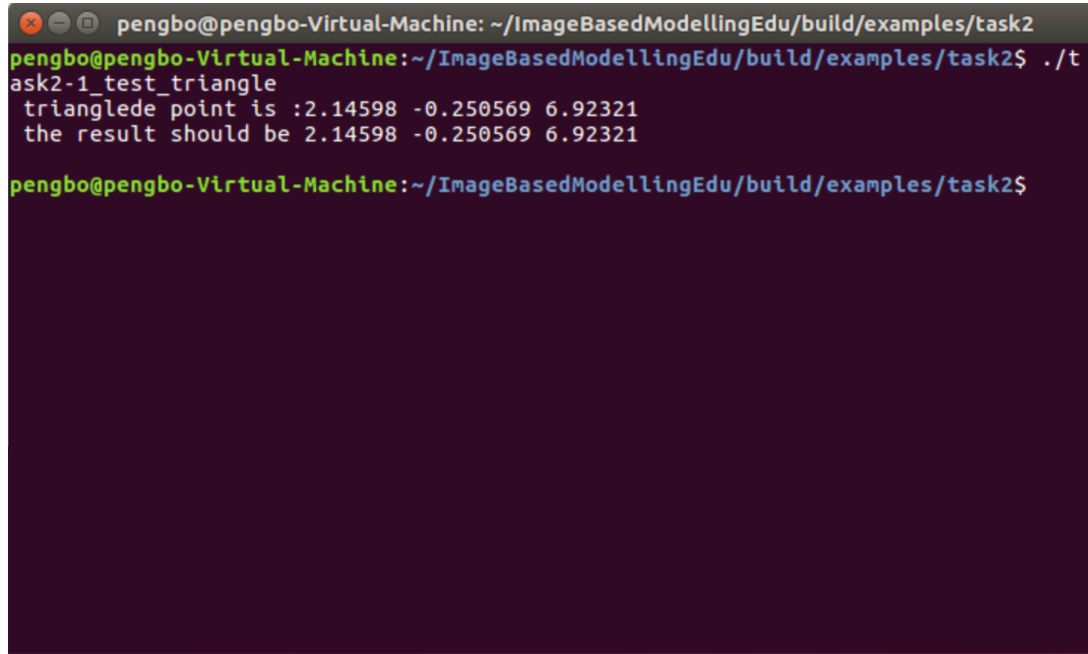


基于图像的三维重建 - 作业 2

peng00bo00

January 30, 2021

1. 补充线性三角化代码后在终端运行程序结果如 Fig.1所示。



```
pengbo@pengbo-Virtual-Machine: ~/ImageBasedModellingEdu/build/examples/task2
pengbo@pengbo-Virtual-Machine:~/ImageBasedModellingEdu/build/examples/task2$ ./task2-1_test_triangle
trianglede point is :2.14598 -0.250569 6.92321
the result should be 2.14598 -0.250569 6.92321
pengbo@pengbo-Virtual-Machine:~/ImageBasedModellingEdu/build/examples/task2$
```

Figure 1: Task 2-1

2. 运行 Kneip 和 Ransac 进行 P3P 求解结果如 Fig.2-Fig.3。

```
pengbo@pengbo-Virtual-Machine: ~/ImageBasedModellingEdu/build/examples/task2
0.255193 -0.870436 -0.420972 3.11342
0.205372 0.474257 -0.856097 5.85432
0.944825 0.132022 0.299794 0.427496

solution 1:
0.255203 -0.870431 -0.420976 3.11345
0.205372 0.474257 -0.856097 5.85432
0.944825 0.132022 0.299794 0.427496

solution 2:
0.999829 -0.00839209 -0.0164611 -0.0488599
0.00840016 0.999965 0.000421432 -0.905071
0.016457 -0.000559636 0.999864 -0.0303736

solution 3:
0.975996 0.122885 0.179806 -1.4207
-0.213274 0.706483 0.67483 -5.68453
-0.0441038 -0.69698 0.715733 1.71501

reproj err of solution 0 0.307975
reproj err of solution 1 0.307975
reproj err of solution 2 3.23739e-07
reproj err of solution 3 0.00146693
pengbo@pengbo-Virtual-Machine:~/ImageBasedModellingEdu/build/examples/task2$
```

