ECE 549 Homework 3 Report

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April 5, 2021

Q1.3. Putative match overlaid on image pairs

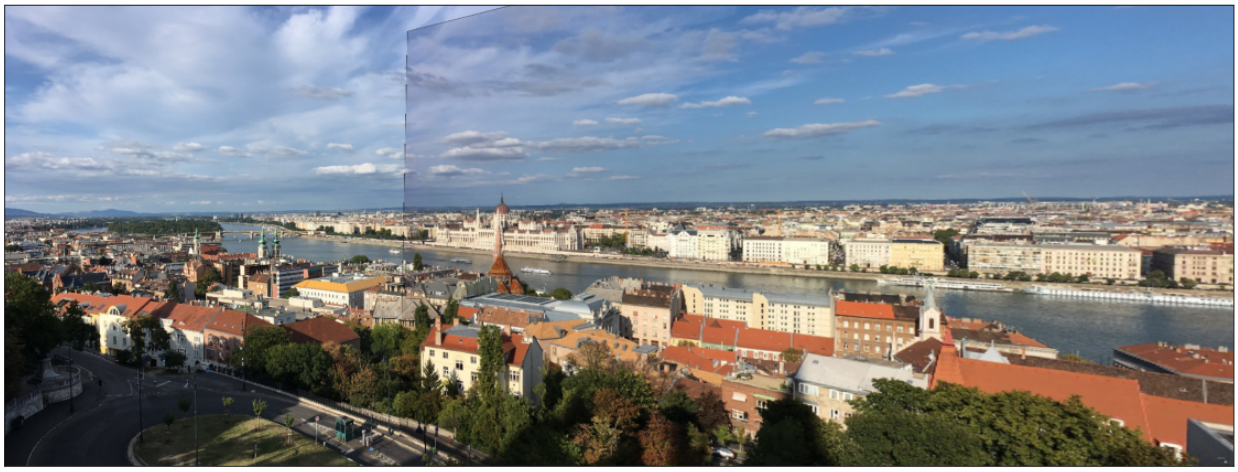
This image is generated with 300 matches.

Q1.4. Homography and RANSAC

To solve this problem, one important part is to figure out the homography between two images. This was done by constructing a matrix described in lecture alignment, slides 43. Then I performed singular value decomposition and retrieved the smallest singular value. Then I reshape this value and scale it so that the last element is 1.

Now we can perform RANSAC to figure out the best transformation given these two images. We start with four randomly chosen matches, then attempt to perform the transformation and check how many other matches satisfying our given criteria. In our case, such criteria is the mean squared distance between predicted projection points and the actual projection points. We keep doing this and find the best random selection as our transformation. After some trial and error, I found 500 RANSAC iterations and an error threshold of 1 pixel gives the best result. I got an average residual of 0.49 and 195 inliers as the result.

Q1.5. Warp and stitch



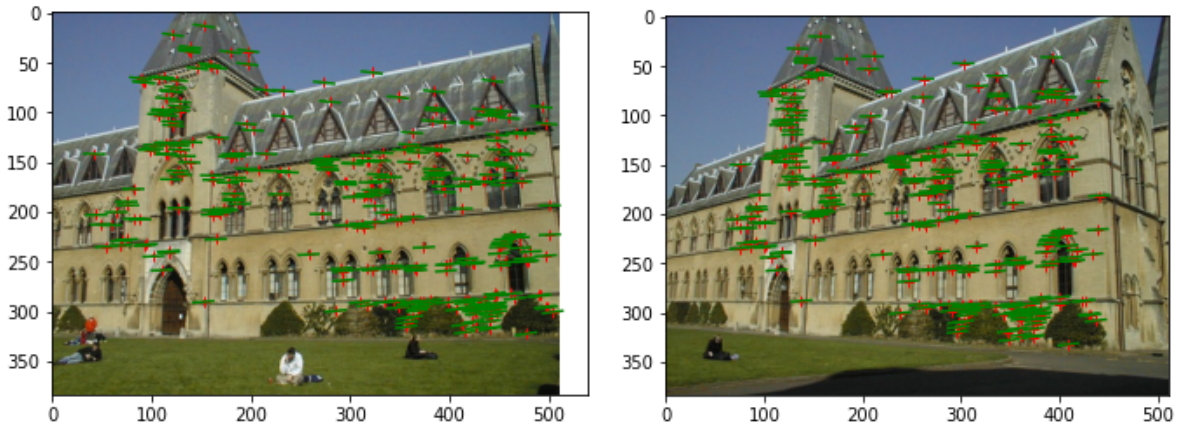
Q2.1. Fundamental Matrix Estimation

Unnormalized Library:

