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Computer Vision Based Real-Time Stairs And Door Detection For Indoor Navigation Of Visually Impaired People

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ABSTRACT:
Door and stairs are significant landmarks for indoor navigation. One of the existing methods to perform indoor navigation is using a topological map in combination with a device that can help visually impaired person commute. Computer vision based navigation aid can improve the mobility of visually impaired person in known or unknown, indoor or outdoor situations. In this work, we propose a computer vision based method to detect doors and stairs for indoor navigation. The images provided my stereo cameras are used to extract information about the segments that belong to the stairs and doors. Several concepts are defined as size, the distance between the segments and many more that can help distinguish doors and stairs from similar structures found in indoor environments. The proposed work has proved to successfully detect doors and stairs under strong perspective deformation. Furthermore according to our experiments this method is suitable for real-time stairs and door detection.
KEYWORDS: Indoor navigation, visually impaired, computer vision, doors, stairs.

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I. INTRODUCTION

In an unfamiliar environment, we spot and explore all the available information whichmight guide us to a desiredlocation. Finding office or room in a building or shopping centeris often a simple task for vision people. But this task is quite difficult for visually impairedpeople[16]. Vision impairment is often due to conditions such as diabetic retinopathy, musculardegeneration, and glaucoma. The visually impaired(VI) community is very diverse in terms of degree of vision loss, age, and abilities. Vision loss affects almost every activity of daily working. Walking, driving, reading, recognizing objects, people, places becomes difficult or almost impossible without vision. Lack of mobility is a severe concern for blind people. They find it extremely difficult to travel independently as they cannot determine their position and orientation in the surroundingenvironment.They often have to rely on people passing by to ask information or if the building isfamiliar they need to memorize all the locations.

[1]World Health Organization(WHO) carried out a survey in 2010 to estimate a totalnumber of visually impaired (VI) people in the world. According to this report, out of 6737 million people in the world, 285 million people are visually impaired. Out of 285 million VI population, approximately 39 million people are completely blind and 246 million people have lowvision. Figures clearly indicate that there is a need for advanced assistive aid that can help VI community.

Human mobility comprises orientation and navigation [3]. Orientation can be thought of as knowledge of one's position with respect to the objects in the environment. Information about the position, route planning is linked with orientation. Navigation is the ability to move within the local environment. This involves information about stationary or moving obstacles in the surrounding, features of the floor etc.Two important indoor structure which playa vital role in indoor navigation is stairs and doors. It is very difficult for blind people to detect location of stairswith just a white cane or location of door.

Electronic travel aids (ETA) have been designed for VI people which convert visual information into auditory or haptic feedback. There are many ETA's based on ultrasound and infra-red technologyfor outdoor navigation which gives information to the user about probable obstacles in front ofthem [4,5]. GPS is also used in few outdoor navigation aids that can help visually impaired peopleto reach to their destination. But this technology cannot be used for indoor navigation. Due to narrow corridors and many structures, indoor navigation is more challenging then outdoor navigation.There are many travel aid prototypes developed for indoor navigation[6]. Most the indoortravel aids are based on RFID technology, Bluetooth, wireless signal technology.ROSHNI[9],an indoor electronic travel aid developed at IIT Delhi uses infra-red wayfinding technology.The prototype downloads the floor plan of the building. It locates and tracks the user insidethe building, finds the shortest path and provides step by step direction.[10]Kinect based doordetection uses a single RGB camera and infrared depth sensor to find if the doors are presentin front of the user. A prototype antenna was developed which is fitted in the door casing. Theradiation pattern shape is similar to a doughnut. The user has a receiver which continuouslymonitors the energy of from the antenna. The prototype guides the person to move in the the direction which has maximum energy.Guidecane[2] uses 8 ultrasound sensors to find the obstacle in front of the user. Two of thesesensors are used to detect stairs. It can detect two upward stairs and two downward stairs. Another prototype uses RFID tags. These tags are placed on each stair. The user has a device that can read the RFID tags and the device gives the useranaudiofeedback to inform the user whether they are upward stairs or downwardstairs.All the above technology used for doors and stairs detection are different from the technologyused for outdoor navigation. The cost of the installment of these devices and the maintenance of thesedevices is high. Moreover, there are two devices that user has to use, one for outdoor and other for indoor navigation.

