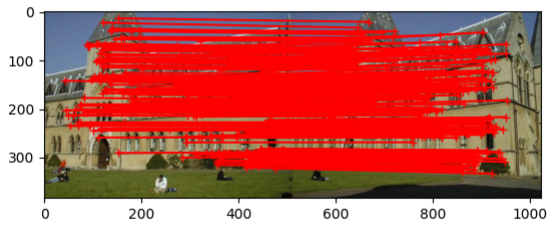
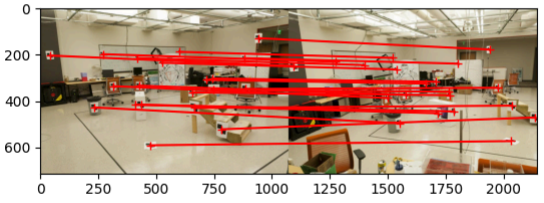
CV HW3 Report

Task1 Fundamental matrix estimation with ground truth matches

直接运行代码框架，可以看见`library`和`lab`图像对的匹配点：



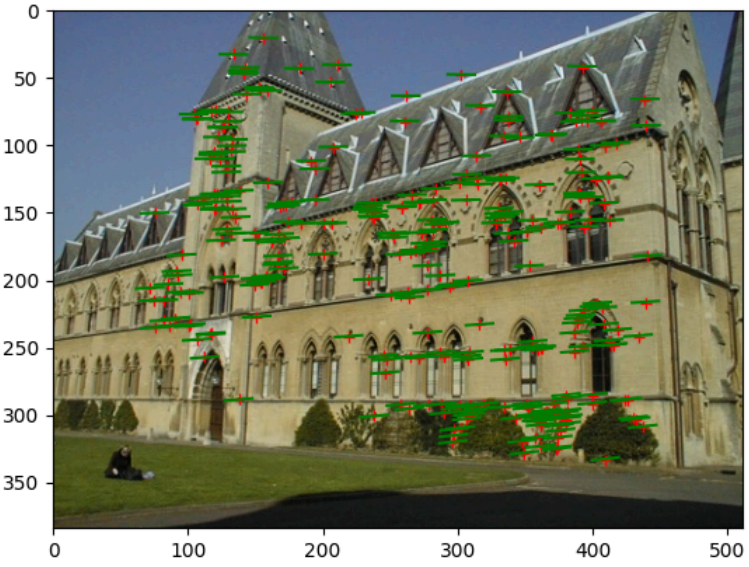


不加归一化的情况

Fundamental matrix 和 evaluation result:

```
library:
Task 1, the fundamental matrix of library is:
[[-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]]
Task 1, the evaluation results of liabrary is:  0.00016149806538390412

lab:
Task 1, the fundamental matrix of lab is:
[[-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]]
Task 1, the evaluation results of lab is:  0.003763402377063063
```

