are present. Authors performed a survey of some critical problems the visually challenged people faced in India from the centre for visually challenged (CVC) School established by UVSM Hospitals. Among the major problems identified through survey, most of these persons prefer carrying out their tasks independently, and depend on public transport buses for migration. However, critical sub-problems being faced include; bus door identification and identifying the bus route number accurately. This article aims to provide solutions in helping visually challenged individuals to identify exact bus that drives them to their destination, its door, bus number, and the path for boarding bus. A video sequence of current scenario would be sent to mobile, in which the actual processing of image is carried out. After the video sequence processing, generated output is a voice message that specifies the bus's location, door, and exact information of the bus number along the road path directly to the user using a wireless device aiming foa a low-cost solution.

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1. INTRODUCTION

According to the survey conducted by the WHO, about 4% of the total population (i.e., 285 million people) are estimated to be visually impaired worldwide, of whom about 246 million persons are suffering from low vision problem, and 39 million people are completely blind [1]. As per the statistics, 90% of the people belong to the lower-income group among the world's visually impaired people. In most developing countries, the public facilities to assist independent traveling of blind people are not well established as in developed countries, making their lives even harder. In India, around 5 million people are estimated to be suffering from some vision-related problems.

The authors surveyed the major problems faced by the visually challenged India via a manual survey of inmates of the centre for visually challenged (CVC) School established by UVSM Hospitals.

Among several issues, one of the major problems they identified is the independent ability to utilize public transport buses, including locating the door of buses, multiple bus confusion, and boarding into the desired bus. Approachability to the environment is important for all individuals. Access includes physical mobility, such as making a trip to a store by a selected transportation mode and recognizing key choice points or decision points in the environment. Accessibility, therefore, involves the ability to integrate, recognize, and understand the layout of features in the environment and be able to travel in as an obstacle-free a manner as possible. In new research directions for electronic travel aids [2], the market requires a less expensive mobility aid technology that is easy to learn and non-distracting from natural cues. However, the technology has to guide and improve travel performance than the existing aids by delivering more information than the existing ones.

This work aims to detect the bus door and alert the visually challenged person about the bus arrival, but some of the major problems encountered are locating the door of buses, multiple bus confusion, and boarding into the desired bus. A detection system using camera-based visual navigation has been considered to overcome them and supports image processing to find the bus and route information, then giving voice response after detection, and in particular, it is used for finding the properties of the bus door. The system is designed to be cost effective and integrated with the low-cost smart cane for vibration alerts, staircase detection [3], and vehicle detection [4].

2. RELATED WORK

For most blind people, the loss of vision is accompanied by a loss of independence. Of the 1.1 million blind people in the United States, about 10,000 use guide dogs, and 100,000 [5] can walk independently on long canes [2], leaving about 1 million people dependent on others for movement. Humans, information processing and environmental interpretation. In developing countries, this relationship is much higher. Of all the disadvantages associated with blindness, the loss of independence may be the most embarrassing. Yamasaki *et al.* [6], state that the persons with visual disabilities are getting demotivated for the lack of support facilities to access public transport, leading to compromise with proper education, work, and self-development opportunities. A study conducted by [7] has pinpointed the dependence of visually challenged persons for sighted assistance for external travel, which leads to frustration.

Identification of bus and its route is a problem that several researchers have addressed before. However, precise recognition of the bus door and navigation to board the bus has not been addressed adequately. The current state of the art methods for recognizing a bus and its route is either image-based or sensor-based. Bus detection and recognition based on satellite signals or wireless network communication has been developed in some bus stations. Maure *et al.* [8] proposed a dual end system, a bus subsystem, and a station subsystem connected to a database and all communicating to one another and the blind persons via radio frequency identification (RFID) tags. All three entities, the blind user, the bus station, and the bus itself, have RFID tags. The bus station and bus also have an RFID reader. The blind person can purchase a ticket and get bus information in an RFID tag. The bus station and bus can read that information to provide appropriate announcements and alert the driver. The system works precisely, but need to be installed on every bus and station. Moreover, the blind person needs to carry an additional device and get trained to use it. Still, the system may not help the blind person board the bus, other than indicating which bus to board and when to get down from the bus.

