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Review Paper on Staircase Detection Using Mobile Phone Camera

[1]**Deepak Sharma**
Assistant Professor (CS)
Punjab University
ddbbpucc@gmail.com

Abstract: *Blinds people need some aid to interact with their environment with more security. A new device is then proposed to enable them to see the world with their ears. Considering not only system requirements but also technology cost, we used, for the conception of our tool, ultrasonic sensors and one monocular camera to enable user being aware of the presence and nature of potential encountered obstacles. In this paper, a comprehensive survey has been done on staircase detection using mobile phone camera as well as previous work is studied thoroughly.*

Keywords: *Stair detection, obstacle detection, visually impaired, blind.*

I. INTRODUCTION

The term blindness refers to people who have no sight at all as well as to those considered as blind and have limited vision, which cannot be said to be severely visually impaired. The concept of walking aids for blind people is not new. This is why many of them use a guide cane that is considered as a cheap and helpful to them. However, a guide cane has also its drawback such that it must be used several times in order for the user to detect any change to the ground or avoid any obstacles/ staircase. A great deal of research has been performed to improve autonomy of visually impaired people especially their ability to explore the environment.

Furthermore, bind person needs to scan the walking area continuously while walking. Another drawback is that the guide cane can only detect an object/obstacle when it has a contact with it or in range of 2 to 3 meters. If there is no contact eventually use will bump or fall down. So, there is need of some better improved technology to overcome these drawbacks. Here, our main focus is on various techniques used to detect staircase in the pathway for blind people.

II. STAIRCASE DETECTION

When we walk in different environments with different architectures and lighting conditions, one brief glance is enough to detect hazardous yet useful places, for example those containing stairs. This is no surprise, because our visual system is an extremely efficient and reliable pattern detector, and it has had a lot of time to learn the patterns, normally periodic sets of edges or bars. Our visual cortex even contains cells which are specialized in detecting periodic bar patterns; they are called grating cells [1]. The detection of stairways offers valuable high-level knowledge to a variety of intelligent systems.

Robotic Systems

Robotic systems navigating public space can use such knowledge to expand their range of operation to multiple floors. Systems assisting visually impaired people can provide guidance towards a stairway and provide information about e.g. the number of steps. Systems relying on a flat world assumption need to detect the traversal of a stairway passage to ensure proper functionality. Autonomous robots which navigate in buildings normally have special sensors for detecting steps and stairs, such that they do not bump into them like a wall or cannot fall down and be damaged. Normally these sensors suffice and are reliable, but if only one sensor fails or is accidentally blocked for some reason, the result can be disastrous. It may be a good idea that the visual functions of the robot include an occasional and rapid analysis of the environment in front to double-check the (in)existence of stairs, for example once per second.

Now imagine blind persons who cannot rely on vision. They must completely rely on the white cane, swaying it constantly in front to stay close to a wall and to detect obstacles, i.e., all possible obstacles. They too need to use stairs, and they have learned to be very cautious in environments like corridors and halls where one can expect steps and stairs.

III. PROJECTS FOR NAVIGATING AID FOR BLINDS

Using a traditional white cane is a universal solution, allowing a less risky journey for blind people. Such a tool is used to explore the environment by a frontal sweep, or contact with the ground to detect the presence of an obstacle. However, this cane does not allow sufficient exploration of objects that are at the top or which are getting too closer. To this end, the realization of an electronic cane automating the detection and recognition of fixed and mobile obstacles can offer more security and comfort to blind persons. This can be done through the integration of various specific sensors, which are designed to provide several types of information such as obstacles form, dimension, color and distance from the user.

Another project for stair case detection is the Blavigator project (the name combines blind and navigator) which aims at developing a visual aid, basically a portable computer with a camera, in order to facilitate the life of blind persons. Being a follow-up project of Smart Vision [2], during which the most basic functionality of the system was developed (path and obstacle detection; see [3]), additional functions are now being developed. One of these concerns stairs, at a distance of a few meters which is sufficient to inform or warn the user before he or she actually reaches them with the white cane. Replacing the functionality of the normal visual system by an artificial (computer) vision system is not a simple task, because one can expect all types of complications that one can imagine: different architectures, constructions, materials, lighting and even partially occluding walls etc.

Existing solutions

Some solutions are already exist on the market such as: Laser Cane [4], Teletact[5], UltraCanne [6], K Sonar cane [7], Smart Cane [8], Isonic [9], Guide cane [10], Palm Sonar [11], SmartWand [12], etc. These products help visual impairment people by collecting information through sensors and then, transmitting recommendations to them, through vibration or sound messages. A classification of these canes with respect to the type of sensors employed for obstacles detection is presented in [13].

