Simple and Efficient Method for Calibration of a Camera and 2D Laser Rangefinder

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Abstract. In the last few years, the integration of cameras and laser rangefinders has been applied to a lot of researches on robotics, namely autonomous navigation vehicles, and intelligent transportation systems. The system based on multiple devices usually requires the relative pose of devices for processing. Therefore, the requirement of calibration of a camera and a laser device is very important task. This paper presents a calibration method for determining the relative position and direction of a camera with respect to a laser rangefinder. The calibration method makes use of depth discontinuities of the calibration pattern, which emphasizes the beams of laser to automatically estimate the occurred position of laser scans on the calibration pattern. Laser range scans are also used for estimating corresponding 3D image points in the camera coordinates. Finally, the relative parameters between camera and laser device are discovered by using corresponding 3D points of them.

Keywords: Camera- laser rangefinder calibration, extrinsic parameters, sensor fusion, perspective n points.

1 Introduction

Nowadays, systems using camera and laser rangefinder (LRF) have been widely applied to various intelligent vehicles, robot applications, intelligent transport systems namely automotive navigation, motion estimation, path planning and mapping, and quality control systems[19]. In order to use multiple devices simultaneously[1][2], the relative pose between devices is required for systems. In recent years, there are many proposed methods for discovering the rigid-body transformation between a camera and LRF. Those methods are separated into several categories of research. The first group of methods focuses on extracting the relative parameters between a camera and 3D laser scanner. The second one tries to deal with the problem between a camera and 2D laser scanner. The difficulty of this task is how to extract corresponding information between devices, due to the laser beams, which are not visualized on the calibration pattern. Therefore, the discontiguous calibration pattern is used to emphasize and visualize the laser beams, which is helpful for extracting corresponding points of a camera and LRF. Corresponding points are used to estimate the absolute rig-body transformation of a camera and LRF.

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This paper proposes a method for automatic discovering the relative position and direction of a camera with respect to a LRF by using the special calibration pattern. The calibration pattern consists of discontiguous depth of right-angled triangles, which emphasizes feature points of laser ranges to extract corresponding feature points between images and laser range scans. The 3D points in the LRF coordinates are used for estimating the 3D points of image in the camera coordinates by using the well-known perspective-n-point (PnP) method. Then, the corresponding 3D points are used for estimating the relative rotation and translation between a camera and LRF.

2 Related Work

Related works are separated into several categories. In the first group of methods, researches proposed methods for extracting rigid-body transformation between a camera and 3D LRF. The full calibration parameters of a camera- 3D LRF system was autonomously recovered by using special calibration pattern [3]. The authors used the center marks of the circle's physical as a calibration pattern. That method does not rely on the corner extraction, but rather on the simple target, which extracted from the center marks of a circle. Experimental results demonstrated that the effectiveness of the method. Other work estimated rigid-body transformation between a camera and 3D LRF by discovering the statistical dependence of two sensors [4]. They proposed the method, which uses maximal mutual information of vision-LRF to estimate the extrinsic parameters. Mutual information was used as registered criterion. The method is able to work in position without any specific calibration targets. On the contrary, a new calibration method based on nature scenes was proposed in [5]. It does not need any special object required for calibration. In their method, the corresponding points are manually selected on common scenes, which are viewed by both sensors. Their paper also presented a novel method to visualize range information, which obtained from a 3D LRF. Discontiguous information of laser ranges is emphasized and superimposed on a color image, which bring the simplicity and efficiency to selected corresponding points between color image and laser range image. Practical experiment had been processed on a camera and rotating laser scanner. The results showed that the method is suitable for real applications. Recently, a real-time calibration of multiple cameras and a 3D laser scanner was proposed in [6]. In this task, the authors described the approach using special checkerboard, which captured by both sensors. The corresponding points were manually selected. The paper did not present how to extract corresponding features between cameras and a LRF. Most recently, [7] presented a web interface toolbox for calibration multiple visions and laser rangefinders, especially for the Kinect 3D and Velodyne HDL-64 device. In that work, authors used multiple checkerboard patterns, which located at difference positions, to deal with solution of information, outliers matching for improving accuracy of results. Usually, most of calibration methods require manual selection of corresponding points. The advantage of a vision and 3D LRF calibration is easy to emphasize a depth image of laser sensor with respect to color image of vision sensor. This task supports to extract corresponding points, which occur on calibration pattern. Authors in [8] presented an algorithm for extracting the relative pose between color cameras