# TSAI Camera Calibration and Triangulation

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## I. Description of Algorithm

For this assignment, we divide the algorithm into three parts. First part is to find the good points to track. We create synthetic 3D locations by making one of the point as origin. Using the points we calibrate the camera using Tsai calibration algorithm which provides intrinsic and extrinsic parameters of the camera. With the intrinsic and extrinsic parameters we can achieve triangulation and estimate the 3D location of a given 2D point.

## II. Description of Code

### A. Finding Corners

Finding corners of the object is critical task. This provides points which can be easily used to create synthetic 3D locations of them. Corners can be found using goodFeaturesToTrack function, available in OpenCV package. Once the points are digitally captured we need fix on of them as origin. Using the origin measure 3D locations of the other points using a measuring tape. 3D points are with respective world coordinate axis. These image locations and world coordinates are paired out. We can create the following equation with the pairs formed.

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} -f & 0 & c_x & 0 \\ 0 & -af & c_y & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} r_{00} & r_{01} & r_{02} & t_x \\ r_{10} & r_{11} & r_{12} & t_y \\ r_{20} & r_{21} & r_{22} & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_p \\ Y_p \\ Z_p \\ 1 \end{bmatrix}$$

### B. TSAI Camera Calibration

Tsai camera calibration uses a different approach towards camera calibration. This methodology uses [2D, 3D] pairs to calibrate the camera. Using this algorithm, intrinsic and extrinsic parameters of the camera are known. Intrinsic parameters are fx, fy and aspect ratio of the camera. Extrinsic parameters are Rotational Matrix and Translation Matrix. Calibration is divided into two parts. First DLT is about find first estimates of Rotational Matrix, Tx, Ty and aspect ratio of the camera. Second DLT is to find Tz and Focal length. Point to be taken care of is, these all are initial estimates. Results using these parameters for triangulation will not give perfect results.

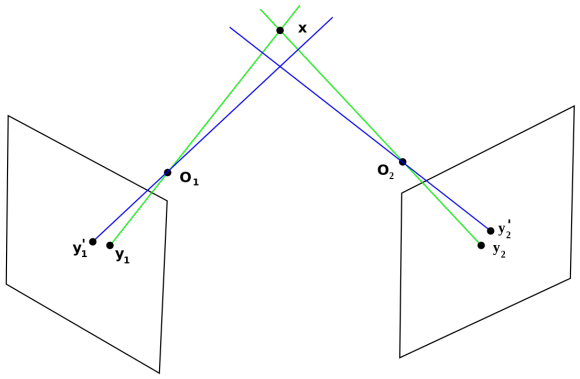


Fig. 1. Basic idea of Triangulation

### C. Triangulation

Triangulation is a process of finding the synthetic depth of the object of interest. This basically needs more than one view of the object. Each camera used for each view needs to be calibrated to get the intrinsic and extrinsic parameters which are used to estimate the 3D location of the given 2D point. Following estimate equation is used to estimate the 3D location using extrinsic and intrinsic parameters.

$$\mathbf{p} = \left( \sum_{j=1}^{N} (\mathbf{I} - \hat{\mathbf{v}}_j \hat{\mathbf{v}}_j^T) \right)^{-1} \sum_{j=1}^{N} (\mathbf{I} - \hat{\mathbf{v}}_j \hat{\mathbf{v}}_j^T) \mathbf{c}_j$$

## III. Results

Fig 2 and Fig 3 are input source images. Fig 4 is the output screenshot.
RIGHT VIEW and LEFT VIEW provide us with extrinsic and intrinsic parameters of the two cameras. These are given as input for the triangulation.

## IV. Conclusion

In this assignment implementation of corner detection, Tsai camera calibration and Triangulation. Testing of the algorithm is done by checking the ground truth. Tsai camera calibration is the most difficult part over here. As a part of this

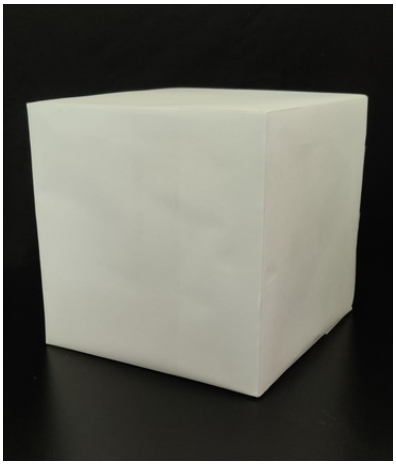

Fig. 2. Input Target File RIGHT VIEW

Fig. 3. Input Target File LEFT VIEW

```
pantamrohit@penguin:~/CV 4$ python3 TriangulationFinal.py
Finding Geometrically Strong Points.....
Calibrating Camera 0.....
Finding Geometrically Strong Points.....
Calibrating Camera 1.....
Estimating 3D Location.....
Real 3D worldCordinates
[170 170   0]
Estimated 3D worldCordinates
[[181.79747674]
 [134.16426662]
 [ 64.1591319 ]]
```

Fig. 4. Estimate from Triangulation

assignment, Tsai calibration is pratially implemented. But, for proper results an online Tsai calibration is used[2]. With Tsai calibration done, triangulation is not so difficult part. Detection of strong geometric points in the image makes the process even more easy.

## REFERENCES


[1] "Shi-Tomasi Corner Detector and Good Features to Track," OpenCV. [Online]. [Accessed: 17-Mar-2020].

[2] Gpmarques, "gpmarques/tsai," GitHub. [Online].[Accessed: 17-Mar-2020].