Obstacle Detection in Indoor Environment for Visually Impaired Using Mobile Camera

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Abstract. Obstacle detection can improve the mobility as well as the safety of visually impaired people. In this paper, we present a system using mobile camera for visually impaired people. The proposed algorithm works in indoor environment and it uses a very simple technique of using few pre-stored floor images. 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 acquires an input image frame and then a region of interest is selected and is scanned for obstacle using pre-stored floor images. The algorithm compares the present frame and the next frame and compute mean square error of the two frames. If mean square error is less than a threshold value $\alpha$ then it means that there is no obstacle in the next frame. If mean square error is greater than $\alpha$ 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 mean square error of next frame and all stored floor types. If minimum of mean square error is less than a threshold value $\alpha$ then flour is changed otherwise there exist an obstacle. The proposed algorithm works in real-time and 96% accuracy has been achieved.

1. Introduction
Obstacle detection is the process of detecting some object or barrier around the autonomous system that can affect movements of a system. Obstacle detection is used to avoid collisions in paths and to ensure safety of vehicles, robots etc. Blind persons have difficulties in navigation. Obstacle detection has a lot of importance in blind navigation. Mostly, blind people use stick cane to detect obstacle and to navigate, but this is not much accurate. 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 other using laser camera. These systems are successfully integrated in automatic driving cars, e.g. Google cars, BMW etc. Different mechanisms are used for example in some cases obstacle are known while in some cases environment is known. In this paper we are presenting an algorithm for detecting obstacle in known environment. We are using an android based mobile camera and scan selected area in front of the camera for obstacle detection.

2. Related work
In the available literature, there exist many approaches for obstacle detection. For example, Tapu et al. [1] have proposed an approach for obstacle detection using smartphone. In this system, a set of interest points are extracted from image and is tracked by Lucas Kanade algorithm [2], then camera and the
background motion is estimated through homographic transforms. Obstacles are marked as urgent or normal based on their distance to the subject and associated vector orientation. The detected obstacle is then sent to an object classifier. Once the obstacle is identified, the degree of danger is determined. Batavia et al. [3] have proposed a system that uses color segmentation and stereo based color homography. Color segmentation classify image areas as free space or obstacle. This system is based on training algorithm. Hesch et al. [4] have proposed sensors combination (e.g. foot mounted pedometer, 2D laser scanner and 3 axis gyroscope) for helping indoor localization. They have introduced two layered estimators. In first layer, the white cane orientation is tracked while in second layer, the 2D position of the person (holding white cane) is tracked. Another system proposed by Saffoury et al. [5] consists of two hardware components, a laser pointer and an android based smartphone. To measure distance of objects in environment, image processing based techniques are used for obstacle avoidance. This is based on laser light triangulation. In this approach edge detection is used for the enhancement of obstacle detection. User is also warned by recognizing stairs if they are present in field of view of the camera. When obstacle is detected, user is informed by acoustic signal. Saez et al. [6] have embodied full six DOF SLAM solution into a stereo wearable device working in real time. Localization technique is used for visually impaired people. The system presented by Fukasawa et al. [7] consists of map information and navigation system. Sensor is installed on white cane which detects navigation line drawn on the floor. RFID tags are used for map information system. Mahmud et al. [8] have used ultrasonic sensor and microcontroller for range determination and action. User is warned by audio and vibration. Ultrasonic signals are sent in three directions (left, right, front). Vlaminck et al. [9] have used RGB-D camera to perceive environment. They implement three things: obstacle detection, obstacle classification and self-localization. In self-localization, depth is perceived and color information based tracking technique is used. To provide semantic information to the user, obstacle is classified as walls, steps and doors etc. Pradeep et al. [10] have used head mounted stereo vision. Here the authors combine features, based on SLAM and visual odometry to create 3D map in order to detect obstacles. Leung et al. [11] estimate ego motion in dynamic environments. Their system consists of head mounted stereo vision for visually impaired. They find ground planes, and then decompose 6DOF into ground plane motion and planer motion of the ground plane. From the analysis of the disparity array they estimate ground plane and normal to the ground plane using visual data. Gangawane et al. [12] have used camera and ultrasonic sensors to detect obstacles. Obstacle is detected using ultrasonic sensor while from camera image, object size is calculated. In the work of Maidenbaum et al. [13] they have used two infrared emitters and sensors. These sensors emit beams and reflected beam is then received by sensors. One of these two sensors perceive waist height obstacles in 5-meter range and the direction is ahead to user. The second one is towards the ground at 45 degrees to detect ground level obstacles. Lee et al. [14] have used mobile parking sensor consisting of three modules (sensing module, processing module and warning module). Ultrasonic pulses are sent and then received if it is reflected by obstacles. Processing module then decides to warn the user or not, by using buzzer. Peng et al. [15] have histogram and edge cues to detect obstacle on floor regardless of obstacle height. Kumar et al. [16] have proposed a system where free space is computed. The system reduces the 3D point cloud obtained from stereo camera for stochastic representation. The algorithm assigns each cell of values (free or obstacle). In the work of Novotny et al. [17] and Benet et al. [18], IR sensors have been used for measuring distance for various surfaces. In the work of Mocanu [19], obstacle information is acquired from smartphone camera and ultrasonic sensors. Then obstacle recognition module recognizes obstacle and inform the user by acoustic signal. The work of Khan et al. [20] uses depth information to assist user. This system is able to detect dynamic obstacle and transmit information to user by audio feedback. In [21] author proposed a system using Microsoft Kinect sensor to detect 3D objects. Tactile device is used for user feedback. When object is found in front of Kinect sensor, user is informed. Brock et al. [22] have also used Microsoft Kinect sensor and depth information for detecting obstacles. Jayron et al. [23] used RFID readers and RFID cards. Cards are used as checkpoints for visually impaired people. In [24] RFID tags and GPRS have been used to guide blind people. User location is sent using GPRS and
server calculates shortest path to destination. [25] Used RFID to self-locate blind in specific locations while [26] Used IR sensor for perceiving environment and four micrometers for haptic display to the user. These motors are adjusted to back vest of the user and provide directional feedback to the user. In [27] a system is proposed where input data is collected from laser data. Obstacle is detected by laser and from images, traversable area is identified using stored knowledge for humanoid robot. Jafari et al. [28] used RGB-D camera for environment perception. In [29] a wearable system is proposed to detect and avoid obstacles based on ultrasonic sensor. Feedback is given to the user by audio and vibration. Cartin et al. [30], presents a system for obstacle detection using multi-sonar system. The system sends vibrotactile feedback to the user.

