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Free Space Segmentation for Gokart Application

V-Disparity

Semester Project

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Supervision

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Abstract

Road and ground detection are closely related key tasks for an autonomous ground vehicle. These computations should be robust and preferably be performed in real-time. This paper aims to show the implementation of the V-Disparity method for ground detection. The approach is based on classic computer vision and does not incorporate learning methods. Basis of the method is a disparity map, for which a row-wise histogram is computed. This V-disparity histogram robustly preserves geometric scene features and can be used for various tasks. Experimental results however show the shortcomings of the implementation and how they could be overcome. In the following, a second pipeline is introduced. A mapping from a Velodyne Vld-16 Lidar to a camera is computed. The binary obstacle - ground mask which is computed from the lidar's point cloud can then be projected onto the camera image. These labels can then be used for e.g. machine learning tasks.

Keywords: Ground detection, V-Disparity.

Contents

Chapter 1

Introduction

The task of segmenting a scene into ground, obstacles and other labels is a well-researched topic. It is a fundamental part of any autonomous ground vehicle, and lays the basis for many different tasks, such as planning, safety features or scene understanding. Over the last few years, solutions to this task, which are based on machine learning methods, have deemed themselves to be robust and accurate. Their ability to generalise and be applied to a variety of scenes make them a reliable choice. There however, exist many approaches to the problem, which are based on classic computer vision, with implementations dating few decades back.

The goal of this semester project is the implementation of a robust and accurate free space detection pipeline based on classic computer vision. The results of this pipeline can be used to e.g. label data for machine learning. If the pipeline does not perform as expected, a second pipeline is introduced, where the focus entirely lies on labeling data for machine learning tasks.

This semester project is part of a more extensive research into autonomous driving, based a self-driving Gokart. The Gokart is basis for a variety of research topics, such as planning, control systems and sensor fusion. The testing environment is a modular indoor Gokart track. The ground is flat, with no uphill or downhill sections. The track is not affected by weather conditions.

1.1 Related Work

Related work on this topic is extensive. After limiting my research to the method of V-Disparity, early implementations can be dated back to 2002, with [1] providing a robust and accurate method for road detection, even for non-flat geometries. A study on the U-V Disparity method can be found in [2], providing a real-time implementation of the stereovision based scene analysis. The method was improved and adapted since it's introduction, becoming more robust and computationally efficient, as shown in [3]. Aside from free space detection, U-V-Disparity can be used solely for obstacle and pedestrian detection, with U-V-Disparity acting as the underlying basis for a SVM Classifier, where the extraced ROIs are used for training. Iloie et al. implemented this framework in [4].

1.2 Structure of this report

This report is structured as follows.

Chapter 2

Method

2.1   V-Disparity

This chapter explains the theoretical basis of the V-disparity method. To begin with, the basis of the V-Disparity method, the disparity map, is outlined.

2.1.1   Disparity Map

It is assumed, that the reader has a general understanding of stereovision systems. Given two calibrated stereo cameras, the respective rectified images can be used to calibrate a disparity for each pixel. These is achieved with different block-matching algorithms, such as the StereoSGBM algorithm implemented in the popular OpenCV library. Given a disparity map, the baseline and focal length, a depth map can be calculated and used for further processing. The V-Disparity method however only makes use of the disparity map.

2.1.2   V-Disparity

Once a disparity map δ is calculated, a V-Disparity histogram can be constructed. For each row u, a histogram of the occuring disparities is computed. The pixel values represent the occurence of the respective disparity in the row. Given a plane in the scene, the projection of the plane onto the V-Disparity image has a useful property. Following the calculations of 2.1.1, a plane will be projected as a linear curve in the V-Disparity image. This simplifies the extraction of the respective plane in the V-Disparity image, as a e.g. Hough Line Transform can be applied to detect the lines. Because the most prominent plane in usually represented by the road, it will be detected as the line with the most votes in the V-Disparity image. Horizontal or vertical lines can be dismissed, the disparity gradient of the road leads to a skewed line. Even though Non-flat road geometry will not be considered in this project, it should be noted that the road in that case consists of a series of planes, which will then be projected as a piecewise linear curve in the V-Disparity image.

Once the line has been fitted in the V-Disparity image, the disparity values for the road surface are known. Extracting the road in the image domain is straightforward. For each row, the values which lie within a threshold of the value of the extracted line are part of the road, all other pixels are masked as non-road.

2.2   Lidar Camera Projection

To project lidar scanning points onto a camera image, the camera's intrinsic parameters should be known. Additionally, the projection matrix from lidar to camera should be known. It can be roughly measured and computed, or determined by externally calibrating the lidar and camera.

Chapter 3

Implementation

3.1 V-Disparity Implementation

This chapter explains the code implementation of the V-disparity method and elaborates on every part of the pipeline.

Chapter 4

Results

Results have been visually evaluated, as there is no ground truth available for this method. The evaluation have shown, that for this project's implementation, the V-Disparity method does not provide the desired results. The generated mask lacks temporal coherency, and for mid-range distances ($>$4m), important features are not detected, such as various obstacles or road boundaries. The reason for this can be found in the generated disparity map. Without post processing, the backprojection of the road requires an accurate disparity map. However the quality of the disparity map diminishes for further distances, edges are not well preserved and artifacts in low-textured areas lead to inaccurate masks.

Chapter 5

Conclusion

Appendix A

AppendixChapter

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