CS543 Assignment 3

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Part 1: Homography estimation

Describe your solution, including any interesting parameters or implementation choices for feature extraction, putative matching, RANSAC, etc.

My homography is

```
[[-7.05746371e-04  2.12185540e-04 -9.92645846e-01]
 [ 3.28873521e-04 -1.27621356e-03 -1.21029477e-01]
 [ 1.09202627e-06  5.16210486e-07 -1.95190322e-03]]
```

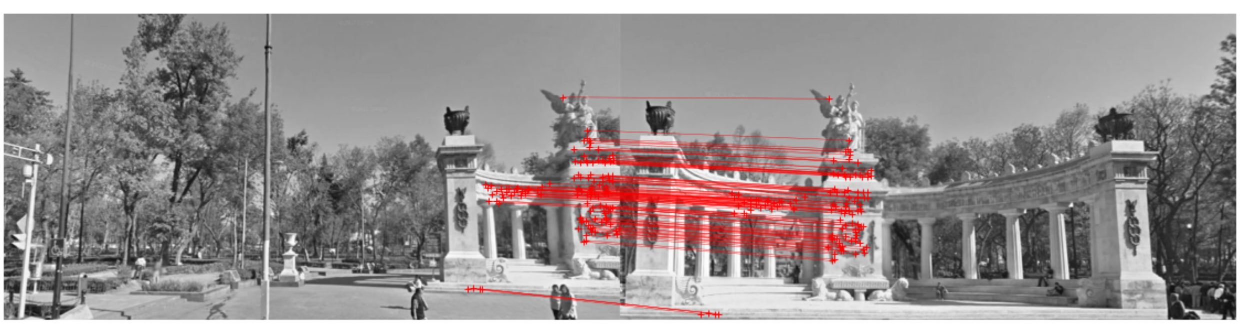
I used the sift algorithm from cv2.xfeatures2d package to calculate the keypoints and descriptors. I set the threshold to 0.005% so that about 700 pairs of keypoints are left. This threshold is based on the density and distribution of keypoints. I managed to visualize the keypoints, and my selected keypoints are well distributed around the monument. I then eliminated the keypoints calculated from different sigma but represent the same position in the pixel coordinates. I set the sample size to 10. The fitting algorithm tries to minimize the error of 10 pairs of input keypoints.

For the image pair provided, report the number of homography inliers and the average residual for the inliers.

