A Mobile Camera Based Navigation System for Visually Impaired People

Sami ur Rahman, Sana Ullah, SehatUllah
Department of Computer Science
University of Malakand, Pakistan
{srahman, sullah,sehatullah}@uom.edu.pk

Abstract
Visually impaired people face difficulty during mobility and they need some external mobility aid that helps them in detecting obstacles in their way. In this paper, we are presenting a mobile camera based solution for blind navigation. The algorithm is also capable of guiding the visually impaired for selecting an alternate path if it finds some obstacle on their way. The algorithm uses few pre-stored images of the floor for finding any obstacle. The algorithm compares the current floor images with the free stored images and based on some similarity metric, it decides if there exists any obstacle on the floor. If the algorithm finds any obstacle, then it guides the visually impaired to follow an alternate path for navigation. Accuracy of the algorithm is 90% in controlled environment.

CCS Concepts
• **Computing methodologies →Artificial intelligence →Computer vision →Computer vision tasks →Scene understanding**

Keywords
Obstacle detection; visually impaired; mobile camera; blind navigation

1. INTRODUCTION
It is very difficult for visually impaired people to walk around without any external aid. Usually, blind people use stick cane for detecting obstacles and for navigation. Computer vision can also help as it provides algorithms that are used for obstacle detection using camera images. Obstacle detection is used to avoid collisions in paths and to ensure safety of vehicles, robots etc. Obstacle detection has a lot of importance in blind navigation. Obstacle detector can aid blind peoples in path navigations and can avoid collisions. Different techniques have been developed to detect obstacles. Some of these techniques are using SONAR (Sound Navigation and Ranging) while others are using laser camera. These systems are successfully integrated in automatic driving cars, e.g. Google cars, BMW etc. In this paper we are presenting an algorithm for detecting obstacle and finding alternate path in indoor environment. We are using an android based mobile camera and we scan selected area in front of the camera for obstacle detection. The proposed algorithm works in indoor environments having same colour floors. Initially unique images of the floor are saved in the device memory and then in real time the region of interest (ROI) is scanned by comparing the ROI with reference area. This paper is extension of our previous work where we had proposed an algorithm for obstacle detection. The focus of this paper is to suggest an alternate way and help avoiding collision with the obstacle.

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2. RELATED WORK
Providing guidance to the visually impaired using computer vision based solutions is an active research area. There exist many solutions that help visually impaired in navigation. In the work of Menikdiwela *et al.* [1], they have used three ultrasonic sensors for obstacle detection in stick cane. These sensors are fixed in the tip of the cane. The middle sensor detects front obstacles while the other two sensors scan sides to search clear path for the user to pass. In this approach Microcontroller is used for decision making. User is informed using haptic feedback. James *et al.* [2] proposed a system based on ultrasonic sensor. Different level obstacles on the bases of different heights are detected. If floor level obstacle is detected, then the user is informed about floor level obstacle. Likewise, knee level obstacle is detected using the proposed system. To pass through the obstacle, two sensors are used on each side. If there is obstacle on the right side the user is directed to move to left and if left side is not clear, then user is directed to move right. Mustapha *et al.* [3] proposed a system which is based on ultrasonic sensors. In this system, two ultrasonic sensors and one IR sensor are mounted in the shoes. IR sensor is connected with the receiver system, which takes decision that either obstacle is detected or not. User is informed using buzzer. Bouhamed *et al.* [4] proposed a system where two ultrasonic sensors and one camera is fixed in cane. One sensor is placed at the bottom of the handle to detect obstacle on the ground plane. The second sensor is fixed in front of the handle to detect head level obstacle. A microcontroller is used for decision making. User is informed by audio feedback. De Silva *et al.* [5] used ultrasonic sensor and Inertial Measurement Unit (IMU) sensor in cane. Ultrasonic sensor detects obstacles and IMU sensor calculates position of the cane. The proposed system can calculate obstacle size. Kasim *et al.* [6] proposed a system having two infrared sensors fixed in cane to detect obstacles in front of the user and ground obstacles. In the proposed system the microcontroller takes decisions. Feedback to the user is given using vibrating motors. Four vibrating motors are fixed at different positions to provide feedback in different directions i.e. left, right, down and front. Aziz *et al.* [7] proposed a system which is based on echolocation principle. They have used

