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Project Report

"Adding Color Information to LiDAR using Camera Calibration"

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Abstract

In recent years, 3D sensing system has aroused increasing attention due to their vast potential applications, such as autonomous driving and mobile robotics. These tasks have high demands for various applications in different field domains. Nowadays, with the popularity of crew-less vehicles, the navigation problems inherent in mobile robots are gathering even greater attention. One of the fundamental problems is the localisation or calibration between different sensors.

LiDAR technology can gather 3D points with an effective range of up to 200 meters. In addition, LiDAR can be used in low-textured scenes and scenes with varying lighting conditions. However, the 3D model data generated by LiDAR is sparse and lacks colour information. A camera is a portable and cheap device that can obtain colour information. However, it needs to correspond to feature points during calculation, which will be time- consuming and sensitive to light. A combination of cameras and LiDAR requires obtaining transformation parameters between the coordinate systems of the two kinds of sensors. The calibration procedure leads to the determination of the transformation parameters, namely the rotation matrix and translation vector, the alignment of the two coordinate systems, and the correspondence between 3D points and 2D images. The 3D point cloud of the LiDAR is combined with the 2D image of the camera to create a 3D LiDAR model with colour information.

Keywords: LiDAR-Camera; Calibration

1. Introduction

Lidar sensors and cameras are frequently combined in autonomous driving applications. A lidar sensor collects 3-D spatial information and position information, and a camera captures the color and texture of the space in 2-D images.

The 3D LIDAR sensor can provide a 3D location and depth data about objects, while the color camera collects their 2D color characteristics. By combining 2D picture data with 3D positional information, it is possible to display the objects with a more realistic perspective and enhance object detection and classification. For autonomous driving and robotics applications, we can also improve the performance of vision and mapping algorithms. As a requirement, however, we must first determine their relative locations and orientations by calibrating the LiDAR and color camera sensors.

Lidar-camera calibration estimates a transformation matrix that gives the relative rotation and translation between the two sensors. We use this matrix to perform lidar-camera data fusion.

A checkerboard plane is utilized for camera and LiDAR calibration. Using a checkerboard for calibrating is often a two-step process.

1) Intrinsic Calibrations
2) Extrinsic Calibrations

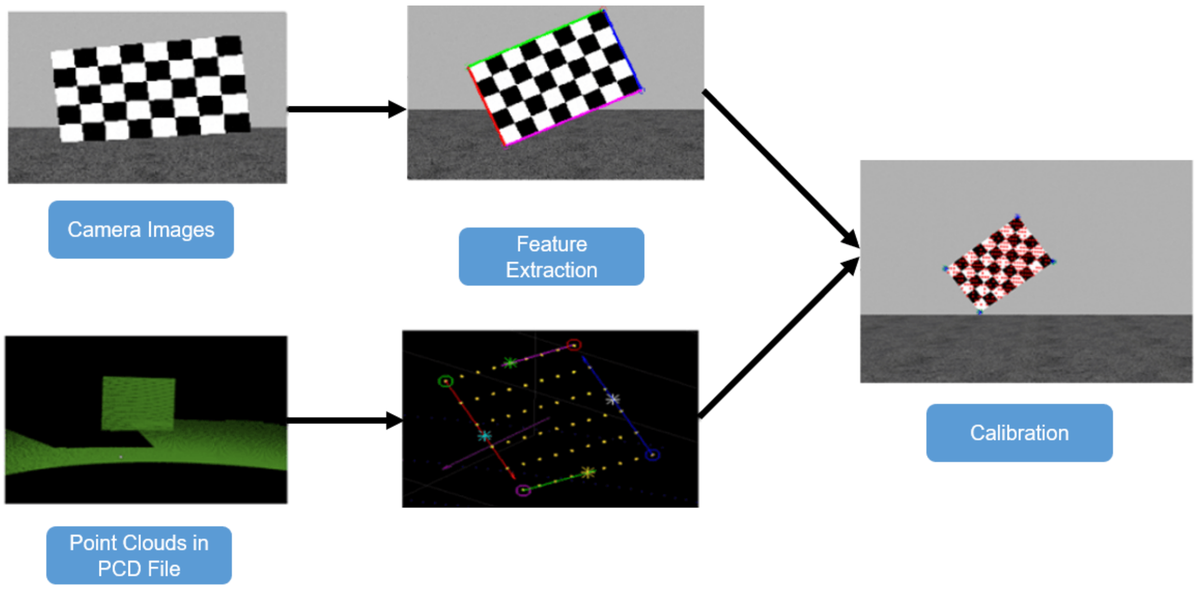
Thus we need two measurements for this two-step calibration process, and two sources of error may occur while performing a measurement. We use a calibration board with a monochromatic color to reduce the impact of reflectivity bias. We use a board with a polygon shape to improve the calibration accuracy.

The estimated vertices serve as reference points for the calibration between the color image and the 3-D scanned data. Using a corner detection method, the vertices of the polygonal planar board in the 2D image are identified, and their corresponding points in the scanned 3D LIDAR data are estimated.

The strategy for calibration is to find correspondences between the 2D picture and the 3D point cloud by estimating the 3D locations of vertices from the scanned laser data and their corresponding corners in the 2D image.

2. Method

This diagram depicts the workflow for the lidar and camera calibration (LCC) procedure, with checkerboard serving as the calibration object. The checkerboard corners and planes are extracted from lidar and camera data, and a geometrical relationship between their coordinate systems is established to perform calibration.



Source: https://in.mathworks.com/help/examples/lidar/win64/LidarCameraCalibrationExample_01.png

We load and extract checkerboard features from images and corresponding point clouds. Then we make use of these features to estimate transformation matrix between camera and lidar.

The programmatic workflow for extrinsic calibration consists of these steps.

1. Extract the 3-D information of the checkerboard from both the camera and lidar sensor.
    a. To extract the 3-D checkerboard corners from the camera data, in world coordinates.
    b. To extract the checkerboard plane from the lidar point cloud data.
2. Use the checkerboard corners and planes to obtain the rigid transformation matrix, which consists of the rotation R and translation t.

The transformation matrix obtained can be used to

- Evaluate the accuracy of LC calibration by calculating the error.

- Project lidar points onto an image.
- Fuse the lidar and camera outputs.
- Estimate the 3-D bounding boxes in a point cloud based on the 2-D bounding boxes in the corresponding image.

3. Result

This project is my starting point to get hands on experience of what research is and explore my research topic. This project made me familiar with the basics of camera calibration and introduced me to research going in the field of Geoinformatics particularly about LiDAR.

The main result of the project is to add color information to LiDAR. This is implemented using the concept of draping. We take depth information from LiDAR and take image from a camera and then we fuse the images after completing LiDAR Camera Calibration.

4. Conclusion and Summary

The 3D LIDAR sensor can provide 3D location and depth data about objects, while the color camera collects their 2D color characteristics. By combining 2D picture data with 3D positional information, it is possible to display the objects with a more realistic perspective and enhance object detection and classification.

We add color information to LiDAR by implementing the concept of draping. We take depth information from LiDAR and take image from a camera and then we fuse the images after completing LiDAR Camera Calibration.

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