Stairway Detection Based on Single Camera by Motion Stereo

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Abstract. In this paper we are proposing a method for detecting the localization of indoor stairways. This is a fundamental step for the implementation of autonomous stair climbing navigation and passive alarm systems intended for the blind and visually impaired. Both of these kinds of systems must be able to recognize parameters that can describe stairways in unknown environments. This method analyzes the edges of a stairway based on planar motion tracking and directional filters. We extracted the horizontal edge of the stairs by using the Gabor Filter. From the specified set of horizontal line segments, we extracted a hypothetical set of targets by using the correlation method. Finally, we used the discrimination method to find the ground plane, using the behavioral distance measurement. Consequently, the remaining information is considered as an indoor stairway candidate region. As a result, testing was able to prove its effectiveness.

Keywords: Stairway segmentation, Gabor filter, Maximum distance of ground plane, Line segments extraction, Stair candidate region.

1 Introduction

Autonomous stair climbing navigation has been studied in computer vision. Nevertheless, most of the publications define in a priori the actual position of the stairway in an image in order to apply the stair recognition algorithm [2]-[6]. In this paper the authors present a stairway detection algorithm for determining stair localization from image sequence processing, without any prior information about the position of the stairs. As mentioned above, this stage is necessary in order to perform the climbing process in unknown environments for autonomous systems.

There are many types of stairs. For example, there are simple stairs, which consist of one straight piece with or without an intermediate landing. Other types of stairs are formed by several straight sections with intermediate landings for a change in direction if so desired. Fundamentally, stairs can be described as structures that follow a series of steps or flights of steps for passing from one level to another. Based on this property, we tried to extract from given images only the set of the longest line segments according to the stairway edges. In an image, this is denoted as a "set of lines which are parallel to each other". The detection of this set of lines is important in

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describing the localization of the candidate region of the stairs in an imaging sequence. Combining this set of line segments with the information of the dynamics of the scene, the proposed algorithm was able to determine the candidate area of the stairs within the image plane.

The authors of several studies have addressed the problem of stair climbing [2]-[6]. Nevertheless, in most of the cases, robots were placed in front of the stairways, and, in some cases, human operators moved the robot towards the stairways region. Consequently, in most of these approaches the localization problem still remains. To this end, the proposed method presents a strategy for solving the stairway localization problem in autonomous robotics. On the other hand, some related works combine brightness information with 3-D data from a stereo camera system. In [3], the authors worked with the correlation-based stereo by knowing the disparity. In addition they also estimated the ground plane by using the Least Median of Square. As a result they created an algorithm for the detection and 3D localization of stairways. Nevertheless, the process mentioned above required a computational complexity.

2 Algorithm Description

Our proposed algorithm for indoor stairs segmentation has six steps which are: (1) extracting frames, (2) finding the maximum distance of the ground plane (MDGP), (3) extracting the line segments, (4) extracting the region of interest (ROI), (5) finding correspondences, and (6) ground discrimination. From the last step we will define the stair candidate.

2.1 Extracting Frames

Using our algorithm, we extracted frames in a short time interval that started just before the earliest detection from the video capture sequence. Due to the fact that frames are collected in a short time interval, there is a temporally close relation between frames. Consequently, from the video image sequences, both the spatial and temporal information is extracted in order to know the dynamics of the scene. Our method was based on the assumptions that stairways are located below the true horizon. Consequently, in the coordinate system of the single camera, axis Z is aligned with the optical axis of the camera. Axes X and Y are aligned with axes x and y of the image plane. In Fig.1 P is a point in the world at coordinate (X,Y,Z), the projection of this point into the image plane is denoted R(xc,yc).

2.2 Finding the Maximum Distances of the Ground Plane

The proposed method consists mainly in extracting the information surrounding the ground plane projected onto the image plane. The MDGP is the maximum distance that the proposed method is able to compute from the camera position to the horizon line onto the image plane by using the Pythagorean trigonometric identities. When given an image, our goal is to compute the MDGP according to the following set of equations (1, 2, 3):