Lab 1

Camera Calibration

Objective

In this experiment, students will use stereo cameras, an image acquisition program and camera calibration algorithms to achieve the following goals:

1. Develop a procedure for camera calibration.
2. Measure the error in calibration using two approaches:
   i. A simple Least Square method
   ii. A non-linear method using a well designed calibration toolbox.

Reference Materials

1. Lecture notes, i.e. camera calibration using least square approach.
3. Caltech Camera Calibration Toolbox.

Lab Procedure

This lab consists of the following three parts:

Part 1: Least Square method for camera calibration

1. Take five snapshots of the calibration pattern using both left and right cameras. Each snapshot should be taken with the pattern at a known XY position and at different heights, parallel to the table.
   You can use the green foams in the lab to raise the pattern. The pattern must be moved only vertically for each of the three heights. That is, there is no translation in the XY direction when moving up for each pattern.

2. Use corner extraction tool in the Camera Calibration Toolbox to determine the pixel coordinate of each corner in the pattern and create a file with XYZ-UV information for the calibration of each camera.

3. Write a simple Matlab program to find the calibration matrix (intrinsic and extrinsic parameters) using the least square approach. The suggestion is to use the method in your lecture notes. That is, re-rewriting the equations to construct one single matrix, A, and minimizing $Aq = 0$ under the constraint $\|q\|=1$, where q contains the calibration parameters in a column vector.
NOTE:
In this case the calibration toolbox won't be able to determine the Z coordinate of the pattern. Therefore make sure you record the different heights at which you placed the pattern and correct the Z coordinate in your code accordingly.

Part 2: Using a non-linear method for camera calibration

In this case you will use the Calibration toolbox.

1. Position the pattern this time at random poses with respect to the camera and take five snapshots with each camera. You may pick any random position, but make sure each one is reasonably different from the others (rotation and translation) and that at all poses, the pattern can be clearly seen by the camera. Also make sure that one such pose of the pattern is well known with respect to the robot world coordinate frame – this will be the reference frame to establish the camera to robot/world transformation. (Hint: use the same initial position used for part 1)

2. Run the Matlab programs provided in the Calibration Toolbox to obtain the calibration matrix (intrinsic and extrinsic parameters) and distortion parameters – the program may use Zhang’s method or any other approach with distortion parameters modeling. You should also save the distortion parameters and image corner points.

Part 3: Error Measurment

At this point you have collected training images in order to learn the parameters for camera calibration using two different methods. Next step is to test and compare the results of the calibration.

1. Take another snapshot of the pattern with known XYZ position for testing purpose. (Hint: record the XYZ position with respect to the world coordinate frame). Make sure that the image of this pattern is different from all the images used for the calibration.

2. Extract the corners of the test image using Camera Calibration Toolbox and save the XYZ-UV coordinate of the pattern. You will use these coordinates as ground truth to compare with results obtained from the calibration parameters learnt in parts 1 and 2.

3. Calculate the error. That is a) observed UV coordinates in the image vs the estimated UV coordinates using the calibration matrix derived in Part 1. b) observed UV coordinates in the image vs the estimated UV coordinates using the calibration matrix derived in Part 2.

4. In step 3 above, you are comparing normalized UV coordinates to distorted coordinates. Therefore, for this step you should take distortions into account – i.e. Repeat step (3) for undistorted and distorted UV coordinates.

Hints:
- Use Weng’s or Zhang’s error measurement technique for converting from normalized UV coordinates to undistorted normalized UV coordinates and vice versa.
- Use the distortion parameters saved in Part 2.
- The flowcharts below give a visual explanation for what you need to do.
Comment the results: what you expected the error to be and why? what error did you get and why?