Heyes [9] present a similar system at a much lower cost suited to Indian needs. It comprises three modules, such as user module, bus module, placed in each bus, and the programming unit to change route numbers at the depot. Upon hearing a bus stopping the bus stop, a visually challenged person can press a query button on the user module fetching the route number of all buses in the vicinity via radio frequency (RF) signal, then sequentially read out by the user module. Users can select the desired route by pressing a button after hearing the route number and initiates a voice output at the selected bus's entry, acting as an auditory cue to assist in moving towards the bus gate. The system is effective but requires a special module to be carried by the user.

Heyes [10] use bluetooth devices on buses communicating with Raspberry Pi installed at the bus stop to detect and announce bus arrival. Auditory cue is a significant help for a visually challenged person. Variations in spatial relationships can be perceived with shifting sounds emitted by the objects in the vicinity. Listening to the echoes of emitted sounds and sounds made by the person can indicate the distance to a wall, the presence of a doorway, and many more [11]. But only after some decent practice can one master this art.

Another cue for direction can come from directionally-specific sources of heat and odor. Goldie [12] suggest detecting an air-conditioned bus's door by the cool air that flows out when the door is opened. However, in Indian settings, most buses are non-air-conditioned. Hence the best solution to date is the auditory signal coming from a speaker mounter at the bus's doorway.

Sensor-based solutions require pre-installation of the sensors and periodic maintenance. Thus vision-based technology can provide an alternative means to detect and recognize the bus. Brabyn [13] design a computer vision-based system to detect a bus. Their bus classifier employs histogram of oriented gradient (HOG)-based feature extraction and a cascaded support vector machine (SVM) learning model. Also, they recognize bus route numbers via a scene text extraction algorithm based on layout analysis and text feature learning. Tsai and Yeh [14] Used a scene text extraction algorithm to localize and recognize the text information of the bus route. This system achieved high accuracy of bus region detection. Furthermore, the scene text extraction algorithm successfully retrieves the bus route number's text information. Tsai and Yeh [14] proposed a text detection method to detect the bus route number in the text region on the bus top panel. They use the background distribution and the thresholds of the boundary to find the area of text that becomes a voice announcement. However, their method only detects the text area on the front panel of the bus and does not extract the route number of the bus. Grantham [15] uses an MSER-based text detection algorithm combined with MSER segmentation to obtain each character. The extracted characters are recognized by a well-trained convolutional neural network (CNN). Guida *et al.* [16] proposes bus number detection and recognition by cascading Adaboost-based classifiers, and then uses robust geometric matching to improve matching. The actual digital segmentation is done through perspective correction, and then converted to hue-saturation-value (HSV) color space and threshold.

Finally, OCR is used to identify numbers. Pan *et al.* [17] use HOG and SVM to detect bus position. For bus route detection, they use adjacent character grouping and intelligent edge detection to find candidate regions, extract Haarlike features from them, and enter them into Adaboost to classify each component [18], [19]. Finally, they used optical character recognition (OCR) software combined with a text-to-speech synthesizer to generate audio. One issue with vision-based approaches is that they violate privacy. Therefore, smart mechanisms must be integrated into the monitoring system so that they can focus on the prominent events of interest (detection doors) without providing any other irrelevant visual information, thus maintaining privacy.

Recently, the literature has proposed clear visual information for detecting doors. Few methods are based on estimating human motion under complex background conditions, such as those found in heavy traffic [20]-[23]. In addition, these methods also include machine learning [24] and congestion algorithms to distinguish bus doors from other doors.