The present work proposes an algorithm based on computer vision that can help detect doors and stairs for indoor navigation. The system captures images at a resolution of 1024x768. These images are given as input to the processing unit. There are two separate modules for door detection and stair detection. Both these modules extract the information about the presence or absence of doors and stairs in captured images and give an auditory feedback to the user of the device informing about the location of the doors and/or stairs.

Paper is organized as follows. Section 2 explains the concept of door detection using computer vision. Section 3 presents the algorithm for stair detection using computer vision. Section 4 presents and discusses experiments and results obtained. Section 5 concludes with final remarks.

II. DOOR DETECTION USING COMPUTER VISION

The major characteristic of any door that distinguishes it from other obstacles and indoor structures are its edges. Doors are made up of four edges. Angle between the adjacent two edges of the door is always 90°. There are two types of door edges as shown in the figure.

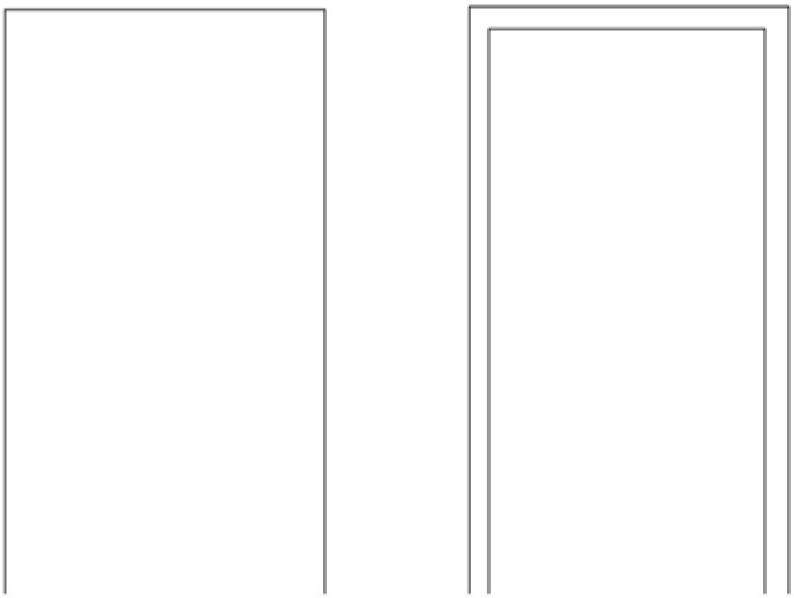


Figure 2.1 Types of doors

They are called single frame doors and double frame doors respectively. Edges of single frame door are the edges between the door and the wall. The double frame door contains two sets of edges, outer edges are the edges between the frame of the door and the wall and the inner edges are the edges between the frame and the door. Due to the perspective projection of the environment on the 2D image plane, the angles between the edges do not always appear as 90°. Hence angle feature cannot be used to detect if a door is present close to the user or not. But the property that two vertical edges will always be parallel to each other and two horizontal edges between the two vertical edges can help to detect doors. To distinguish between doors and objects with similar properties like cupboards, we put a limitation on the minimum length of vertical edges and limits on the distance between two detected horizontal edges.The algorithm makes the following assumptions

1. The doors are not made up of transparent material like glass.
2. Both the vertical edges of the door should be visible.
3. Atleast one horizontal edge on the door should be visible.
4. Doors in the image have a certain width and height.

Figure 2.2 Corners and edges of door

As shown in the figure 2.2 C1, C2, C3, C4 are corners of the door and E12, E23, E34, E41 are the edges of the door. Let D be the diagonal of the image. The ratio of the edge length and diagonal distance D is given by the equation 2.1 and angle of the edge is given by the equation 2.2

Vertical edges and horizontal edge: $angle_{ij} = tan^{-1}\frac{|(x_i - x_j)|}{|(y_i - y_j)|}x\frac{180}{\Pi}$ w (2.2) ctively.

The flowchart of the algorithm is as given

$$height_{low} < S_{ij} < height_{high}$$
$$width_{low} < S_{ij} < width_{high}$$ (2.3)

III. STAIR DETECTION USING COMPUTER VISION

Stairs are one of the most important structures in indoor navigation. Like doors, stairs can be distinguished from other obstacles by its unique property that all the edges of stairs are parallel.As shown in figure 3.1, stairs are characterized by one more feature, they have the parallel edges bounded between two diagonal lines or one diagonal edge.

