Mid Term Report for SURGE 2022

Project Title: Adding Colour Information to LiDAR using Camera Calibration
Project Mentor: Prof. Salil Goel
Dept: CE
Name: Aman Kumar Singh
Roll No: 200100

Aim:
Add colour information to 3D LiDAR models using camera calibration and machine learning tools.

Research Problem:
The 3D models generated using LiDAR lack colour and texture information in them. The research problem is to add colour information to the models using LiDAR-Camera Calibration.

Keywords:
LiDAR-Camera; Calibration.

Introduction:
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.

Camera Calibration

Geometric camera calibration, also called camera resectioning, estimates the parameters of a lens and image sensor of an image or video camera. We can use these parameters to correct lens distortion, measure the size of an object in world units, or determine the camera's location in the scene.

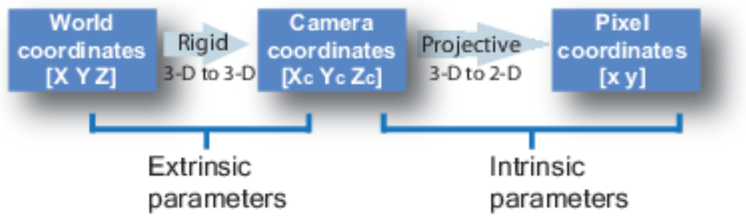
Camera parameters include intrinsic, extrinsic, and distortion coefficients. We need to have 3-D world points, and their corresponding 2-D image points to estimate the camera parameters. We can get these correspondences using multiple images of a calibration pattern, such as a checkerboard.

Camera Calibration is basically a method to find a camera's internal and external parameters.

Topics:
(1) Linear Camera Model
(2) Camera Calibration
(3) Extracting Intrinsic and Extrinsic Matrices
(4) Example Application: Simple Stereo

Camera Calibration Parameters

The calibration algorithm calculates the camera matrix using the extrinsic and intrinsic parameters. The extrinsic parameters represent a rigid transformation from the 3-D world coordinate system to the 3-D camera's coordinate system. The intrinsic parameters represent a projective transformation from the 3-D camera's coordinates into the 2- D image coordinates.



Extrinsic Parameters

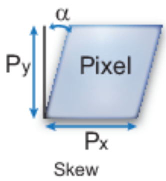
The extrinsic parameters consist of a rotation, R, and a translation, t. The origin of the camera's coordinate system is at its optical center and its x and y axis define the image plane.

Intrinsic Paramters

The intrinsic parameters include the focal length, the optical center, also known as the principal point, and the skew coefficient. The intrinsic camera matrix, K, is defined as:

$$\begin{matrix} f_x & 0 & 0 \\ s & f_y & 0 \\ c_x & c_y & 1 \end{matrix}$$

The pixel skew is defined as:



$c_x \quad c_y$:- Optical center (the principal point), in pixels.
(f_x, f_y) :- focal length in pixels

$$f_x = F/p_x$$
$$f_y = F/p_y$$

F :- Focal length in world units, typically expressed in millimetres
(p_x, p_y) :- Size of pixel in world units.
S :- Skew coefficient which is non-zero if the image axes are not perpendicular.
$s = f_x \tan\alpha$