Estimated Fundamental Matrix:

```
[[-1.32341616e-06  1.36640519e-05 -6.82803870e-04 ]
 [-2.88178174e-05  2.66440807e-07  4.09069255e-02 ]
 [ 5.62362952e-03 -3.72771609e-02 -9.98451273e-01]]
```

Residual combined: 0.16416823310143447

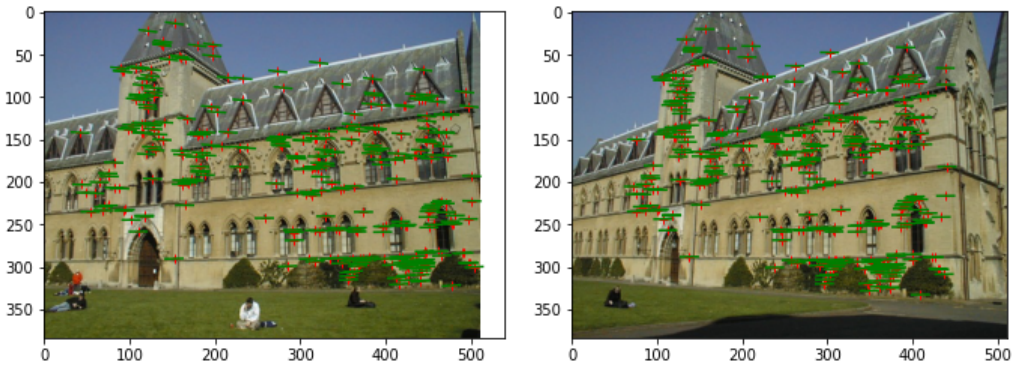


Normalized Library:

Estimated Fundamental Matrix:

```
[[-3.44725739e-08  7.27167745e-07 -1.09292791e-04 ]
 [-4.37299224e-06 -4.44216115e-08  8.10999749e-03 ]
 [ 1.04291060e-03 -7.28410119e-03 -1.97254324e-01]]
```

Residual combined: 0.057532343337116106

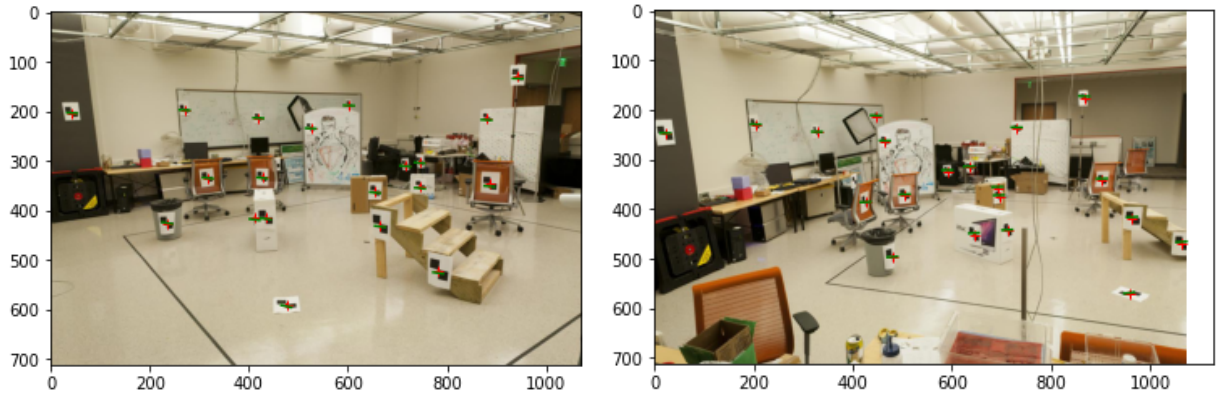


Unnormalized Lab:

Estimated Fundamental Matrix:

```
[[-5.36264198e-07  7.90364771e-06 -1.88600204e-03 ]
 [ 8.83539184e-06  1.21321685e-06  1.72332901e-02 ]
 [-9.07382264e-04 -2.64234650e-02  9.99500092e-01]]
```