Figure 2: Task 2-2 Kneip

```
pengbo@pengbo-Virtual-Machine: ~/ImageBasedModellingEdu/build/examples/task2
pengbo@pengbo-Virtual-Machine:~/ImageBasedModellingEdu/build/examples/task2$ ./t
ask2-2_test_p3p_ransac
2D-3D correspondences inliers: 99
Estimated pose:
0.999539 0.029919 -0.00522629 -0.478246
-0.0297788 0.999241 0.0251186 -4.81399
0.00597385 -0.0249514 0.999671 0.0831591

The result pose should be:
0.99896 0.0341342 -0.0302263 -0.292601
-0.0339703 0.999405 0.0059176 -4.6632
0.0304104 -0.00488465 0.999526 -0.0283862

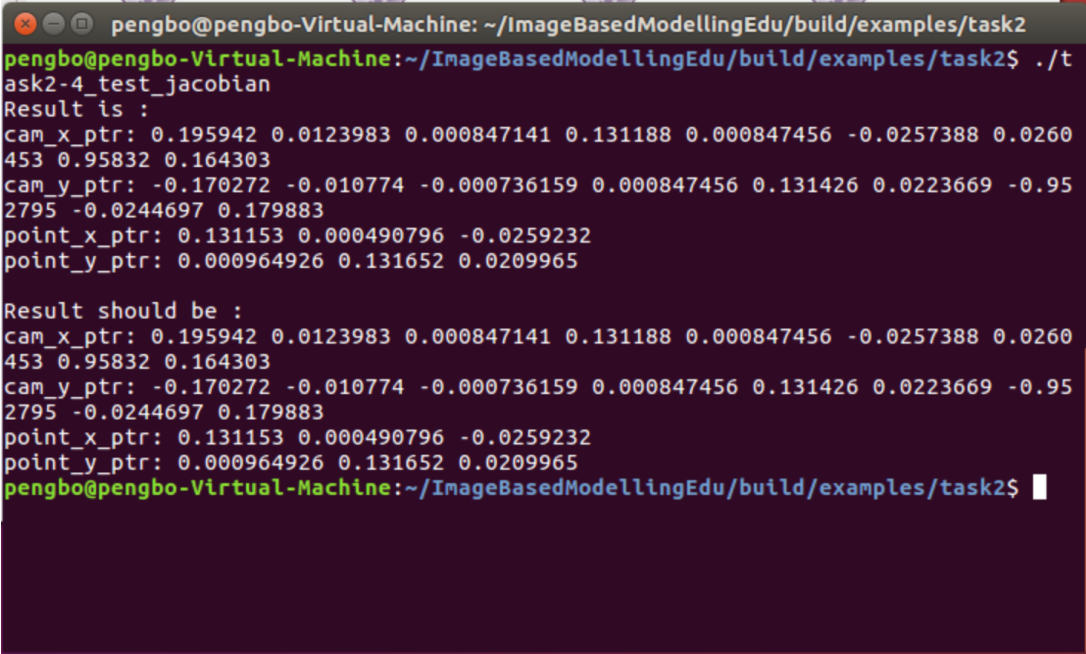
pengbo@pengbo-Virtual-Machine:~/ImageBasedModellingEdu/build/examples/task2$
```

Figure 3: Task 2-2 Ransac

3. LM 算法进行 Bundle Adjustment 流程如下:

- (a) 初始化参数如重投影误差、置信域大小等;
- (b) 计算重投影误差对相机参数以及三维点位置的 Jacobian 矩阵 J_C, J_P ;
- (c) 利用 Schur 补技巧求解正规方程 $(J^T J + \frac{1}{\lambda} I) \Delta x = b$, 得到迭代步长 Δx ;
- (d) 尝试利用求解结果更新相机参数和三维点位置, 并计算更新后的重投影误差;
- (e) 根据重投影误差是否减小来判断是否求解成功:
 - i. 如果求解成功则对相机参数和三维点位置进行更新, 同时增大置信域;
 - ii. 如果求解失败则不进行更新, 同时减小置信域;
- (f) 重复以上步骤直至达到最大迭代次数或迭代步长收敛;