The major disadvantages of these solutions are:

1) They only detect obstacle existence and distance without specifying indication about their nature which is important for the user to know.
2) They are unable or inaccurate in detecting some obstructions that are not protruding but present potential threat such as descending stairs, holes, etc.
3) The system communicates its recommendations, through intensity or frequency variations. Thus feedback information is often sent to the user through vibration or sound signals. So a training course is needed to keep the user informed about how to understand and react in real time to alerts that are transmitted regarding the existence of obstacles as well as their recognition. On the one hand, such training can be sometimes more expensive than the product itself. On the other hand, it is often difficult and complex for the users to assimilate it properly.

Many different types of sensors e.g. monocular and stereo cameras or laser scanning have been used for detecting stairs, all of them having intrinsic advantages and disadvantages.

Furthermore, in the case, where information is transmitted as an acute sound, that may happens several times especially when the obstacle is very close, it may be embarrassing for the blind person when they are in public. Therefore, our interest is specifically focused, on the development of an electronic tool using two types of sensors which are ultrasonic sensors and monocular camera. Stairways are inevitably present in human-made environments and constitute a major problem in robot and human navigation.

IV. RELATED WORK

Many approaches were described in the literature using different algorithms to detect and recognize descending and ascending stairs. Such systems are often essentially based on a laser sensor, infrared sensor or monocular camera.,

Se and Brady [14] used a texture detection method based on Gabor filters to detect distant staircases. When close enough, staircases are then validated by looking for groups of parallel edges, where convex and concave ones are partitioned using intensity variation information. Staircase pose is estimated by a homography search approach. They employed an a priori staircase model.

Lu and Manduchi [15] presented a stereo vision system to localize curbs and stairways for autonomous navigation. Their algorithm combines brightness information in the form of edges with 3D data from a commercial stereo system.

In [16], Zhong et al. presented a navigation system for robot autonomous stairway climbing, as well as stairway modeling in mapping and building reconstruction, based on the combination of Gabor filters and fuzzy fusion phase grouping (FFPG).

Hernandez and Kang-Hyun [17] localized and recognized outdoor stairways by combining the longest segments of diagonal edges, the vanishing point, and Gabor filters to detect horizontal edges.

Later, Hernandez et al. [18] presented a localization method for indoor stairways. Their method analyses the edges of stairs by employing planar motion tracking and directional filters. They extracted the horizontal edges by using again Gabor filters. From the specified set of horizontal edge segments, they extracted a hypothetical set by using a correlation method. Finally, they applied a discrimination method to find the ground plane on the basis of behavioral distance measurement.

Lee et al. [19] employed many small image patches in order to train (AdaBoost) a cascade classifier until true and false positive detection rates of 0.983 and $7.6 \cdot 10^{-6}$ were obtained. On real test sequences, this classifier could obtain a precision of 0.76 for recall rates up to 0.7. However, by combining this classifier with ground plane estimation and the temporal consistency in the sequences, the precision increased to 0.84. They mention that the total number of false positive detections was reduced from 1400 to 501. To the best of our knowledge this is the only study which presented quantitative results.

Joel A. Hesch, et.al, [20], presents a strategy for descending-stair detection, approach, and traversal using inertial sensing and a monocular camera mounted on an autonomous tracked vehicle. At the core of our algorithm are vision modules that exploit texture energy, optical flow, and scene geometry (lines) in order to robustly detect descending stairwells during both far- and near-approaches. As the robot navigates down the stairs, it estimates its three-degrees-of-freedom attitude by fusing rotational velocity measurements from an on-board tri-axial gyroscope with line observations of the stair edges detected by its camera. We employ a centering controller, derived based on a linearized dynamical model of our system, in order to steer the robot along safe trajectories. A real-time implementation of the described algorithm was developed for an iRobot Packbot, and results from real-world experiments are presented.

Se et.al, [14] also developed a Gabor filter based texture detection method to detect distant stair cases. When the stairs are close enough, stair cases were then detected by looking for groups of concurrent lines, where convex and concave edges were portioned using intensity variation information. The pose of stairs was also estimated by a homograph search model.

CONCLUSION

In this paper our main focus is on staircase detection for blind people for easy navigation aid by using mobile phone camera. Here, we study about various existing solutions available in market as well as various projects working for improvement in navigating aid along with the safety of blind person.

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