可视化结果：



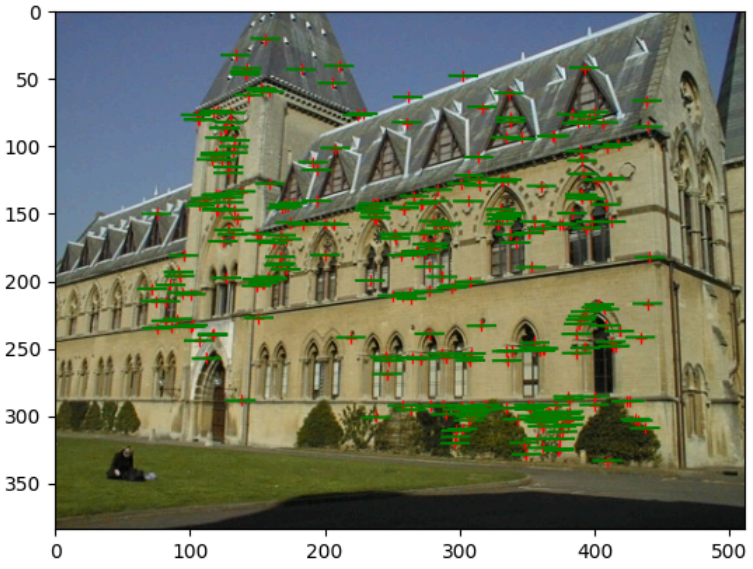
添加归一化的情况

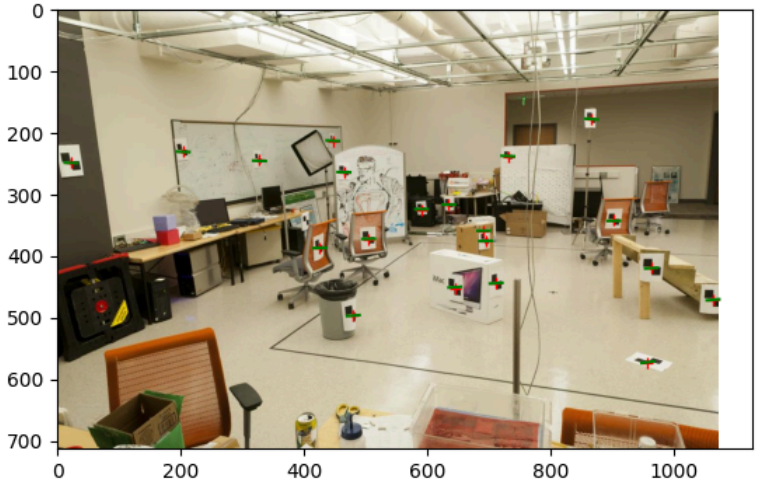
在`def normalize_points(pts)`函数中，通过将点集的质心平移到原点，并将平均距离缩放到根号2，有效提升了数值稳定性，结果如下：

Fundamental matrix 和 evaluation result:

```
library:
Task 1, the fundamental matrix of library is:
[[-3.97207498e-08  8.77931029e-07 -1.35897408e-04]
 [-5.49242694e-06 -5.84606056e-08  1.02361782e-02]
 [ 1.31412493e-03 -9.19136315e-03 -2.49063082e-01]]
Task 1, the evaluation results of liabrary is:  4.439106162408923e-06

lab:
Task 1, the fundamental matrix of lab is:
[[-1.38658662e-07  1.90121655e-06 -4.75233745e-04]
 [ 1.31494983e-06 -3.23051895e-07  3.82232149e-03]
 [-2.78892873e-05 -5.25395458e-03  1.22296750e-01]]
Task 1, the evaluation results of lab is:  1.0349441577175738e-05
```

可视化结果：





Task2 Camera calibration

输出projection matrix `P`、映射后的坐标、residual error以及square distance如下：

```
//lab_a
projection matrix P:
 [[ 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]]
coordinates of projection points:
 [[879.43531686 214.59058625]
 [ 43.28902536 203.7754311 ]
 [269.69419411 196.85865326]
 [885.64083549 346.61597834]
 [745.19622221 302.1975164 ]
 [943.30558516 127.59738245]
 [476.27412336 589.79921126]
 [419.07534418 213.33337687]
 [316.51808951 334.43432408]
 [783.11356251 520.45896816]
 [236.0911369  426.27162131]
 [665.61978329 429.20446161]
 [655.75554372 361.38294476]
 [426.8828759  333.2729898 ]
 [410.18194978 417.23285334]
 [746.29121723 350.72579922]
 [433.96035106 415.18280409]
 [524.69004557 233.6069015 ]
 [715.79907875 308.16824223]
 [602.39833531 187.2710445 ]]
residual:  13.545832894885326
distance:  3.965229591406653

//lab_b
projection matrix P:
 [[ 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]]
coordinates of projection points:
 [[ 731.3233801   238.32245529]
 [  22.58416159  247.95687968]
 [ 204.3347898   229.65451052]
 [ 902.49416733  342.13955281]
 [ 636.04640362  316.52386236]
 [ 866.79132847  176.41723922]
 [ 958.74837153  572.01025005]
 [ 327.15268466  244.26211238]
 [ 425.12830466  385.69678371]
 [1063.08566694  470.30378138]
 [ 479.87511362  495.24994826]
 [ 965.27319424  419.49571931]
```

```
  [ 693.66897465  374.18393371]
  [ 505.47445399  371.68637724]
  [ 644.60640608  452.34119156]
  [ 690.92381323  357.95979565]
  [ 713.32079426  443.79676077]
  [ 465.2963562   263.24279184]
  [ 591.58111204  323.78383073]
  [ 446.75875527  213.12239281]]
 residual:  15.544953464915645
 distance:  3.861780699808377
```