4. 补充计算 Jacobian 矩阵代码后得到程序运行结果如 Fig.4。



```
pengbo@pengbo-Virtual-Machine: ~/ImageBasedModellingEdu/build/examples/task2
pengbo@pengbo-Virtual-Machine:~/ImageBasedModellingEdu/build/examples/task2$ ./task2-4_test_jacobian
Result is :
cam_x_ptr: 0.195942 0.0123983 0.000847141 0.131188 0.000847456 -0.0257388 0.0260453 0.95832 0.164303
cam_y_ptr: -0.170272 -0.010774 -0.000736159 0.000847456 0.131426 0.0223669 -0.952795 -0.0244697 0.179883
point_x_ptr: 0.131153 0.000490796 -0.0259232
point_y_ptr: 0.000964926 0.131652 0.0209965

Result should be :
cam_x_ptr: 0.195942 0.0123983 0.000847141 0.131188 0.000847456 -0.0257388 0.0260453 0.95832 0.164303
cam_y_ptr: -0.170272 -0.010774 -0.000736159 0.000847456 0.131426 0.0223669 -0.952795 -0.0244697 0.179883
point_x_ptr: 0.131153 0.000490796 -0.0259232
point_y_ptr: 0.000964926 0.131652 0.0209965
pengbo@pengbo-Virtual-Machine:~/ImageBasedModellingEdu/build/examples/task2$
```

Figure 4: Task 2-4

5. 调试./task2-5_test_ba 的结果如下:

```
pengbo@pengbo-Virtual-Machine:~/ImageBasedModellingEdu/build/examples/task2$ ./task2-5_test_ba /home/pengbo/ImageBasedModellingEdu/examples/data/sequence/IMG_0191.JPG /home/pengbo/ImageBasedModellingEdu/examples/data/sequence/IMG_0192.JPG
Loading /home/pengbo/ImageBasedModellingEdu/examples/data/sequence/IMG_0191.JPG...
Loading /home/pengbo/ImageBasedModellingEdu/examples/data/sequence/IMG_0192.JPG...
Focal length: 0.972222 0
Focal length: 0.972222 0
Focal length: f1 0.972222 f2: 0.972222
SIFT: Creating 4 octaves (0 to 4)...
SIFT: Generating keypoint descriptors...
SIFT: Generated 492 descriptors from 445 keypoints, took 209ms.
SIFT: Creating 4 octaves (0 to 4)...
SIFT: Generating keypoint descriptors...
SIFT: Generated 463 descriptors from 448 keypoints, took 205ms.
Image 1 (702x468) 492 descriptors.
Image 2 (702x468) 463 descriptors.
Consistent Sift Matches: 266
RANSAC-F: Running for 1000 iterations, threshold 0.0015...
RANSAC-F: Iteration 1, inliers 29 (10.9023%)
RANSAC-F: Iteration 4, inliers 230 (86.4662%)
RANSAC-F: Iteration 8, inliers 261 (98.1203%)
RANSAC-F: Iteration 23, inliers 262 (98.4962%)
RANSAC-F: Iteration 324, inliers 263 (98.8722%)
F: 0.0016963 -0.0705411 -0.698898
0.0543137 0.00206532 0.126149
0.685457 -0.133537 0.00329399

Number of Matching pairs is 263
E: -0.00499314 -0.0172686 0.342859
0.0237567 -0.000765821 -0.0267099
-0.342119 0.0311955 -0.00556201

P1: 0.972222 0 0 0
0 0.972222 0 0
0 0 1 0

P2: -0.95832 0.163708 -0.0061403 0.0764011
0.161803 0.951541 0.116643 0.966964
0.0263835 0.117209 -0.992757 0.0679174

A: -0.972222 0 0.180118 0
-0 -0.972222 -0.156568 -0
0.963815 -0.139297 -0.200623 -0.0622558
-0.162736 -0.955687 -0.081525 -0.969366

P1: 0.972222 0 0 0
0 0.972222 0 0
0 0 1 0
```