ultrasonic sensor to calculate distance between subject and the obstacle. These sensors are mounted in cane. To provide information to the user, they have used buzzer in the proposed system. Bhatlawande *et al.* [8] presented electronic navigation system. In the proposed system, two Ultrasonic sensors are fixed in eyeglasses and three sensors in waist belt to detect different level obstacles i.e. head level and waist level. A microcontroller is used to process sensors data and inform user through audio feedback. Milios *et al.* [9] proposed a system that uses a Laser Range Finder (LRF) sensors for obstacle detection. 3D space is scanned using LRF sensor and range data is converted to different sounds for user information. The system proposed by Niitsu *et al.* [10] is based on Ultrasonic sensor. Range data is transferred to smartphone using Bluetooth. Smartphone takes decisions about obstacle and informs the user through audio feedback. Strakowski *et al.* [11] presented a system which is based on phase beamforming principle. According to this principle, they calculate the direction of the ultrasonic sound reflected back from obstacle. Villamizar *et al.* [12] proposed a system that consists of ultrasonic sensor and controller. Distance to obstacle is calculated by controller using IR sensor. For user information the vibrator is installed in the proposed system. The system is attached with neck strap. In the work of Zhang *et al.* [13] infrared sensor is used for obstacle detection. The proposed system consists of two units, feedback unit and sensor unit. In sensor unit one infrared sensor is used underneath the shoe for road surface reflection detection and long range sensor to detect front obstacles. Villanueva *et al.* [14] used IR sensor in their proposed system. For user feedback vibrator is used in cane. Peng *et al.* [15] used smartphone camera to detect obstacle on floor. They assume a small area at the bottom of the frame as safe region and then compare region of interest with that small area to confirm obstacles. Audio feedback is given to the user. In our previous work [16] we have proposed an algorithm for obstacle detection in indoor environment using smartphone. This paper is an extension of our previous paper and the focus of this paper is to suggest an alternate way if the visually impaired faces an obstacle. The paper presents an algorithm that helps navigation without collision with the obstacle.

3. PROPOSED ALGORITHM

The proposed algorithm is based on images from smartphone cameras. The algorithm is capable of guiding the visually impaired for selecting an alternate path if it finds some obstacle on their way. It uses few pre-stored images of the floor for finding any obstacle. The algorithm compares the current floor images with the free stored images and based on mean square error (MSE) as similarity metric, it decides if there exist any obstacle on the floor. If the algorithm finds any obstacle, then it guides the visually impaired to follow an alternate path for navigation.

In indoor environment all unique floor types are considered and a single image is stored for each unique floor type. These floor images are considered as reference images.

The algorithm performs two tasks

A. Obstacle detection
B. Alternate path finding

3.1 Obstacle Detection

Details about obstacle detection phase are available in our previous work [16]. For detecting an obstacle, first the algorithm needs to find the floor type in which the blind person is currently standing. The camera acquires an image of the current floor and a region of interest (ROI) is segmented from this image. This ROI is compared with all the stored images for different floor types. Mean Square Error $(MSE)_k$ is computed for every floor type k. $(MSE)_k$ is computed as follows.

$$(MSE)_k = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}[CF(i,j) - (F)_k(i,j)]^2 \quad (1)$$

CF represents ROI of the current floor, F_k represents ROI of floor k, and m and n represent the number of rows and columns in both images.

The algorithm sets the current floor type as the one for which minimum of $(MSE)_i$ is less than a threshold value α. It then compares the current frame and the next frame, and computes mean square error (MSE) of the two frames. If MSE is less than the threshold value α then it means that there is no obstacle in the next frame. If MSE is greater than α then there are two possibilities: either there is an obstacle or the floor type is changed. In order to check if the floor is changed, the algorithm computes $(MSE)_i$ of next frame and all stored floor types k. If minimum $(MSE)_i$ is less than a threshold value α then floor is changed otherwise there exists an obstacle.