Residual combined: 8.163873462958108

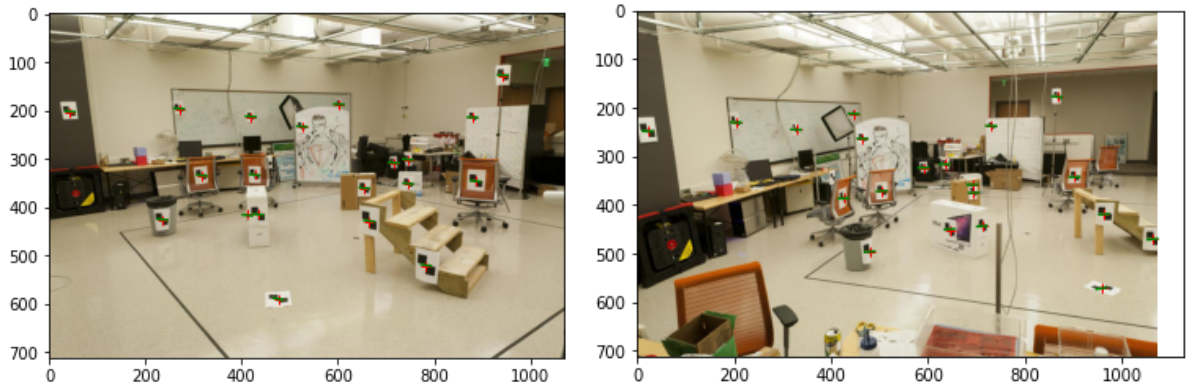


Normalized Lab:

Estimated Fundamental Matrix:

```
[[-1.17248591e-07  1.60824663e-06 -4.01980786e-04 ]
 [ 1.11212887e-06 -2.73443755e-07  3.23319884e-03 ]
 [-2.36400817e-05 -4.44404958e-03  1.03455561e-01]]
```

Residual combined: 0.5633121055571138



Q2.2. Camera Calibration

Lab 1 Camera Projection Matrix:

```
[[-3.09963996e-03 -1.46204548e-04  4.48497465e-04  9.78930678e-01 ]
 [-3.07018252e-04 -6.37193664e-04  2.77356178e-03  2.04144405e-01 ]
 [-1.67933533e-06 -2.74767684e-06  6.83964827e-07  1.32882928e-03]]
```

Lab 1 Residual: 13.545832894595353

Lab 2 Camera Projection Matrix:

```
[[ 6.93154686e-03 -4.01684470e-03 -1.32602928e-03 -8.26700554e-01 ]
 [ 1.54768732e-03  1.02452760e-03 -7.27440714e-03 -5.62523256e-01 ]
 [ 7.60946050e-06  3.70953989e-06 -1.90203244e-06 -3.38807712e-03]]
```

Lab 2 Residual: 15.544953448155711

Q2.3. Camera Center

Lab 1 Camera Center:

```
[305.83276769 304.20103826  30.13699243]
```

Lab 2 Camera Center:

```
[303.10003925 307.18428016  30.42166874]
```

Library 1 Camera Center:

```
[  7.28863053 -21.52118112  17.73503585]
```

Library 2 Camera Center:

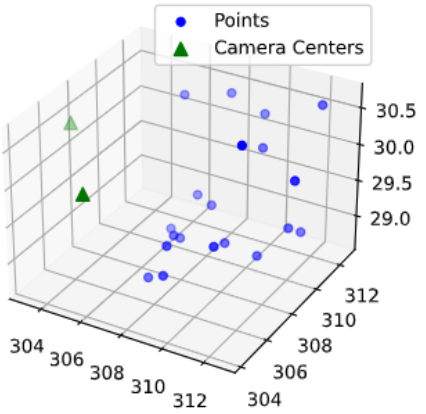
```
[  6.89405488 -15.39232716  23.41498687]
```

Q2.4. Triangulation

Lab 1 Reprojection Error: 10.899446047635067

Lab 2 Reprojection Error: 1.5485148072400858

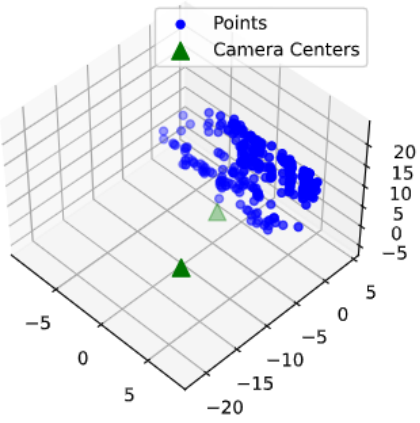
Lab Reconstruction:



Library 1 Reprojection Error: 24.6620711968708

Library 2 Reprojection Error: 28.649537735259145

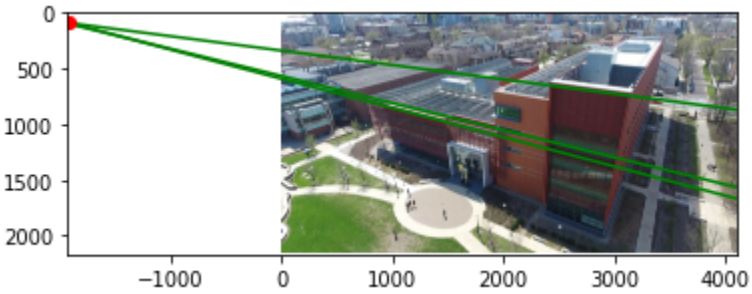
Library Reconstruction:



