

# **Computer Vision**

## **Fall 2016**

# **Problem Set #4**

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# 1a: Solve Least Squares

Matrix M recovered from normalized points

```
[[ 0.76785834, -0.49384797, -0.02339781,  0.00674445], [-0.0852134, -  
 0.09146818, -0.90652332, -0.08775678], [ 0.18265016,  0.29882917, -  
 0.07419242,  1.0]]
```

$\langle u, v \rangle$  projection of the last point given in M Matrix

```
[ 0.14190586, -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:

```
[[ 1.29646485], [ 1.83564907], [ 1.9029142 ], [ 6.09497882], [ 6.3001995 ], [  
 1.34743108], [ 1.21544078], [ 1.34552663], [ 0.81685448], [  
 4.29358514]]
```

k = 12:

```
[[ 1.04318113], [ 0.94819695], [ 1.57413416], [ 4.28855474], [ 1.21006889], [  
 3.06534099], [ 1.23555988], [ 1.64587229], [ 1.2568693 ], [ 3.3676641 ]]
```

# 2a: Camera Calibration

Average Residuals for each trial of each K (list of 10 x 3 residuals)

K = 16:

```
[[ 1.37677011], [ 1.34492826], [ 0.94807493], [ 1.25069612], [ 1.60429483], [  
 1.46431875], [ 1.20065003], [ 1.02605448], [ 0.94123338], [ 0.6283024 ]]
```

# 2a: Camera Calibration

Explanation of difference seen between the results for the different k's

Average residual of 10 iteration with k = 8: 2.6449044549999998

Average residual of 10 iteration with k = 12: 1.9635442429999999

Average residual of 10 iteration with k = 16: 1.178532329

There is clear dip in the Average residual of 10 iteration as k increases from 8 to 16, and minimum average residual could be found when k = N. This is because, more the points considered in calculating Transformation matrix, M.

# 2a: Camera Calibration

The best M matrix (3x4)

```
[[ -2.04894446e+00, 1.19304678e+00, 3.85197425e-01, 2.42805712e+02], [-4.56870737e-01, -3.01538367e-01, 2.14878286e+00, 1.65723307e+02], [-2.24849382e-03, -1.09161844e-03, 5.52608204e-04, 1.00000000e+00]]
```

# 2b: Real Coordinates

Location of the camera in real 3D world coordinates

`[[303.08628319, 307.18152689, 30.4241826]]`

# 3a: F Matrix (Full Rank)

The Matrix F-tilda generated from Least Squares function

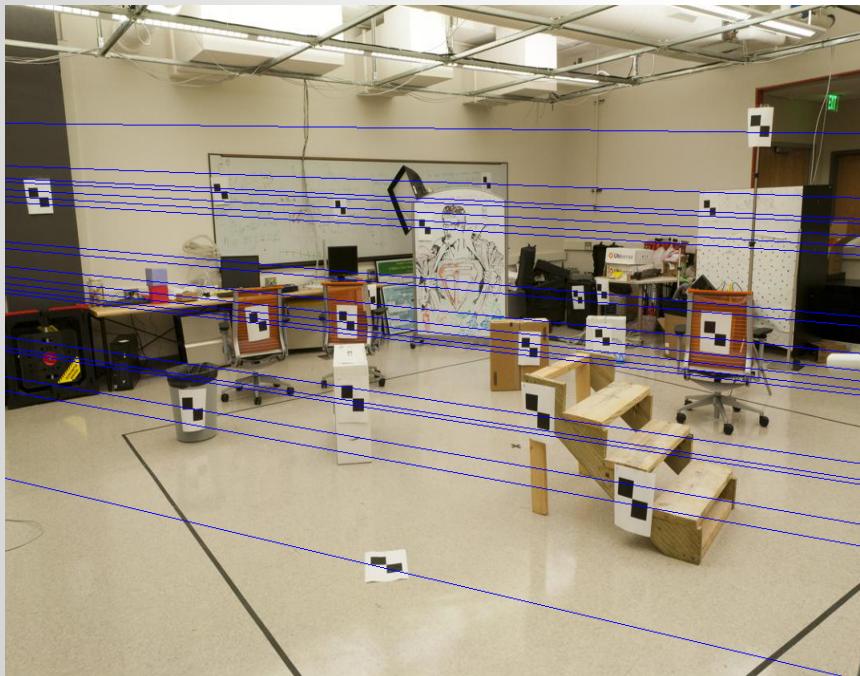
```
[[ -6.60675944e-07, 7.90642197e-06, -1.88480992e-03], [8.82674944e-06,  
1.21863596e-06, 1.72276843e-02], [-9.08539064e-04, -2.64201801e-02,  
1.00000000e+00]]
```

# 3b: Fundamental Matrix (reduced)

The Fundamental Matrix (reduced rank) generated from Least Squares function

```
[[ -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]]
```

# 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

```
[[0.00422627, 0.0, -2.36227228], [0.0, 0.0085811, -2.79400691], [0.0, 0.0,  
1.0]]
```

The Matrix Tb

```
[[0.00385727, 0.0, -2.37877704], [0.0, 0.00958482, -3.32497426], [0.0, 0.0,  
1.0]]
```

# 4a: Better Matrices

The Matrix F-circumflex

```
[[0.44720886, -2.90494019, -0.77544803], [-1.49856418, 0.22407905, -  
22.87264578], [-4.04727901, 24.04278695, 0.999255]]
```

# 4b: Fundamental Matrix (reduced)

The new Fundamental Matrix F

```
[[ 7.29032987e-06, -9.61523855e-05, 2.42411761e-02], [-6.07038629e-05,  
1.84301264e-05, -1.91300631e-01], [-5.42660556e-04, 2.59217380e-01, -  
5.20302725e+00]]
```

# 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