Figure 5: Task 2-5

```

0.0237567 -0.000765821 -0.0267099
-0.342119 0.0311955 -0.00556201

P1: 0.972222 0 0 0
0 0.972222 0 0
0 0 1 0

P2: -0.95832 0.163708 -0.0061403 0.0764011
0.161803 0.951541 0.116643 0.966964
0.0263835 0.117209 -0.992757 0.0679174

A: -0.972222 0 0.180118 0
-0 -0.972222 -0.156568 -0
0.963815 -0.139297 -0.200623 -0.0622558
-0.162736 -0.955687 -0.081525 -0.969366

P1: 0.972222 0 0 0
0 0.972222 0 0
0 0 1 0

P2: -0.95832 0.163708 -0.0061403 -0.0764011
0.161803 0.951541 0.116643 -0.966964
0.0263835 0.117209 -0.992757 -0.0679174

A: -0.972222 0 0.180118 0
-0 -0.972222 -0.156568 -0
0.963815 -0.139297 -0.200623 0.0622558
-0.162736 -0.955687 -0.081525 0.969366

P1: 0.972222 0 0 0
0 0.972222 0 0
0 0 1 0

P2: 0.972051 -0.0117274 0.013995 0.0764011
0.0119748 0.971996 -0.0172299 0.966964
-0.0141778 0.0178964 0.999739 0.0679174

A: -0.972222 0 0.180118 0
-0 -0.972222 -0.156568 -0
-0.975004 0.0154547 0.194222 -0.0622558
-0.0114732 -0.972629 -0.0181347 -0.969366

P1: 0.972222 0 0 0
0 0.972222 0 0
0 0 1 0

P2: 0.972051 -0.0117274 0.013995 0.0764011
0.0119748 0.971996 -0.0172299 0.966964
-0.0141778 0.0178964 0.999739 0.0679174

```

Figure 6: Task 2-5

```

Successful triangulation: 263 points
BA: #0 success, MSE 6.79034e-07 -> 5.44002e-08, CG 22, TRR 1000, MSE Ratio: 0.919886
BA: #1 success, MSE 5.44002e-08 -> 5.21847e-08, CG 26, TRR 3000, MSE Ratio: 0.0407265
BA: #2 success, MSE 5.21847e-08 -> 5.1636e-08, CG 32, TRR 9000, MSE Ratio: 0.0105151
BA: #3 success, MSE 5.1636e-08 -> 5.14147e-08, CG 38, TRR 27000, MSE Ratio: 0.0042852
BA: #4 success, MSE 5.14147e-08 -> 5.12402e-08, CG 42, TRR 81000, MSE Ratio: 0.00339452
BA: #5 success, MSE 5.12402e-08 -> 5.1181e-08, CG 47, TRR 243000, MSE Ratio: 0.00115461
BA: #6 success, MSE 5.1181e-08 -> 5.11757e-08, CG 38, TRR 729000, MSE Ratio: 0.00010345
BA: #7 success, MSE 5.11757e-08 -> 5.11756e-08, CG 35, TRR 2.187e+06, MSE Ratio: 1.91983e-06
BA: #8 success, MSE 5.11756e-08 -> 5.11756e-08, CG 36, TRR 6.561e+06, MSE Ratio: 2.45222e-07
BA: #9 success, MSE 5.11756e-08 -> 5.11756e-08, CG 41, TRR 1.9683e+07, MSE Ratio: 1.04848e-07
BA: #10 success, MSE 5.11756e-08 -> 5.11756e-08, CG 21, TRR 5.9049e+07, MSE Ratio: 2.32928e-08
BA: #11 success, MSE 5.11756e-08 -> 5.11756e-08, CG 10, TRR 1.77147e+08, MSE Ratio: 7.87516e-10
BA: Satisfied delta mse ratio threshold of 1e-08
BA: MSE 6.79034e-07 -> 5.11756e-08, 12 LM iters, 388 CG iters, 10ms.
# Cam 0 #
Params before BA:
f: 0.972222
distortion: 0, 0
R: 1 0 0
0 1 0
0 0 1

t: 0 0 0
Params after BA:
f: 0.97919
distortion: -0.0648399, 0.100804
R: 1 -0.000287086 -0.000652844
0.000284915 0.999993 -0.00429935
0.000653779 0.00429922 0.999993

t: 0.000631155 0.0298994 0.0223038
# Cam 1 #
Params before BA:
f: 0.972222
distortion: 0, 0
R: 0.999824 -0.0120624 0.0143949
0.0123169 0.999767 -0.0177222
-0.0141778 0.0178964 0.999739

t: 0.0785839 0.994591 0.0679174
Params after BA:
f: 0.978153
distortion: -0.0705936, 0.117592
R: 0.999808 -0.0125212 0.0150941
0.0127197 0.999836 -0.0130745
-0.0149276 0.0132639 0.999803