In our proposed system, we use only a smartphone camera without using any other extra sensors to detect obstacles.

3. Proposed algorithm

The proposed algorithm is developed for indoor 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.

First the algorithm needs to find the floor type in which the blind person is currently standing. The camera takes an image of the floor and segment a region of interest (ROI) from this image. This ROI is compared with all the stored images for different floor types. Mean Square Error \((\text{MSE})_k\) is computed for every floor type \(k\). \((\text{MSE})_k\) is computed as follows.

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

Where \(CF\) 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 set the current floor type as the one for which minimum of \((\text{MSE})_l\) is less than a threshold value \(\alpha\). The algorithm then compares the present frame and the next frame and compute mean square error \(\text{MSE}\) of the two frames. If \(\text{MSE}\) is less than the threshold value \(\alpha\) then it means that there is no obstacle in the next frame. If \(\text{MSE}\) is greater than \(\alpha\) 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 \((\text{MSE})_l\) of next frame and all stored floor types \(k\). If minimum \((\text{MSE})_l\) is less than a threshold value \(\alpha\) then floor is changed otherwise there exist an obstacle.

The different steps of the algorithm are as follows:

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

4. Introduction experimental setup
For experiments we have considered three different building. These buildings are:

**Academic Block, University of Malakand:** Corridor of the Academic block is made of marble having white color. These marbles have zigzag patterns on it. Floor of the rooms are made of chips having white color.

**Education Block, University of Malakand:** Floor of the Education block is made of yellowish marble having dot patterns on it. It has one unique floor.

**Social Science Block, University of Malakand:** Social science block has one unique color floor. All the corridors and rooms floor are made of chips gray color.

**Obstacle:** Different obstacles that have been detected are tables, chairs, rotated chairs, tubs, bricks, human, stone, flower pot, Jug, cottons and dustbin etc.

**Blind People:** Tests were conducted by actors who worked as blind people.

**Selection of threshold value:** Threshold values are selected heuristically.

5. Results
We tested this algorithm in indoor environment having obstacles. Twenty different obstacles were placed in front of the camera and were tested on different floors. Algorithm has been tested by five users holding smartphone with tilt angle of 40 degrees. Details of the tests are as follows:

**Test 1:** During first test, actor was allowed to walk through in open corridor of academic block of the university. Five obstacle were placed in front of the camera.

**Test 2:** In second test, actor was allowed to walk through in closed corridor of the academic block of University. This time four obstacle were placed in front of the user.

**Test 3:** In third test, actor was allowed to walk around in classroom having chairs.

**Test 4:** Fourth test was conducted in the corridor of the education block. Ten obstacles were placed in front of the user.

**Test 5:** Fifth test was conducted in Social Sciences block of the University. Actor were allowed to walk through corridor having obstacles. Obstacles contained tables, chairs, bricks, dustbins etc. having various colors and sizes.

The result of these tests is shown in figure 1. The overall accuracy of the algorithm is 96%
6. Conclusion
In this paper, we have presented preliminary results of our algorithm for obstacle detection in indoor navigation using android-based mobile camera. The algorithm produces 96% accuracy. However, this algorithm has some limitations. Currently the threshold value $\alpha$ is computed heuristically which will be addressed in our future work and an automatic method will be developed for computing this value. Similarly, in this paper we have not presented mechanism for obstacle handling which will be presented in our next paper.

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