Assignment 4: Tsai Camera Calibration

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Abstract

Using half of a cube I built with three planes which represent x, y, and z along with the Tsai 3D calibration algorithm, we are able to calibrate the image sensor on my cell phone. The algorithm produces intrinsic parameters, extrinsic parameters, and distortion parameters that can be used in order find the real world depth of an object and other dimensions.

1. Algorithm

The Tsai 3D algorithm[1] that I implemented comes from C code I found online. The algorithm needs 3D planes formed with the z plane normal to the surface, and x being the plane to the left and y the plane to the right. Using this half cube along with matching real world points to the pixel location, we can calculate the instrinsic, extrinsic, and distortion values for my cell phone's rear image sensor. First you must build the cube, to which I used three foam board pieces cut to 176x176 mm squares. I then wrote a program that would make an 11x11 grid with each square in that grib being exactly 16 mm. This allows us to get count the real world coordinates x, y, and z. From there, we take a couple of pictures of the half-cube and then use GIMP to find the pixel's x,y coordinates of the previously selected points on the cube's checkerboard. We take these corresponding points and put them into a file which the program will read in order to generate the intrinsic, extrinsic, and distortion values. We then have to search online in order to find the sensor make and model that is present on our cell phone. This proves to be a tedious endeavour at the least, as it seems to be hard to find reliable or easily accessible data on the sensor's intrinsic parameters. Once you have found the focal length, image resolution, pixel size, center x, and center y it is time to run the algorithm. The Tsai 3D camera calibration algorithm iterates over the corresponding points in order to solve for the rotation and translation matrices and from this the cameras intrinsic values like focal length can be calculated/estimated and then finally the len's distortion. It will also calculate the extrinsic parameters which include Euler angles, yaw, pitch, and tilt. You can use these values to rid yourself of the len's distortion in order to calculate real world coordinates from just a single image. Tsai has proven, over the years, to be a very robust solution that needs only one camera and one image in order to calibrate for use in the real world where other solutions call for multiple images in multiple positions in order to properly calibrate the image sensor.

2. Related Work

The main work used in this was the paper and code from https://webserver2.tecgraf.puc-rio.br/ mgattass/calibration/ along with the classe's text book and information randomly found online for my rear image sensor.

3. Examples

Here are two images I took with my cell phone rear camera, one being landscape and other being portrait, which in turn swawps the width and height values of the image. I have chosen 7-8 points from both the real world and pixel x,y location. I chose corresponding points from these images in order to calibrate the rear image sensor on my cell phone.

Figure 1. 3D Half Cube Portrait

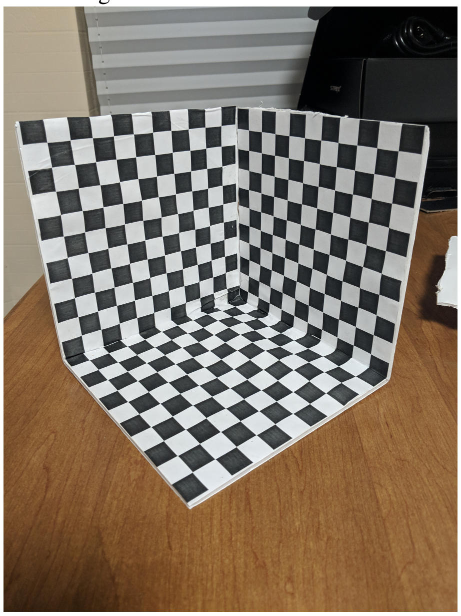
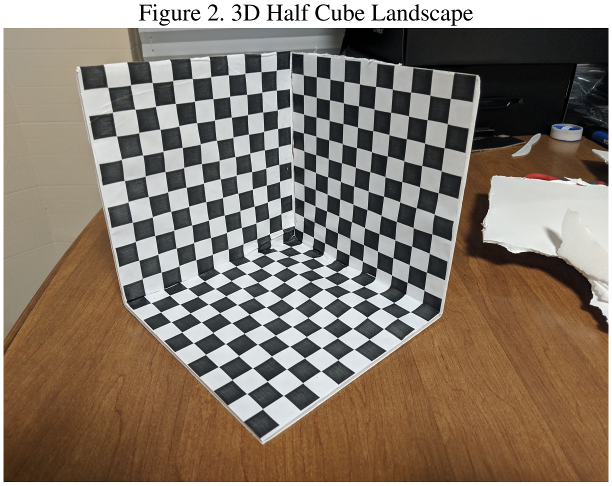


Figure 2. 3D Half Cube Landscape



4. Lessons Learned

I learned quite a few things during this project, most importantly that it is a pain to build a very precise 3D plane using half a cube. The angles and dimensions must be exact and I realized far too late that it would have been easier if I had purchased something cube like and machined in a shop to precise specifications, much like a Rubix Cube. I also learned the importance of lens distortion and how much it actually distorts the image comparatively to a real world situation. Just from looking at images it is very hard to notice any distortion but it is most definitely there and causes great pains in trying to calculate real world coordinates from an image. It is far more involved than I had originally believed and requires quite a sophisticated algorithm in order to calibrate the sensor using just a singe image a 3D checkerboard plane. I also learned about the importance of transformations using matrices and how useful they can actually be. I also learned how to use this in research I am doing which involves using an image sensor in order for a robot to interact with the real world, which happens to be extremely important in many of our test cases.

References

[1] Ansi c implementation of classical camera calibration algorithms: Tsai and zhang. https://webserver2.tecgraf.puc-rio.br/ mgattass/calibration/.