Task3 Calculate the camera matrices

根据task2中循环的部分`projection_matrix[key] = P`, 此时`projection_matrix`字典中有四个key: lab_a, lab_b, library_a,library_b它们的KRT结果输出如下:

```
Task 3, result of K is : [[780.56750258   1.99846116 545.67044543]
 [  0.         779.99109405 384.15959109]
 [  0.           0.           1.        ]]
Task 3, result of R is : [[ 0.84996668 -0.5261548  -0.02679126]
 [-0.13167568 -0.16292373 -0.97781254]
 [ 0.51011583  0.83463584 -0.20776153]]
Task 3, result of T is : [ -99.08341704  119.30063513 -403.64591749]
---------------
Task 3, result of K is : [[767.01522299   8.37481023 536.20619575]
 [  0.         772.02253385 390.71267556]
 [  0.           0.           1.        ]]
Task 3, result of R is : [[ 0.43076697 -0.90177034 -0.03535629]
 [-0.21279825 -0.06342282 -0.97503561]
 [ 0.8770158   0.42753689 -0.21921561]]
Task 3, result of T is : [ 147.519785    113.64386256 -390.48723313]
---------------
Task 3, result of K is : [[-5.79790975e+02  1.11782151e-06  2.56991552e+02]
 [ 0.00000000e+00 -5.39711147e+02  2.04317558e+02]
 [ 0.00000000e+00  0.00000000e+00  1.00000000e+00]]
Task 3, result of R is : [[-0.00966193 -0.44135514 -0.8972805 ]
 [-0.98017972 -0.17338541  0.09583956]
 [-0.19787463  0.88042214 -0.43093212]]
Task 3, result of T is : [ 6.48524008  1.71299092 28.03255592]
---------------
Task 3, result of K is : [[-5.47469106e+02  7.30842576e-06  2.58430094e+02]
 [ 0.00000000e+00 -5.12933585e+02  2.04985542e+02]
 [ 0.00000000e+00  0.00000000e+00  1.00000000e+00]]
Task 3, result of R is : [[ 0.01861384 -0.67624076 -0.73644549]
 [-0.981381   -0.15319028  0.11586227]
 [-0.19116708  0.72057697 -0.6665013 ]]
Task 3, result of T is : [ 6.70661749  1.69482607 28.01539193]
---------------
----end of task 3----
Can't find filter element
Can't find filter element
PS E:\cv\Problem_Set_3>
```

即 对于`lab`对，其projection matrix和相机内外参KRT的结果为:

	lab_a	lab_b
P	[[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]]

