

Computer Vision

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Problem Set #4

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1a: Solve Least Squares

- Matrix M recovered from normalized points
 - $\begin{bmatrix} 0.76785834 & -0.49384797 & -0.02339781 & 0.00674445 \\ -0.0852134 & -0.09146818 & -0.90652332 & -0.08775678 \\ 0.18265016 & 0.29882917 & -0.07419242 & 1. \end{bmatrix}$
- $\langle u, v \rangle$ projection of the last point given in M Matrix
 - $[0.14190586 \quad -0.45183985]$

1a: Solve Least Squares

- Residual between projected location and actual one

- ```
[[0.00265589], [0.00272786], [0.00117601]
 [0.00176557], [0.00088366], [0.00162143]
 [0.00124975], [0.00220188], [0.00238704]
 [0.00186283], [0.00422666], [0.00216373]
 [0.00318443], [0.00096588], [0.00944]
 [0.00135103], [0.00061994], [0.00161859]
 [0.00086915], [0.00156369]]
```

## 2a: Camera Calibration

- Average Residuals for each trial of each K (list of 10 x 3 residuals)
  - $K = 8$ 
    - ```
[[ 1.50177045], [ 2.51906014], [ 1.78804693]
 [ 2.3391243 ], [ 1.57934437], [ 7.67573665]
 [ 1.53263454], [ 0.99896001], [ 1.96607268]
 [ 1.54765639]]
```

2a: Camera Calibration

- Average Residuals for each trial of each K (list of 10 x 3 residuals)
 - $K = 12$
 - ```
[[2.38354049], [1.76308218], [1.23519904],
 [1.06094053], [1.03667884], [1.37364327],
 [1.22703481], [1.63097794], [2.6630533],
 [1.15857855]]
```

## 2a: Camera Calibration

- Average Residuals for each trial of each K (list of 10 x 3 residuals)
  - $K = 16$ 
    - ```
[[ 0.82346949], [ 0.79822741], [ 1.931041  ],  
 [ 1.42815495], [ 1.17660155], [ 1.07900225],  
 [ 1.27697918], [ 0.70941771], [ 1.02612479],  
 [ 0.90618429]]
```

2a: Camera Calibration

- Explanation of difference seen between the results for the different k 's
 - We need at least 6 points to solve the projection matrix. Usually the more points were used to calculate the projection matrix, the lower the error and the residual would be. In some cases, this were not the case and it would depend on how similar the k points used to calculate M and the 4 points used to calculate the residual. In general, however, when I took 100 runs and averaged the error and residual, it showed that the error and residual were lower for $k=16$ points.
- The best M matrix (3×4)

2a: Camera Calibration

- The best M matrix (3x4)

- $\begin{bmatrix} -2.04627226e+00 & 1.18705551e+00 & 3.86676348e-01 & 2.43810741e+02 \\ -4.56727301e-01 & -3.02235694e-01 & 2.14543282e+00 & 1.66004073e+02 \\ -2.24548148e-03 & -1.09464848e-03 & 5.53809501e-04 & 1.00000000e+00 \end{bmatrix}$

2b: Real Coordinates

- Location of the camera in real 3D world coordinates
 - `[[303.09470755 307.18030485 30.42202349]]`

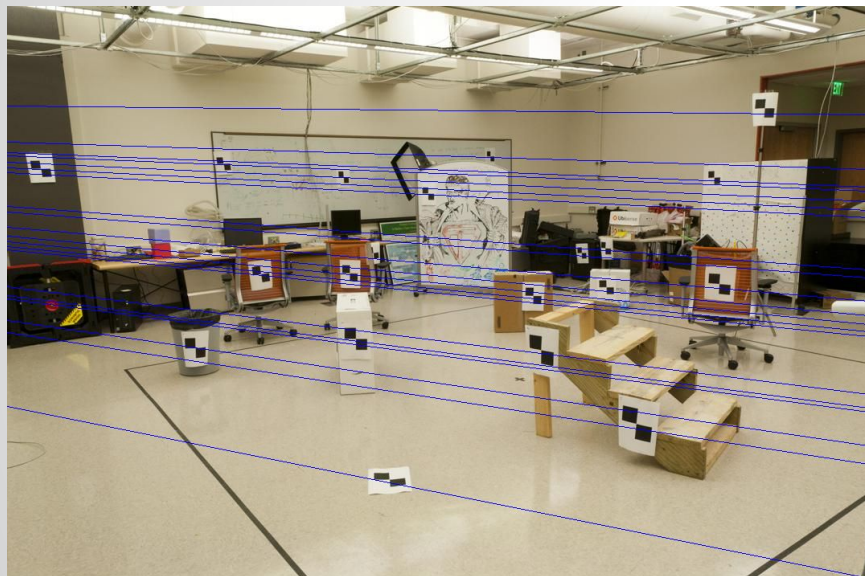
3a: F Matrix (Full Rank)