3. METHODOLOGY

This work's main motive is to detect the bus door and alert the visually challenged person about the bus arrival and guide him in boarding the bus. Nevertheless, some of the major problems encountered during this process are locating the door of buses, multiple bus confusion, recognizing the staircase to board the bus, and boarding into the desired bus. In this work, a detection system using camera-based visual navigation has been considered for overcoming those problems and supports image processing, which is used to process images, then giving voice response after detection, and in particular, it is used for finding the properties of the door of the bus and staircase in the bus.

3.1. System architecture

The entire process of boarding the bus by a visually impaired person can be divided into 3 different phases, Recognition of intended bus, identifying the bus door and bus boarding/disembarking. The proposed model has been demonstrated in the Figure 1. The Figure 1 depicdts the entire working model of the proposed system. The Figure 1 clearly depicts the logical working of the proposed system.

3.2. Recognition of intended bus

Figure 2 (a) demonstrates the overall system architecture for bus recognition, and Figure 2 (b) shows the flow of detecting the bus (vehicle), and in [25], the bus recognition system has been already developed, which is used for this phase. The work has been proven its efficiency compared to existing techniques in terms of accuracy in identifying the bus and less time. In the earlier work done, the mobile device, which is equipped with a camera, analyses the bus and its movements during the motion, commonly called data acquisition, which means retrieving the images from the sources (likely hardware).

To figure out the exact object through the camera, which is located at the visually impaired person, the scene/snapshot should be processed below to produce the person's voice signals.

- Detection: The probability of finding real edge points should be maximum, and non-edge should point to a minimum.
- Localization: The obtained edges should be as close as possible to the real edges.
- The number of responses: The real edges must belong to only one detected edge.

– Smoothing: Blurring of the image to remove noise.
– Finding gradients: The edges should be marked where the gradients of the image have large magnitudes.
– Non-maximum suppression: Only local maxima should be marked as edges.
– Double thresholding: Potential edges are determined by thresholding.
– Edge tracking by hysteresis: Final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge.

If the analysis indicates the bus object is detected, then a relevant voice message will be sent to the user, which specifies the bus's location and the path for the user.