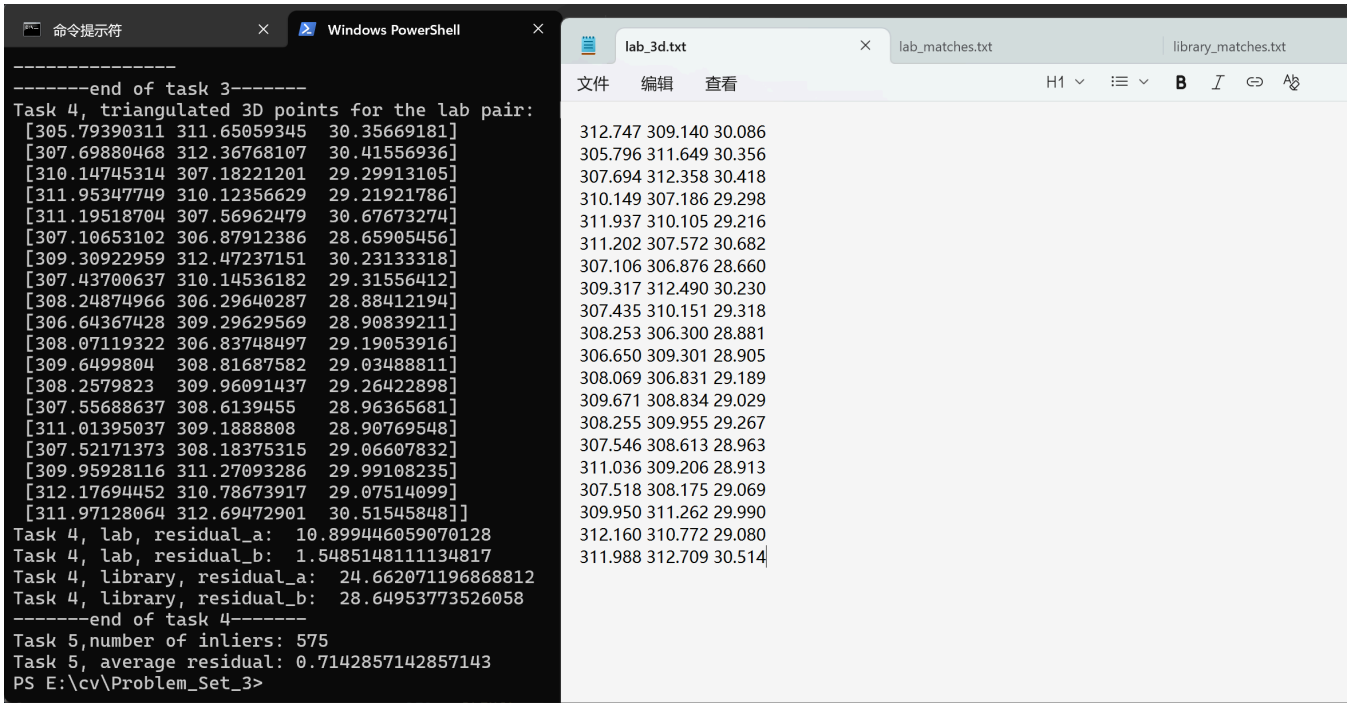
	lab_a	lab_b
K	[[780.56750258 1.99846116 545.67044543] [0. 779.99109405 384.15959109] [0. 0. 1.]]	[[767.01522299 8.37481023 536.20619575] [0. 772.02253385 390.71267556] [0. 0. 1.]]
R	[[0.84996668 -0.5261548 -0.02679126] [-0.13167568 -0.16292373 -0.97781254] [0.51011583 0.83463584 -0.20776153]]	[[0.43076697 -0.90177034 -0.03535629] [-0.21279825 -0.06342282 -0.97503561] [0.8770158 0.42753689 -0.21921561]]
T	[-99.08341704 119.30063513 -403.64591749]	[147.519785 113.64386256 -390.48723313]

对于`library1_camera.txt`和`library2_camera.txt`中的 已知的projection matrix，其相机内外参KRT的结果为：

	library1_camera.txt	library2_camera.txt
K	[[-5.79790975e+02 1.11782151e-06 2.56991552e+02] [0.00000000e+00 -5.39711147e+02 2.04317558e+02] [0.00000000e+00 0.00000000e+00 1.00000000e+00]]	[[-5.47469106e+02 7.30842576e-06 2.58430094e+02] [0.00000000e+00 -5.12933585e+02 2.04985542e+02] [0.00000000e+00 0.00000000e+00 1.00000000e+00]]
R	[[-0.00966193 -0.44135514 -0.8972805] [-0.98017972 -0.17338541 0.09583956] [-0.19787463 0.88042214 -0.43093212]]	[[0.01861384 -0.67624076 -0.73644549] [-0.981381 -0.15319028 0.11586227] [-0.19116708 0.72057697 -0.6665013]]
T	[6.48524008 1.71299092 28.03255592]	[6.70661749 1.69482607 28.01539193]