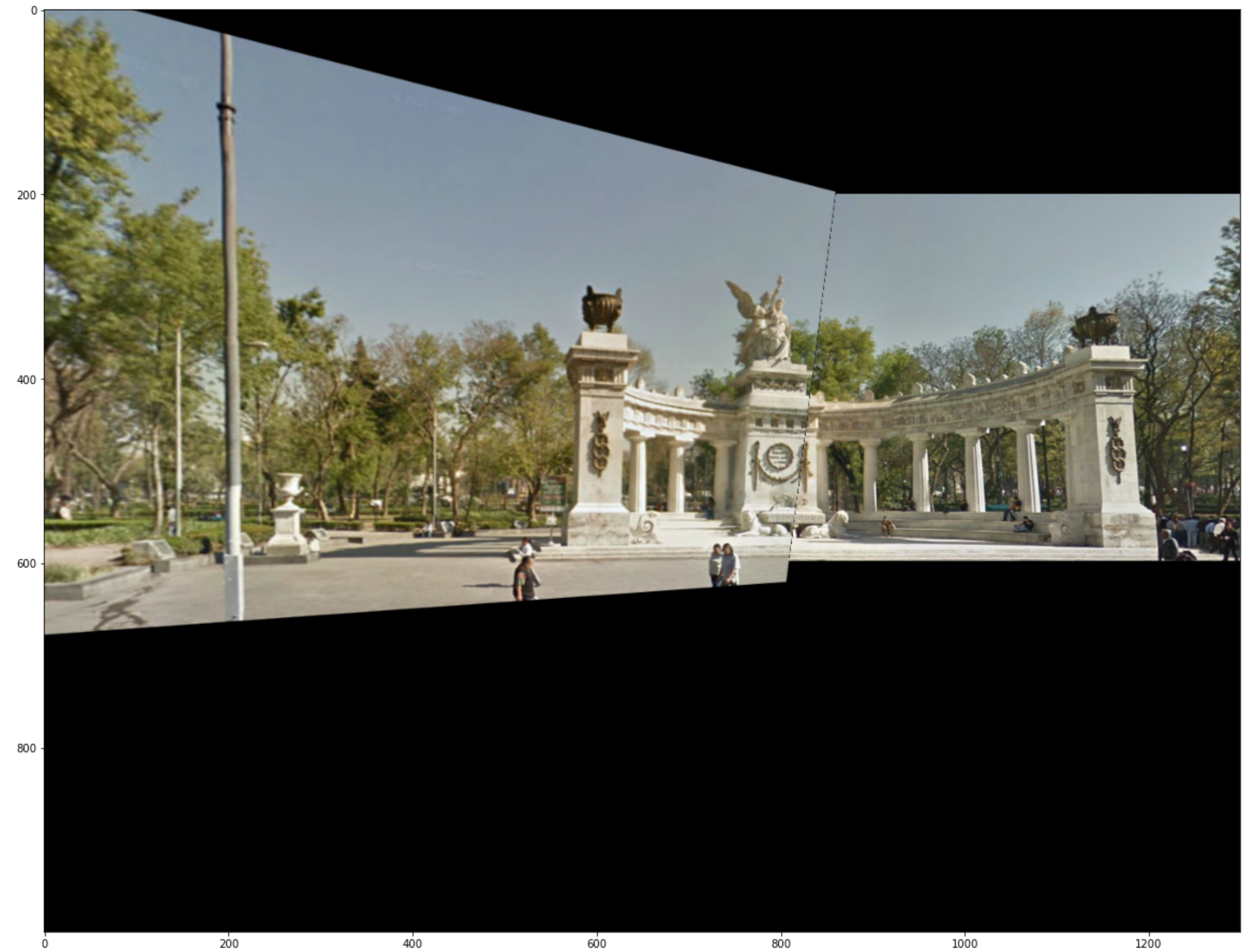
Inliers 115

Average residual(mean 2-norm of difference) = 1.86

Also, display the locations of inlier matches in both images.



Display the final result of your stitching.



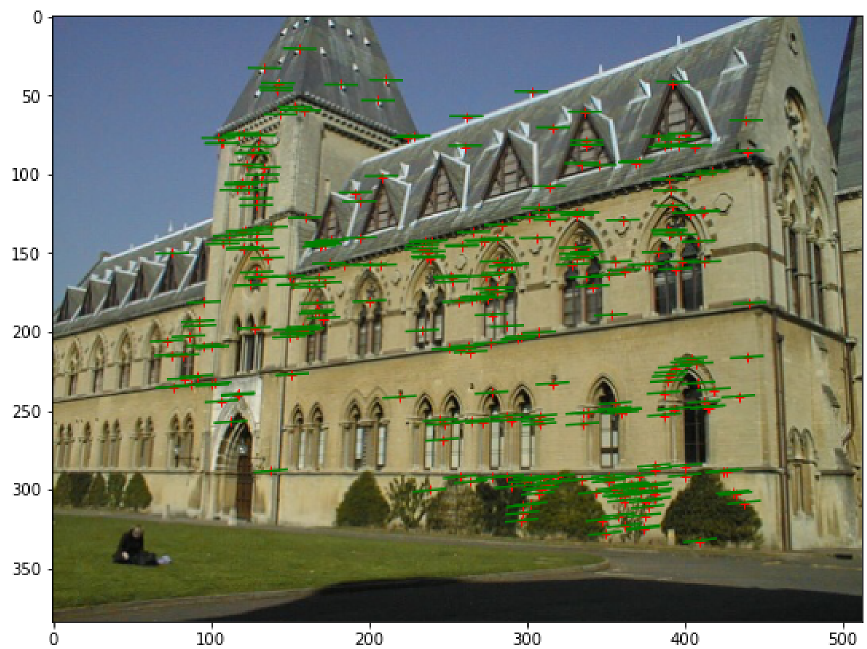
Part 2: Fundamental Matrix Estimation, Camera Calibration, Triangulation

For both image pairs, for both unnormalized and normalized fundamental matrix estimation, display your result (points and epipolar lines) and report your residual.