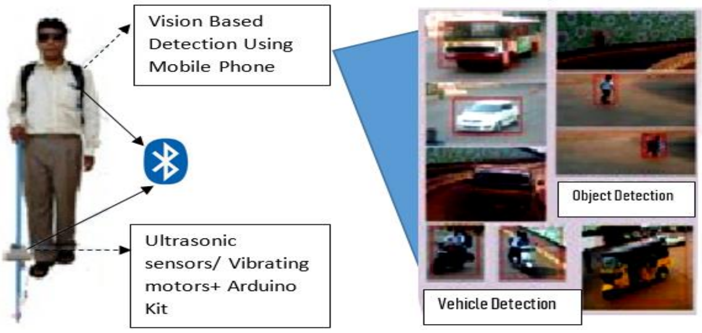


Figure 1. Proposed support for visually impaired people

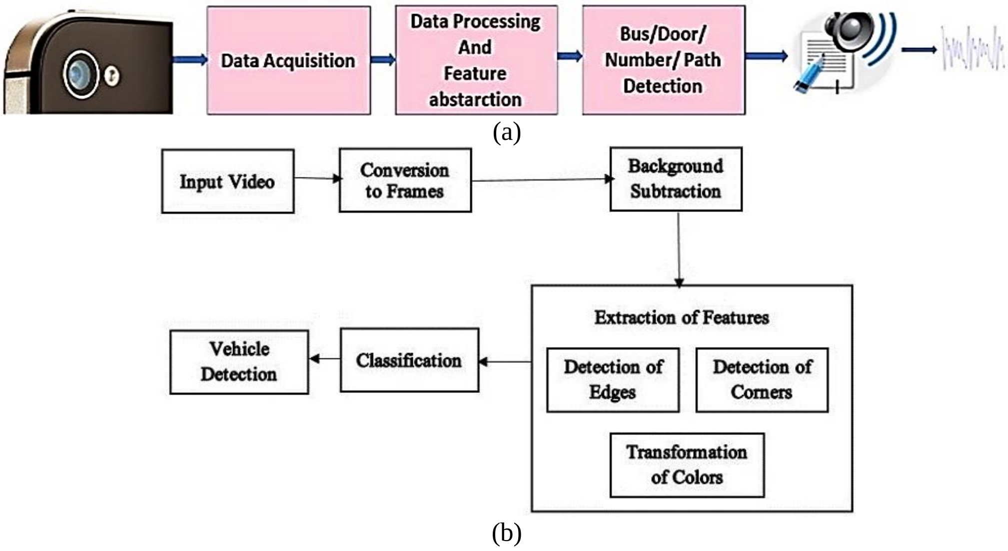


Figure 2. Proposed architecture: (a) system architecture for bus recognition and (b) flow diagram of bus detection model

3.3. Bus boarding/disembarking

The model for bus boarding or disembarking has also been implemented based on [26]. The bus boarding or embarking process has a crucial task of identifying the staircase, and the system should guide the impaired person properly. For doing so, in [26], a detector model like multivariate generalized Gaussian mixture model based on the extracted features using histogram of oriented gradients has been used in this model. The experimentation has clearly shown the accuracy of the model as 96.89%.

3.4. Identifying the bus door

Before executing the bus boarding/disembarking phase, the most promising phase is identifying the Bus door and its location. This work focuses on the proposed methodology for identifying the bus doors and navigating the user till the bus door. Identifying bus doors is the most critical section in the entire proposed system. In this paper, we have utilized Hough tansformation algorithm for effective detection process.

3.5. Bus objects detection process

The entire flow or process of the bus door detection system is shown above. The Figure 3 demonstrates how the bus detection algorithms [25] process the given video. Once the system is activated, foreground detection takes place. The process involves isolating the bus from the background. The background will appear as black, and the foreground will appear as white. A clear outline of the test subject can be seen, and spots are labeled as the foreground. To negate the shadow effect that inevitably occurs with each image, and HSV, color space is used. After this process, the person must be isolated from the rest of the pixels, extraneous for the processing algorithms. Also, it eliminates all noise and decreases the possibility of false positives.

In this work, the bus is detected using [25] multivariate generalized Gaussian mixture model (MGGMM) using histogram oriented gradient for feature extraction from the video sequence, and then the bus door is found using Hough transform. After detecting the bus door, the door's distance is measured from the user's position and give the directions to reach the door safely through a voice message. When the bus is detected, the door is identified using Hough transform, a feature extraction technique used in image analysis and digital image processing. The technique's main motive is to detect the imperfect image matching based on generalized scale-space interest points for improving the mobility instances of the objects within a certain category of shapes by the voting procedure. For computing the Hough transform, in parameter space, the voting procedure is carried out from which the object candidates are derived as local maxima in the accumulator space, which is explicitly constructed by the algorithm.

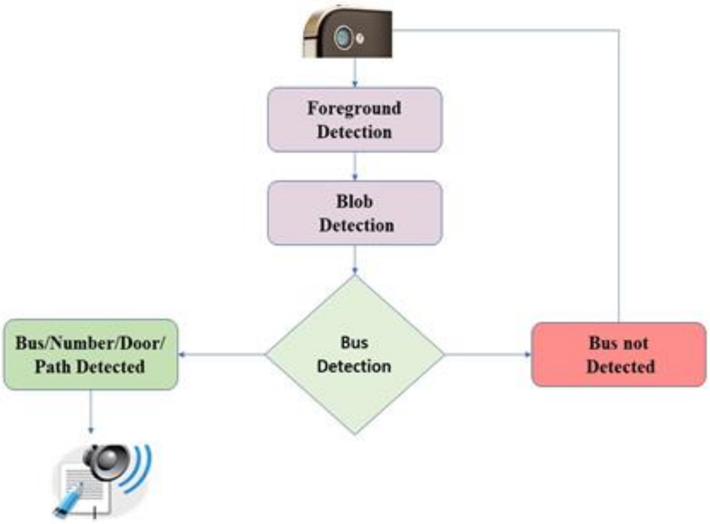


Figure 3. Bus door detection process

Hough Transform Algorithm

```
1. Initialize H [d, θ] = 0
2. for every edge point I[x, y] in the image
         For θ = [θmin to θmax]
        d = x cos θ − y sin θ
          H [d, θ] += 1
3. Find the values of (d, θ) where, H [d, θ] is maximum.
4. The detected line from the image is given by
        d = x cos θ − y sin θ
```