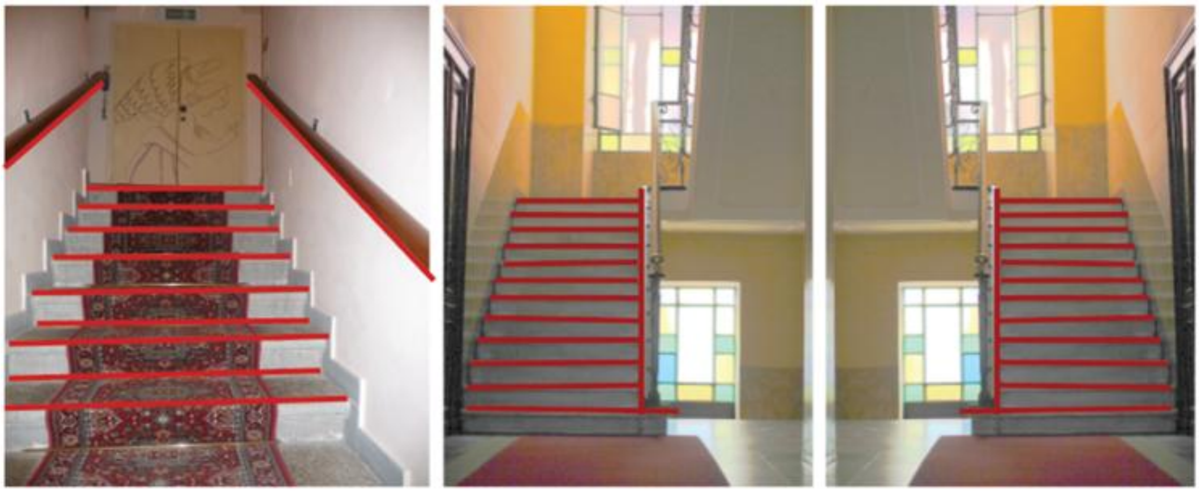


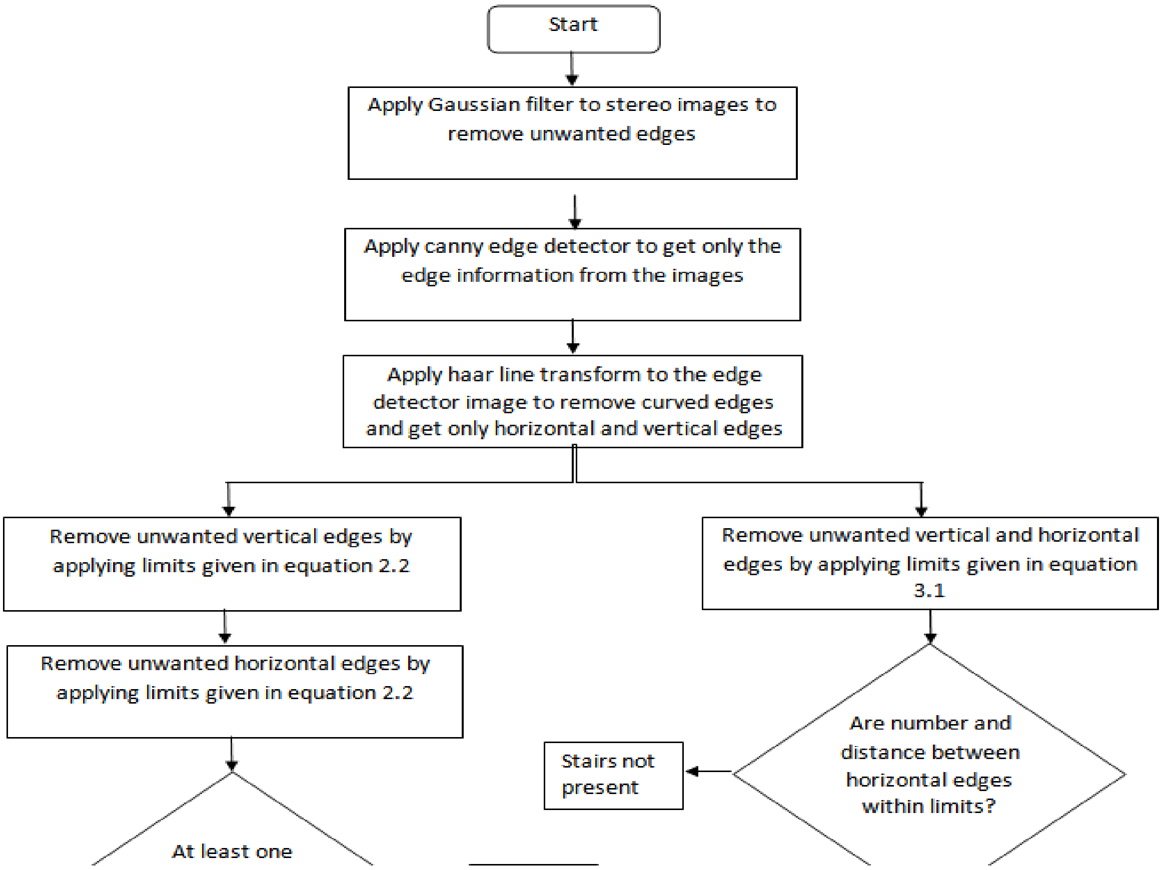
Figure 3.1 Stairs with horizontal edges and diagonal edges