Q3.1. Vanishing Points

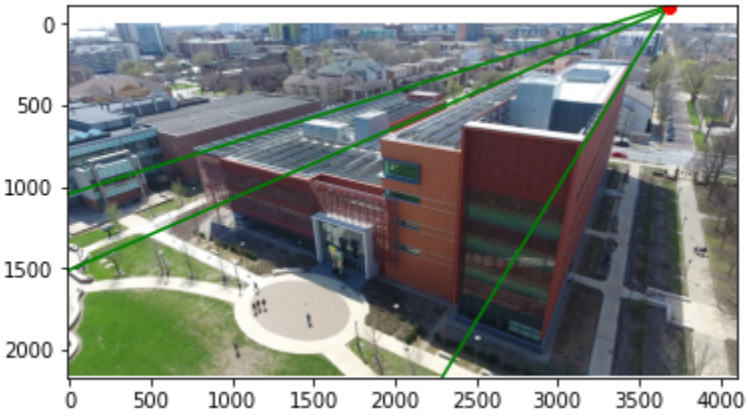
Vanishing Point Z:

```
[-9.98796820e-01  4.90371219e-02  5.22710722e-04]
```



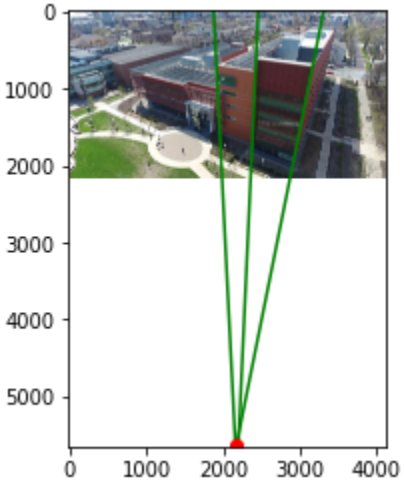
Vanishing Point X:

```
[ 9.99586487e-01 -2.87538057e-02  2.71651619e-04]
```



Vanishing Point Y:

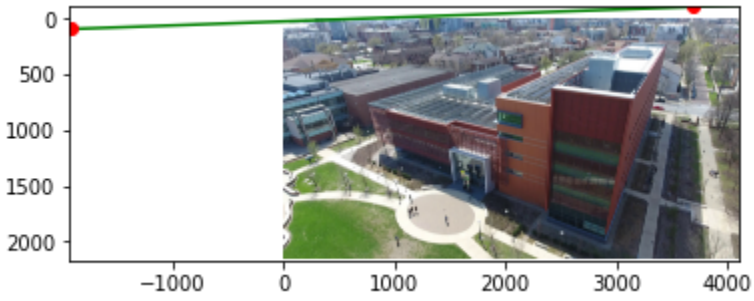
```
[-3.60112213e-01 -9.32908981e-01 -1.65505966e-04]
```



Q3.2. Horizon

Horizon:

```
0.03569184 * x + 0.99936284 * y - 25.55329752 = 0
```



Q3.3. Camera Calibration

Referencing from lecture calibration, slides 50, and this paper, we know that we have three unknowns: focal length f, principal point (u, v). We know the intrinsic matrix K is:

```
[[ f 0 u ]
 [ 0 f v ]
 [ 0 0 1]]
```

Hence we can get the middle matrix inv(K).T @ inv(K), where '@' is the dot product:

```
[1/f**2,  0,       -u/f**2                ]
[0,       1/f**2,  -v/f**2                ]
[-u/f**2, -v/f**2, (u**2+v**2+f**2)/f**2]]
```

We have three known vanishing points v0, v1, and v2. hence we can write down three equations:

```
eq1 = v0.T @ inv(K).T @ inv(K) @ v1
eq2 = v0.T @ inv(K).T @ inv(K) @ v2
eq3 = v1.T @ inv(K).T @ inv(K) @ v2
```

We then just solve these three equations for numerical solution with sympy.

We get focal length:

```
f = 2014.57714556581
```

Principal point:

```
(u, v) = (1121.77522448985, 2296.55057471668)
```

Q3.4. Rotation Matrix

```
[[-0.84189382  0.53870444 -0.031817   ]
 [-0.22047167 -0.39717232 -0.89086833 ]
 [ 0.49255156  0.7430018  -0.45314599]]
```