The main reason for choosing the Hough transform is that the Hough transform is a global method for detecting straight lines. Once the analysis indicates the bus object is detected, a relevant voice message will be sent to the user, specifying the bus door's location, the path to the bus that the user wants to board, and boarding the bus. The process of boarding the bus involves identifying the staircase. In this work, the staircase identification has been carried out using the bivariate Gaussian mixture model [26]. In the next section, the experimentation results produced with case studies in different scenarios are presented.

4. CASE STUDY

This work aims to detect the bus object in the current scenario, detect its door, and finally, the path to board the bus via the staircase as output in the form of relevant voice signals. Thus, the current scenario captured through a mobile camera is fed as input for the system for every case. The input video sequence bus is detected using MGGMM, and then we find the bus door using the Hough transform. After detecting the bus door, we will measure the door's distance from the user's position and give the directions to reach the door safely through voice message as output. Upon reaching the bus, the user needs to be guided for boarding the bus via the staircase detected using the bivariate Gaussian mixture model. The Figures 4 to 7 demonstrates the case study-I & II of experimentation.

Figure 4. Bus detected after performing MGGMM method from the video sequence

Figure 5. The bus doors of the detected bus after performing using the Hough transform

Figure 6. Bus detected after performing MGGMM method from the video sequence

Figure 7. Bus detected after performing MGGMM method from the video sequence

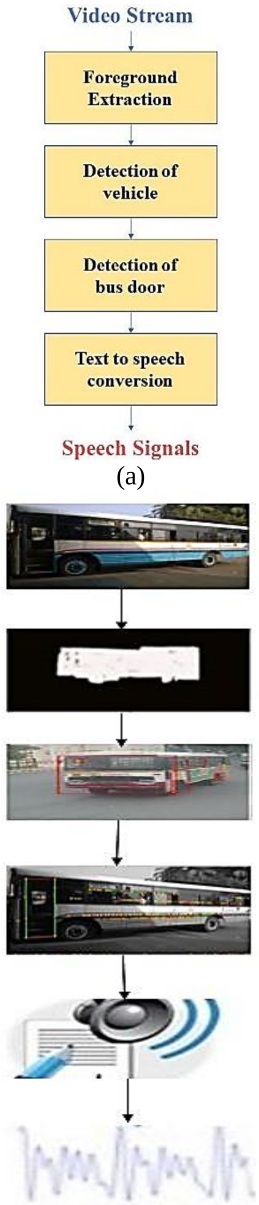
4.1. Case study–I

In this case study, we have utilized multivariate generalized Gaussian mixture model method (MGGMM) method for detecting the bus initially and then identify the bus doors when the bus is in running condition on the roads and is halted at bus stop. The Figure 4 demonstrates that the bus is initially identified. Later in Figure 5 clearly identifies the bus doors and is marked as bounding box. Input: the environmental scenario. Input image as shown in Figure 4 and output image as shown in Figure 5

4.2. Case study–II

In this case study, we have utilized multivariate generalized Gaussian mixture model method (MGGMM) method for detecting the bus initially and then identify the bus doors when the bus is stationed at the bus depot for passengers to board the bus. The Figure 4 demonstrates that the bus is initially identified. Later in Figure 5 clearly identifies the bus doors and is marked as bounding box. Input: the environmental scenario. Input image as shown in Figure 6. Output image as shown in Figure 7.