The different steps of the algorithm are as follows:

1. CF = Read frame
2. $(MSE)_k = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}[CF(i,j) - (F)_k(i,j)]^2$
3. $Min\ (MSE)_k$ = minimum of $(MSE)_k$
4. If $Min\ (MSE)_k > \alpha$
   a. Obstacle exists
   b. Handle obstacle
   c. Goto step 1
5. If $Min\ (MSE)_k \leq \alpha$
   a. CF = floor for which $Min\ (MSE)_k \leq \alpha$
   b. NF= read next frame
   c. Compute MSE of current frame and next frame
   d. If MSE <= α
   e. No obstacle exists
   f. Current frame = NF
   g. Goto to step 5 (b)
   h. If MSE > α
   i. Goto step 4 (a)

3.2 Alternate Path Finding

If there exists an obstacle, then the algorithm suggests an alternate path. For alternate path finding, the algorithm works as follows. The camera divides the current frame in three sub-regions i.e. main ROI, right ROI and left ROI (see Figure 1). Main ROI will be checked for obstacle using the method presented in section 3.1. If obstacle is detected, the algorithm will check right ROI using the same technique for obstacle detection. If there exist no obstacles at the right ROI then user will be directed to move right and if it is not clear, then left side will be checked. If the left side is found clear, user will be directed to move left and if both sides are not found clear then user will be directed to move back.

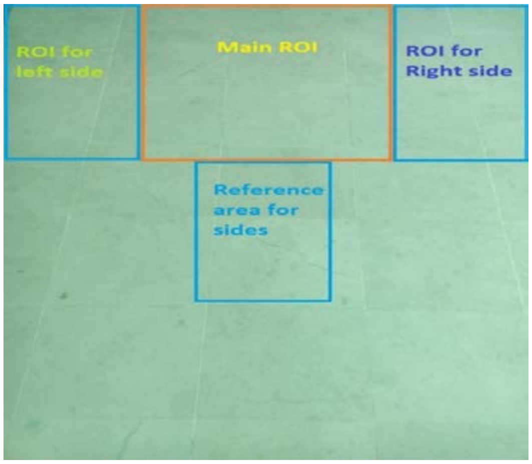

Figure 1. Selecting different regions of interests.

4. RESULTS

The proposed algorithm has been tested in indoor environment having different obstacles (Figure 2). These obstacles were placed in front of the camera and were scanned on different floors. Four actors were hired to test the algorithm in different corridors of the building holding smartphone. Three buildings of the University of Malakand were used for the tests.

Figure 2. Obstacles used in the experiments

Experiment 1: The actors were allowed to walk in corridor of the building 1. There were four obstacles in the corridor (Figure 3).

Figure 3. Obstacles used in first experiment

Experiment 2: The actors walked in classroom having chairs at various positions (Figure 4).

Figure 4. Obstacles used in second experiment

Experiment 3: Third test was conducted in building 2 and seven obstacles were placed (Figure 5). All obstacles were detected successfully and users were guided towards alternate path.

Experiment 4: Fourth test was conducted in the corridor of building 3. This time eleven obstacles were placed (Figure 6).

The algorithm was able to detect the obstacles in all the four tests with 90% accuracy. It was also able to correctly guide the user towards alternate path.

Figure 5. Obstacles used in third experiment

Figure 6. Obstacles used in fourth experiment

5. CONCLUSION

In this paper, we presented a mobile camera based solution for blind navigation. The algorithm is capable of guiding the visually impaired for selecting an alternate path if it finds some obstacle on their way. The algorithm uses few pre-stored images of the floor for finding any obstacle. We have presented preliminary results of the proposed algorithm. In these experiments we have heuristically selected the threshold value α. In our future work, some automatic technique will be developed for selecting the value of α. Accuracy of the algorithm is 90% in controlled environment.

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