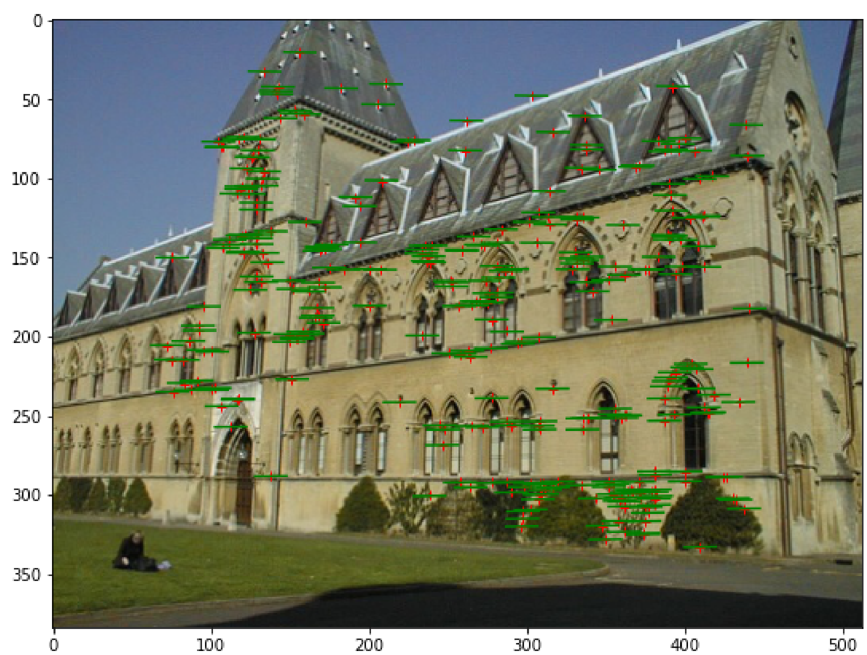
Normalized: `1.3187982852873092`

Unnormalized:`13.20106138737857`

Unnormalized



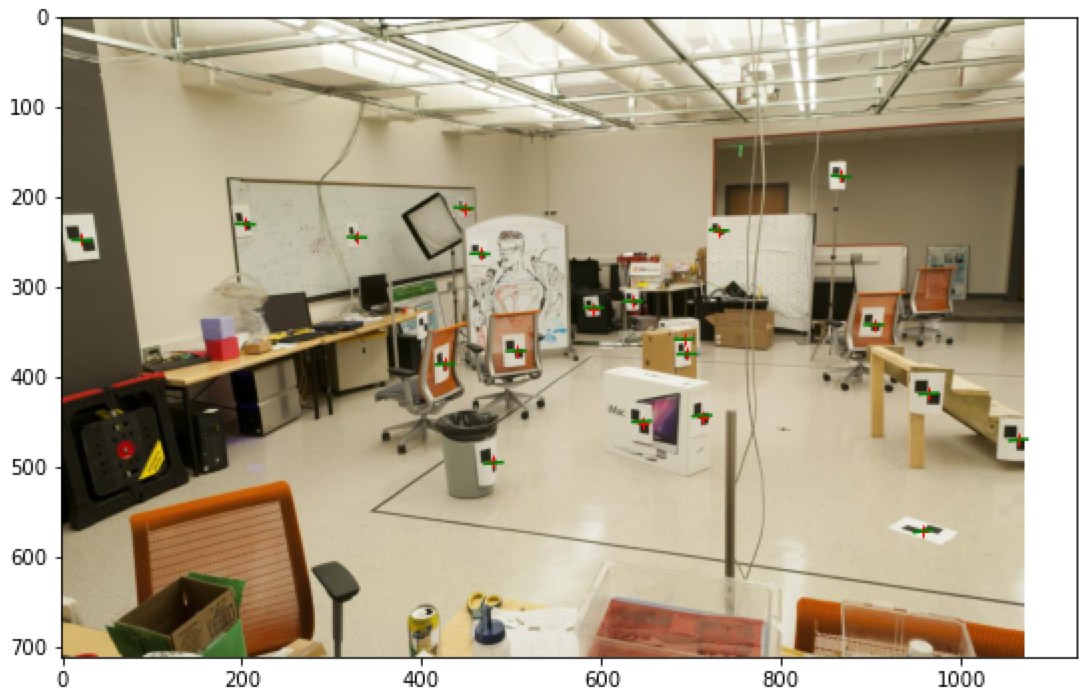
Normalized




```
Normalized: 0.9064654437128721
Unnormalized: 12.200768947343281
```

Unnormalized

Normalized



For the lab image pair, show your estimated 3x4 camera projection matrices.

```
[[-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]]

[[ 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]]
```