```

Figure 7: Task 2-5

```

Params after BA:
  f: 0.97919
  distortion: -0.0648399, 0.100804
  R: 1 -0.000287086 -0.000652844
0.000284915 0.999993 -0.00429935
0.000653779 0.00429922 0.999993

  t: 0.000631155 0.0298994 0.0223038
# Cam 1 #
Params before BA:
  f: 0.972222
  distortion: 0, 0
  R: 0.999824 -0.0120624 0.0143949
0.0123169 0.999767 -0.0177222
-0.0141778 0.0178964 0.999739

  t: 0.0785839 0.994591 0.0679174
Params after BA:
  f: 0.978153
  distortion: -0.0705936, 0.117592
  R: 0.999808 -0.0125212 0.0150941
0.0127197 0.999836 -0.0130745
-0.0149276 0.0132639 0.999803

  t: 0.0803135 0.966225 0.0527785
points 3d:
( 1.3239, -1.1441, 7.10012 )-->( 1.32741, -1.14971, 7.14934 )
( 0.01922, 0.913034, 7.42332 )-->( 0.0186685, 0.929084, 7.54959 )
( -1.12621, -1.24291, 7.21142 )-->( -1.13187, -1.2475, 7.26197 )
( -1.00236, -0.569467, 7.2902 )-->( -1.01123, -0.572129, 7.37812 )
( 0.06407, -0.909536, 7.37132 )-->( 0.0626125, -0.914857, 7.46424 )
( 0.570494, -0.273843, 7.23417 )-->( 0.573645, -0.274518, 7.33266 )
( 0.797949, -1.18866, 7.25639 )-->( 0.799984, -1.19492, 7.32414 )
( 2.39641, -1.254, 6.90262 )-->( 2.40096, -1.25944, 6.90976 )
( -1.10257, -0.980587, 7.25937 )-->( -1.10993, -0.985164, 7.32673 )
( 2.49171, -0.935465, 6.84661 )-->( 2.49781, -0.940309, 6.85597 )
( 1.5339, 0.193847, 6.7062 )-->( 1.54007, 0.194297, 6.75115 )
( -1.38395, -0.797737, 6.97675 )-->( -1.38982, -0.800731, 7.02167 )
( 0.879657, -0.533451, 7.15799 )-->( 0.883903, -0.536366, 7.23998 )
( -2.30034, -1.51935, 6.08983 )-->( -2.28231, -1.51224, 6.02193 )
( -0.0962403, -0.153187, 7.09531 )-->( -0.0984692, -0.152998, 7.18788 )
( -2.55057, 0.29427, 6.30603 )-->( -2.55395, 0.292969, 6.29632 )
( -1.27061, 0.649312, 7.07174 )-->( -1.28336, 0.65787, 7.1571 )
( -2.51367, -0.0259013, 6.37275 )-->( -2.51532, -0.0277912, 6.36179 )
( 0.0582737, 0.839783, 7.35532 )-->( 0.0580914, 0.853746, 7.47524 )
( -2.45614, 0.0398558, 6.39829 )-->( -2.45912, 0.0382599, 6.39234 )
( -2.45614, 0.0398558, 6.39829 )-->( -2.45912, 0.0382599, 6.39234 )
( 0.325461, -1.15201, 7.26753 )-->( 0.325018, -1.15785, 7.34046 )
( 1.98933, 0.935293, 6.61175 )-->( 2.00283, 0.942212, 6.65025 )

```

Figure 8: Task 2-5