- The Matrix F-tilda generated from Least Squares function
 - $\begin{bmatrix} -6.60675944e-07 & 7.90642197e-06 & -1.88480992e-03 \\ 8.82674944e-06 & 1.21863596e-06 & 1.72276843e-02 \\ -9.08539064e-04 & -2.64201801e-02 & 1.00000000e+00 \end{bmatrix}$

3b: Fundamental Matrix (reduced)

- The Fundamental Matrix (reduced rank) generated from Least Squares function
 - $$\begin{bmatrix} -5.35883058e-07 & 7.89972529e-06 & -1.88480998e-03 \\ 8.83820595e-06 & 1.21802118e-06 & 1.72276843e-02 \\ -9.08539027e-04 & -2.64201801e-02 & 1.00000000e+00 \end{bmatrix}$$

3c: Images with Epipolar Lines



pic_A with epipolar lines - **ps4-3-c-1.png**



pic_B with epipolar lines - **ps4-3-c-2.png**

4a: Better Matrices

- The Matrix Ta

- $$\begin{bmatrix} 2.49017580e+02 & 0.00000000e+00 & -1.39188376e+05 \\ 0.00000000e+00 & 2.49017580e+02 & -8.10801240e+04 \\ 0.00000000e+00 & 0.00000000e+00 & 1.00000000e+00 \end{bmatrix}$$

- The Matrix Tb

- $$\begin{bmatrix} 2.74670839e+02 & 0.00000000e+00 & -1.69389507e+05 \\ 0.00000000e+00 & 2.74670839e+02 & -9.52833142e+04 \\ 0.00000000e+00 & 0.00000000e+00 & 1.00000000e+00 \end{bmatrix}$$

4a: Better Matrices

- The Matrix F-circumflex

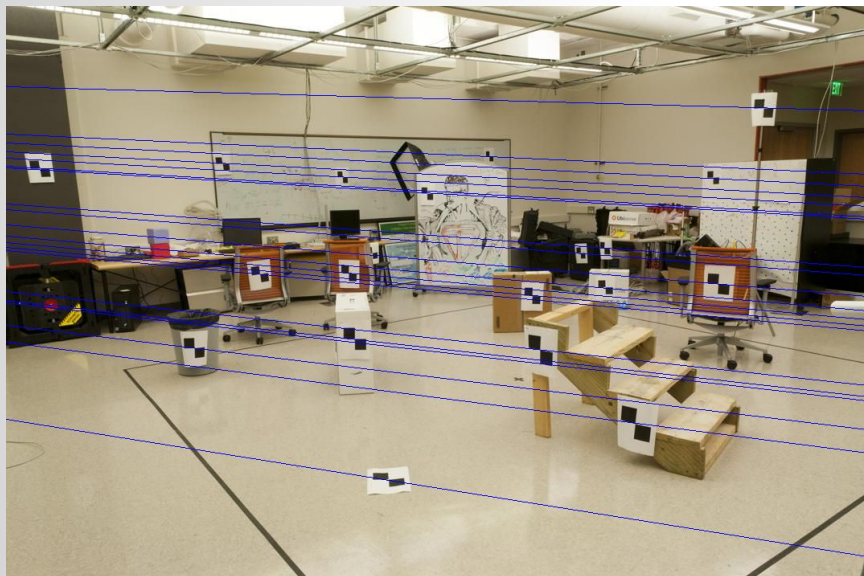
- $\begin{bmatrix} 1.07547648e-10 & -1.41173365e-09 & -1.08034006e-05 \\ -8.86150702e-10 & 2.69998620e-10 & -7.98162244e-04 \\ -6.88875138e-05 & 8.28441480e-04 & 1.00000000e+00 \end{bmatrix}$

4b: Fundamental Matrix (reduced)

- The new Fundamental Matrix F

- $$\begin{bmatrix} 7.35602976e-06 & -9.65595714e-05 & 2.43607645e-02 \\ -6.06108184e-05 & 1.84673298e-05 & -1.91366439e-01 \\ -6.64772589e-04 & 2.59438463e-01 & -5.22006245e+00 \end{bmatrix}$$

4b: Images with Epipolar Lines (cont.)



pic_A with “better” epipolar lines - **ps4-4-b-1.png**



pic_B with “better” epipolar lines - **ps4-4-b-2.png**