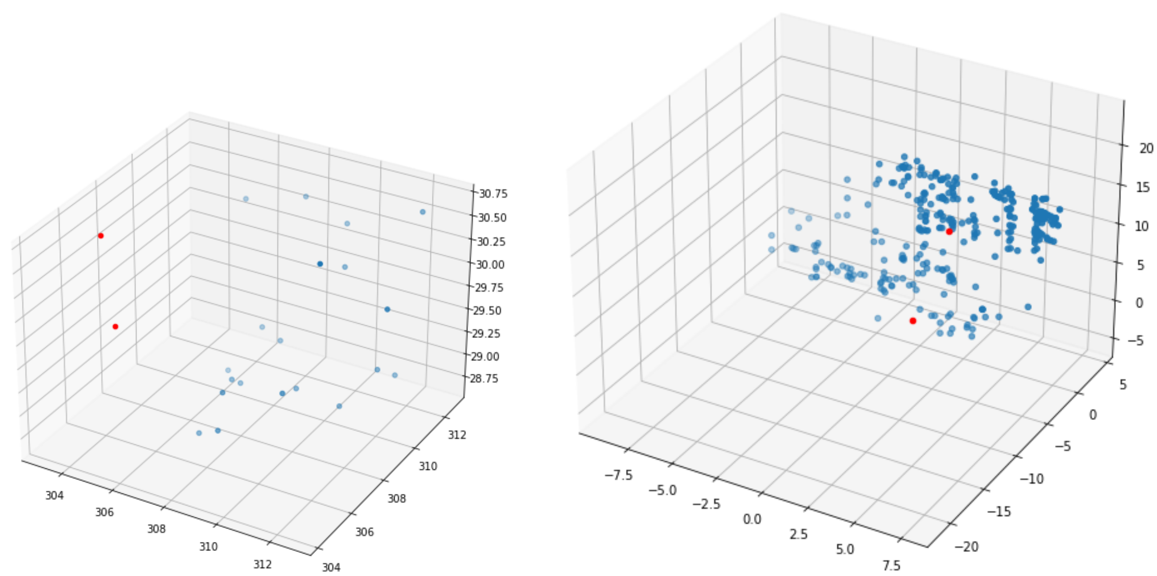
Report the residual between the projected and observed 2D points.

```
camera0: residual=  13.545832894770703
camera1: residual=  15.544953451653466
```

For both image pairs, visualize 3D camera centers and triangulated 3D points.

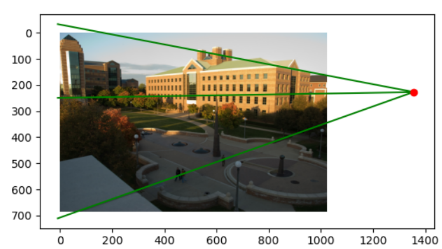
Camera0: `305.83276769 304.20103826  30.13699243`

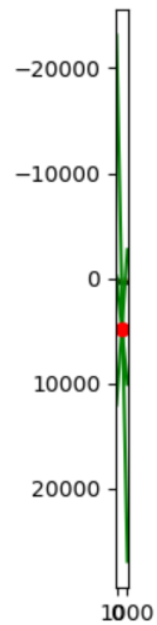
```
Camera1:303.10003925 307.18428016  30.42166874


Library:
Camera0:7.28863053 -21.52118112  17.73503585
camera1:6.89405488 -15.39232716  23.41498687
```

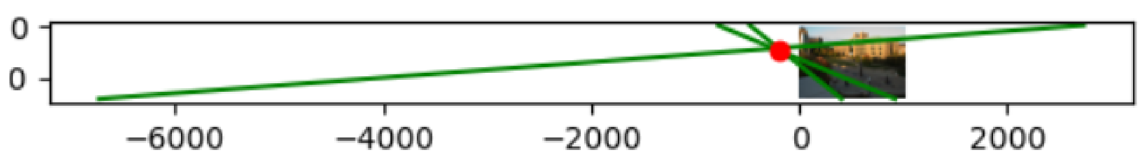


Part 3: Single-View Geometry

Plot the VPs and the lines used to estimate them on the image plane using the provided code.







Specify the VP pixel coordinates.