Task4 Triangulation

关于Sanity check，终端输出`lab`三角化的三维点与`lab_3d.txt`中原始三维点比对，可以看出结果很接近：



二维点与三维点重投影之间的残差：

1. `lab`：residual_a = 10.899446059070128，residual_b = 1.5485148111134817
2. `library`：residual_a = 24.662071196868812, residual_b = 28.64953773526058

Task5 Fundamental matrix estimation without ground-truth matches

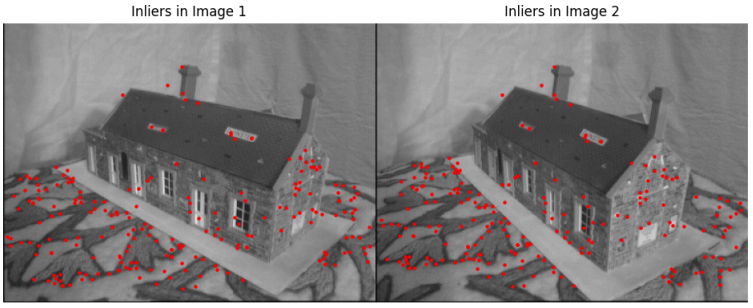
在`fit_fundamental_without_gt`中，使用 SIFT 提取两幅图像的关键点，然后通过 Brute-Force 匹配器进行特征匹配并用 RANSAC 从中筛选出内点匹配对；接着将这些内点传入`fit_fundamental`函数，显式归一化匹配点并估计基础矩阵，确保数值稳定性和精度。过程中借助了一些库函数如：`cv2.SIFT_create()`和`detectAndCompute`(提取图像中的关键点和描述字)、`cv2.BFMatcher`(暴力匹配器对两个图像的描述子进行匹配)、`cv2.findFundamentalMat`(利用 RANSAC 从匹配点中筛选出几何一致的内点对)

结果如下：

内点数与平均残差：

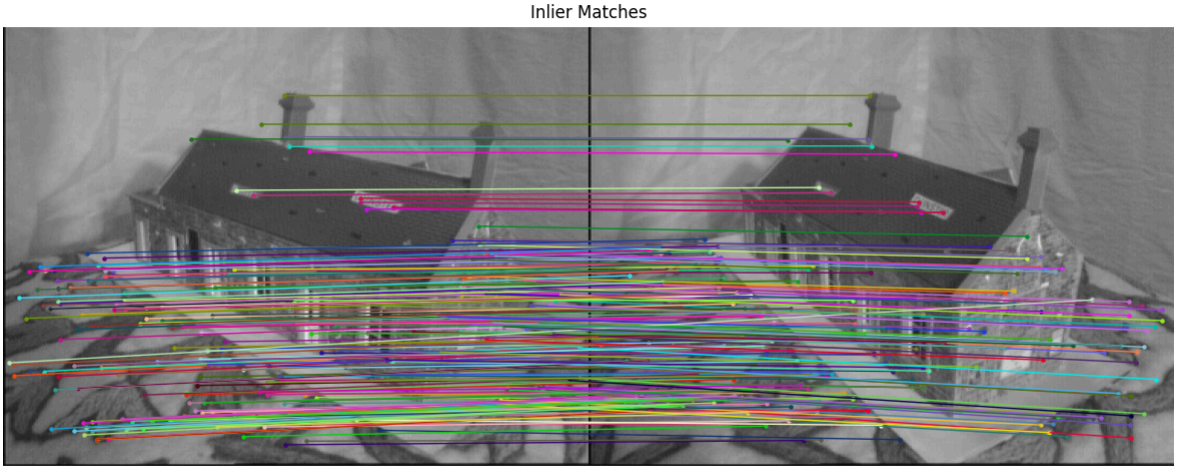
```
House pair result:
Number of inliers: 222
Average residual: 0.7375415282392026

Gaudi pair result:
Number of inliers: 316
Average residual: 0.2631140716069942
```

内点可视化结果与`visualize_fundamental`呈现：


Inliers in Image 1
Inliers in Image 2


Inliers in Image 1
Inliers in Image 2

(内点匹配)


Inlier Matches

Inlier Matches