Now, let us see how the bus door is detected from the video sequence's input image. The flow is as shown in Figure 8. The input for bus door detection system is the video stream from which the foreground is extracted from each and every frame which is then used for detecting the vehicle. After the vehicle is detected, in the next step, bus door is detected. Once the bus door is detected, the textual information is converted to speech and sent to the speaker.



(a)

(b)

Figure 8. Bus door detection: (a) system's general flow and (b) voice signal generation

5. EXPERIMENTS AND RESULTS

Ninety-Two (92) videos are taken from different bus directions during initial preparation and analyzed using the program. In this state, the algorithms were correctly detecting a bus door and differentiate it from a non-bus door with almost 88.33% accuracy. When it is implemented to detect in real-time, the algorithm struggled to loop back and continuously analyze the surrounding environment due to low resources, and the program's nature was written.

While the goal is to detect bus doors for visually challenged people, the problem is mitigated by preventing boarding into the wrong bus. The entire project has been implemented using two hardware devices, an Android Mobile and a Stick embedded with an Arduino kit. The setup with the mobile is equipped with a camera that takes the input scenario and in which the actual processing occurs and can provide immediate assistance and alert is sent to the user. The input scenario is processed or analyzed to detect whether or not the bus is detected. After detecting the bus from the given scenario, the bus door, and the path to board the bus through the staircase is given as output in the relevant voice message.

The experimentation has been performed on about 92 different subjects. It is observed that the experimentation has been successfully enjoyed by about 81 subjects whereas 11 subjects found few difficulties while getting navigated near to bus doors when the bus has two doors specifically and boarding the bus. However, the accuracy in detecting the bus doors and successfully boarding the bus is nearly 88%. Figures 9 and 10 are the bus recognition in different scenarios and detect the bus doors while the bus arrives at the bus stop. The bounding box for bus and bus door: result set 1 as shown in Figure 9; and result 2 as shown in Figure 10.

Figure 9. Foreground detection process of the input scenario

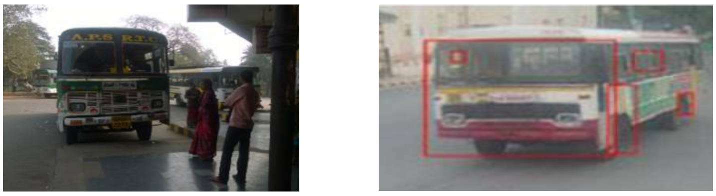


Figure 10. Foreground detection process of the input scenario

For evaluating the proposed method, quantitative analysis based on [27] is used. The analysis is based on the success rate (SR) of the subject boarding the correct bus without any difficulty and the center location error (CLE). However, the failure might occur either in detecting the bus correctly, identifying the bus door's location properly, or boarding the bus in the right way using the staircase in the bus. If the overlapping degree (OD) is more than 0.5, it is observed as successful. SR=SAS/TAS, where SAS is the successful attempts made by subjects and the TAS is total attempts made by subjects.

To compute the SR, CLE, and OD, the experimentation has been carried out on about 92 persons of different age groups. All the persons have been categorized into three groups based on their age, viz., age between 10-25 as a youth (Y), 25-35 as millennials (M), and above 35 as old aged (O). Table 1 lists the number of persons considered for experimentation with different age groups. People's gender considered for experimentation is male, and literacy & usage of gadgets are high for youth and millennials, but the old age group's gadgets are moderate. The Figure 11 shows the chart related to the sharing of experimental subjects among different age groups. The reason for choosing different age groups, literacy levels, and gadgets like mobiles is that the experimental devices' efficiency varies based on all these aspects. Hence, to attain maximum accuracy, persons (subjects) of different categories are chosen.

The experimental values have been shown in Table 2 and Table 3. In Table 2, the success rate in identifying the bus and properly boarding the bus by locating the bus doors is presented, and the graph is shown in Figure 12. The success rate is much higher for youth & millennials, whereas it is low for old age groups. Upon exploring the results, it is observed that the usage of modern electronic gadgets (mobile phones) by the old age group in India is, to some extent, less when compared to the other two groups. Hence, the success rate is low for old age people due to confusion raised in instructions from the devices leading to a reduced success rate.