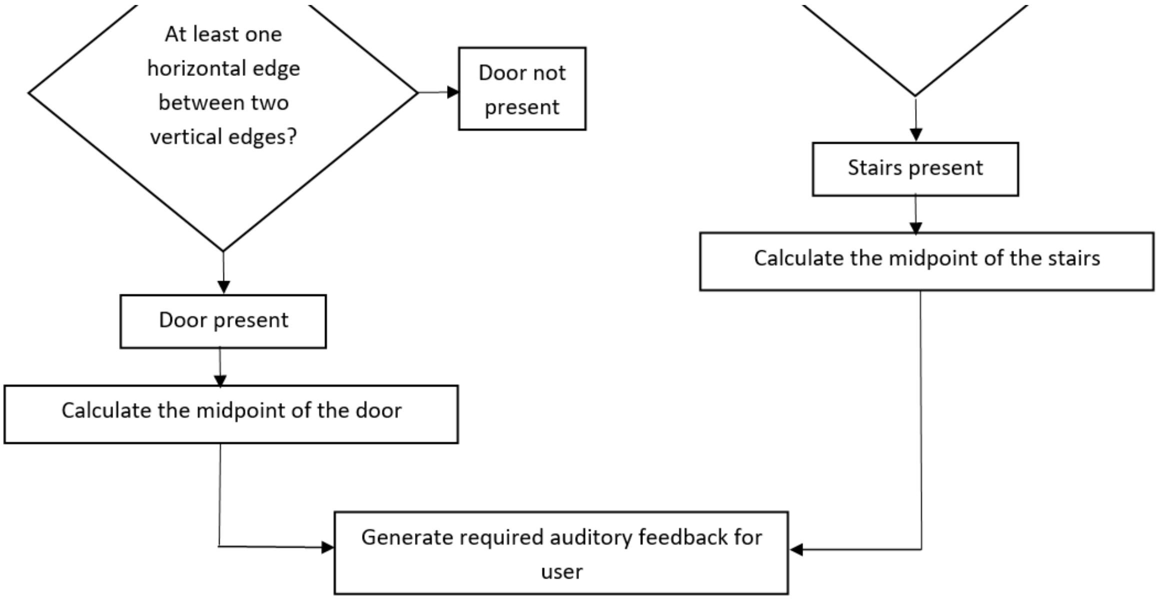
The above shown features are similar to other structures like book rack found during indoor navigation. To distinguish between stairs and other similar structure, we put limits on extracted features from stereo images. Let *n*be the total number of horizontal lines in the given image, a_v be the angle of diagonal lines, a_h be the angle of horizontal lines and let *d*be the maximum distance between two consecutive horizontal lines. For the algorithm to recognize stairs:

$$a_{h\_min} < a_h < a_{h\_max} \qquad a_{v\_min} < a_v < a_{v\_max} \quad (3.1)$$

$$n_{min} < n < n_{max} \qquad d_{min} < d < d_{max} \quad (3.2)$$

The value of n_{max}, n_{min}, d_{max} *and* d_{min} are depended on the distance between the cameras and the stairs. The flowchart of door detection algorithm and stair detection algorithm is as shown below