Right:`1.35617939e+03, 2.27120362e+02`

Vertical:`5.49926702e+02  4.84513324e+03`

Left:`-1.97639747e+02  2.24906754e+02`

Plot the ground horizon line and specify its parameters in the form a * x + b * y + c = 0. Normalize the parameters so that: a^2 + b^2 = 1.

```
[ 1.42462252e-03 -9.99998985e-01  2.25188088e+02]
```

Using the fact that the vanishing directions are orthogonal, solve for the focal length and optical center (principal point) of the camera. Show all your work.

$$\underset{3}{v_i^T}\ \underbrace{K^{-T}K^{-1}}_{9}\ \underset{3}{v_j} = 0.$$

f, p_x, p_y

$K^{-T}K^{-1}$

$$= \begin{bmatrix} 1/f & 0 & 0 \\ 0 & 1/f & 0 \\ -p_x/f & -p_y/f & 1 \end{bmatrix}\begin{bmatrix} 1/f & 0 & -p_x/f \\ 0 & 1/f & -p_y/f \\ 0 & 0 & 1 \end{bmatrix}$$

$a = 1/f$

$b = -p_x/f$

$c = -p_y/f$

$$\left(\frac{p_x^2}{f^2} + \frac{p_y^2}{f^2} + 1\right) f^2$$

$$p_x^2 + p_y^2 + f^2 = \gamma$$

$$= \begin{bmatrix} a & 0 & 0 \\ 0 & a & 0 \\ b & c & 1 \end{bmatrix}\begin{bmatrix} a & 0 & b \\ 0 & a & c \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} a^2 & 0 & ab \\ 0 & a^2 & ac \\ ab & ac & b^2+c^2+1 \end{bmatrix}$$

$$\frac{-p_x/f}{1/f} = -p_x$$

$$= \begin{bmatrix} 1 & 0 & \cancel{ab}\ b/a \\ 0 & 1 & c/a \\ b/a & c/a & \frac{b^2+c^2+1}{a^2} \end{bmatrix} a^2$$

$$\underset{v_i}{(x\ y\ 1)}\begin{pmatrix} 1 & 0 & b/a \\ 0 & 1 & c/a \\ b/a & c/a & \frac{b^2+c^2+1}{a^2} \end{pmatrix}\overset{v_j}{\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix}} a^2 = 0$$

$b/a = \alpha = -p_x$

$c/a = \beta = -p_y$

$$\frac{b^2+c^2+1}{a^2} = \gamma = p_x^2 + p_y^2 + f^2$$

$$(x\ y\ 1)\begin{pmatrix} x' + b/a \\ y' + c/a \\ x' b/a + y' c/a + \frac{b^2+c^2+1}{a^2} \end{pmatrix} = 0$$

$$\left((x+x'), (y+y'), 1\right)\begin{pmatrix} \alpha \\ \beta \\ \gamma \end{pmatrix} = -xx' - yy'$$

$3 \times 3.$

$\cancel{xx' + xb/a}$

$$(x\ y\ 1)\begin{pmatrix} x' + \alpha \\ y' + \beta \\ x'\alpha + y'\beta + \gamma \end{pmatrix} = 0$$

$$x'x + \alpha x + y'y + \beta y + x'\alpha + y'\beta + \gamma = 0$$

Focal length = `765.5233269011928`

`U = 556.3212597477082`

`V = 356.53979633140676`

Compute the rotation matrix for the camera.

```
[[ 0.71755684 -0.00140434 -0.69649854]

 [-0.11610284  0.98576538 -0.12160075]

 [ 0.68675491  0.16812091  0.70717964]]
```

Estimate the heights of (a) the CSL building, (b) the spike statue, and (c) the lamp posts assuming that the person nearest to the spike is 5ft 6in tall. In the report, show all the lines and measurements used to perform the calculation.

In meters

```
Estimating height of CSL building

28.51973347497568

Estimating height of the spike statue

12.358220638234098

Estimating height of the lamp posts

4.896751934872732
```

How do the answers change if you assume the person is 6ft tall?

In meters


0
100
200
300
400
500
600
0
200
400
600
800
1000


0
100
200
300
400
500
600
0
200
400
600
800
1000


```
Estimating height of CSL building

31.77759584949543

Estimating height of the spike statue

13.526281612945644

Estimating height of the lamp posts

5.354648948956677
```

Extra Credit

Don't forget to include references, an explanation, and outputs to receive credit. Refer to the assignment for suggested outputs.

Part 1

Part 2

Part 3

The person in red jacket and jeans is the tallest. If we assume the person under the statue is 1.82m, the man in red is 1.91m