The experimental results of the overlapping degree are tabulated in Table 3. Figure 12 showcases the graph of overlapping degree. From the Table 3 and the Figure 13 depicts that the overlapping degree is low for the age groups youth and millennials, and the overlapping degree is higher for old age people. The higher overlapping degree in old age people is that the instructions were misinterpreted and some of the people could not locate the bus door properly.

The accuracy of the work is presented in Table 4 and Figure 14. The experimental results show that the accuracy is much higher, with an average accuracy of more than 88%. The accuracy of both youth and millennial age groups is more than 90%, but the old age group's accuracy is about 81% due to lack of familiarity in using gadgets and following the instructions properly.

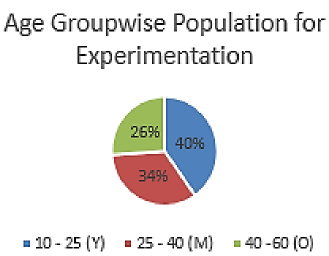


Figure 11. Chart demonstrating the people age group used for experimentation

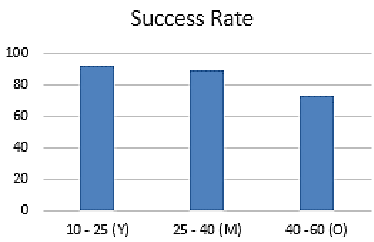


Figure 12. Graph of success rate for different age group people

Table 1. Count of people considered for experimentation

Age Group	Count
10 - 25 (Y)	37
25 - 40 (M)	31
40 -60 (O)	24

Table 2. Success rate for different age group people

Age Group	Success Rate
10 - 25 (Y)	92
25 - 40 (M)	89
40 -60 (O)	73

Table 3. Overlapping degree for different age group people

Age Group	OD
10 - 25 (Y)	03
25 - 40 (M)	04
40 -60 (O)	09

Table 4. Accuracy for different age group people

Age Group	Accuracy
10 - 25 (Y)	93
25 - 40 (M)	91
40 -60 (O)	81

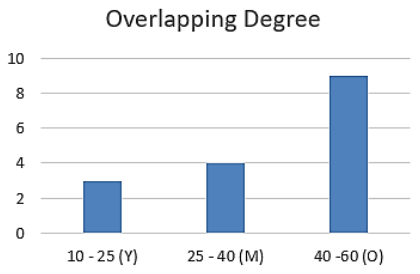


Figure 13. Graph demonstrating the overlapping degree

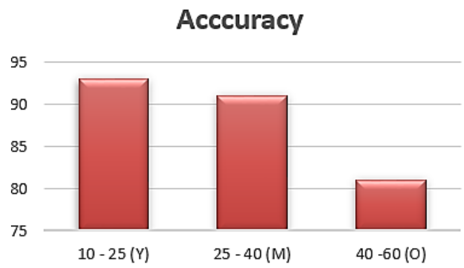


Figure 14. Graph demonstrating the accuracy

6. CONCLUSION

A novel and sophisticated system is proposed to detect bus doors for visually impaired people. This visual monitoring system relies completely on the algorithms. The proposed system can automatically detect the door of a bus through a mobile camera. The system will automatically reconfigure itself to adapt to any background changes, including minor modifications and texture changes. The system consists of two parts. The first is to use foreground fragment focus to automatically extract foreground objects from the background, enriching online strategies for working in high-dynamic scenes. The dynamic background modeling is ensured by the iterative motion in the scene and the position of the moving bus. The second is in charge of tracking down the door of the bus. Through an in-depth examination of the experimental results of real video sequences with complex visual backgrounds, it is verified that the proposed system can identify the bus in a robust and efficient way even under complex conditions. Bus door detection conditions when the bus is in motion, bus door identification when there are many people at the door are left for future scope.

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