IV. EXPERIMENTS AND RESULTS

Experimentation process for door and stair detection algorithm was performed in two stages. Stage 1 experiments included studying a number of images with doors and stairs and images having objects with structures similar to doors and stairs. This stage of experimentation was used to decide the limiting values required to classify doors and non-doors, stairs and non-stairs. For this stage, our hardware prototype captured 60 images. Out of these 60 images, 20 images contained doors, 20 contained stairs, 10 contained images of the cupboard as they have a structure similar to doors and 10 images contained book rack as their structure is similar to stairs. For all these images, the distance between objects and camera system was at least 3 meters. At this distance, it was observed that for a vertical edge to be qualified as the edge of the door, the height of the vertical edge should be between 520 pixels to 600 pixels. Similarly, for the horizontal to be qualified as the edge of the door, the horizontal edge should have length should be between 250 pixels to 320 pixels. In case of stair detection, the distance between two parallel lines should be between 10 pixels to 50 pixels and the number of parallel lines should be between 7 to 20.

Stage two experiments were actual validation experiments. In validationprocess,the training set contained 230 images. 90 images were used to validate the door detection module. These 90 images were a mixture of images containing doors and no doors. 140 images were used to validate the stair detection module. The obtained results are given in the following table

Number of images for validation	Identified the object as door or stairs	Identified the object as bookshelf or cupboard	Percentage accuracy of the modules
50 images with the door	38	12	76.00%
40 images without a door	3	37	92.50%
70 images with stairs	49	21	70.00%
70 images with no stairs	5	65	92.80 %

The figure 4.1 and figure 4.2 shows detected doors and stairs.

Figure 4.1 Example of stair detection

Figure 4.2 Example of door detection

V. CONCLUSION AND FUTURE SCOPE

In this paper, we have presented the door and stair detection module that can provide information about the location of stairs and doors to a visually impaired person. The time required for the door detection and stair detection module to process the images, extract information about stairs and doors from the image and give auditory feedback to the user about the presence or absence of stairs or doors is 0.15 seconds and 0.2 seconds respectively. Hence the software module can work at a frame rate of 5 frames per second. The accuracy of door detection of the door detection modules I approximately 75 % and that of stair detection modules is 70 %. There is a vast scope for improvement in the design. In the near future, we would like to extend the possibility of using a support vector machine to better classify the doors and stairs. Depth information generated by the stereo cameras used for stairs and door detection can also help to further classify stairs as upward or downward stairs.

REFERENCES

[1]. Global data on visually impairment. World Health Organization, 2010

[2]. L. Dunai, I. LenguaLengua, I. Tortajada, and F. Brusola Simon, “Obstacle detectors forvisually impaired people,” in International Conference on Optimization of Electrical andElectronic Equipment (OPTIM), pp. 809–816, May 2014

[3]. R. Jafri, S. A. Ali, H. R. Arabnia, and S. Fatima, “Computer vision-based objectrecognition for the visually impaired in an indoors environment: a survey,” The VisualComputer, vol. 30, no. 11, pp. 1197–1222, 2014

[4]. X. Lu and R. Manduchi, “Detection and localization of curbs and stairways using stereovision,” in Proceedings of the 2005 IEEE International Conference on Robotics andAutomation, pp. 4648–4654, April 2005.

[5]. S. Wang and H. Wang, “2d staircase detection using real AdaBoost,” in 2009 7thInternational Conference on Information, Communications and Signal Processing(ICICS), pp. 1–5, Dec 2009.

[6]. Y. H. Lee, T. S. Leung, and G. Medioni, “Real-time staircase detection from awearable stereo system,” in Proceedings of the 21st International Conference on PatternRecognition (ICPR2012), pp. 3770–3773, Nov 2012

[7]. “RGB-d image-based detection of stairs, pedestrian crosswalks and traffic signs,” Journalof Visual Communication and Image Representation, vol. 25, no. 2, pp. 263 – 272, 2014

[8]. “Stairs detection with odometry-aided traversal from a wearable RGB-d camera,” ComputerVision and Image Understanding, vol. 154, pp. 192 – 205, 2017

[9]. D. Jain, “Path-guided indoor navigation for the visually impaired using minimal buildingretrofitting,” in Proceedings of the 16th International ACM SIGACCESS Conference onComputers and Accessibility, pp. 225–232, 2014

[10]. Y. Zhou, G. Jiang, G. Xu, X. Wu, and L. Krundel, “Kinect depth image based doordetection for autonomous indoor navigation,” in The 23rd IEEE International Symposiumon Robot and Human Interactive Communication, Scotland, UK,, pp. 147–152, 2014.