

选题 4:手写 Bundle Adjustment

1、BAL 数据集介绍

16 22106 83718

0 0 -3.859900e+02 3.871200e+02

1 0 -3.844000e+01 4.921200e+02

16 为相机个数， 22106 为路标个数， 83718 为观测数据个数

第一行：0 为第 0 个相机， 0 为第 0 个路标， 后面 2 个为观测数据， 像素坐标， 83718 后面是相关参数， 前面是相机参数有 9 维：-R(罗德里格斯向量 3 维), t(3 维), f(相机焦距), k1(畸变参数), k2(畸变参数)。依次对应相机 0 – num_cameras，再后面是路标点空间 3D 参数。

2、相机模型

$P = R * X + t$ (conversion from world to camera coordinates)//把世界坐标转换为相机坐标

$p = -P / P.z$ (perspective division)//相机坐标归一化处理

$p' = f * r(p) * p$ (conversion to pixel coordinates)//转换得到像素坐标

$r(p) = 1.0 + k1 * ||p||^2 + k2 * ||p||^4.$

3、残差和雅克比

3.1 残差

```
const Eigen::Vector3d ptc = camera_ -> getPose() * map_point_ -> getPosition();
Eigen::Vector2d p = -Eigen::Vector2d(ptc[0]/ptc[2], ptc[1]/ptc[2]);
double r_p = 1.0 + camera_ -> getK1() * p.squaredNorm() + camera_ -> getK2() * p.squaredNorm() * p.squaredNorm();
Eigen::Vector2d u(camera_ -> getFocus() * r_p * p[0], camera_ -> getFocus() * r_p * p[1]);
e = ob_z_ - u;
```

3.2 位姿的雅克比

```

const Eigen::Vector3d ptc = camera_>getPose() * map_point->getPosition();
Eigen::Vector2d p = -Eigen::Vector2d(ptc[0]/ptc[2],ptc[1]/ptc[2]);
double f = camera_>getFocus();
double r_p = 1.0 + camera_>getK1() * p.squaredNorm() + camera_>getK2() * p.squaredNorm() * p.squaredNorm();
const double& x = ptc(0);
const double& y = ptc(1);
const double& z = ptc(2);

JT.setZero();
const double z2 = z*z;

JT(0,0) = f*r_p/z;
JT(0,1) = 0;
JT(0,2) = -f*r_p*x/z2;
JT(0,3) = -f*r_p*x*y/z2;
JT(0,4) = f*r_p+f*r_p*x*x/z2;
JT(0,5) = -f*r_p*y/z;

JT(1,0) = 0;
JT(1,1) = f*r_p/z;
JT(1,2) = -f*r_p*y/z2;
JT(1,3) = -f*r_p-f*r_p*y*y/z2;
JT(1,4) = f*r_p*x*y/z2;
JT(1,5) = f*r_p*x/z;

```

3.3 3D 点的雅克比

```

const Eigen::Vector3d ptc = camera_>getPose() * map_point->getPosition();
Eigen::Vector2d p = -Eigen::Vector2d(ptc[0]/ptc[2],ptc[1]/ptc[2]);
double f = camera_>getFocus();
double r_p = 1.0 + camera_>getK1() * p.squaredNorm() + camera_>getK2() * p.squaredNorm() * p.squaredNorm();
const double& x = ptc(0);
const double& y = ptc(1);
const double& z = ptc(2);

JX.setZero();

Eigen::Matrix<double, 2, 3> Jtmp;
Jtmp.setZero();

Jtmp(0,0) = f*r_p / z;
Jtmp(0,1) = 0;
Jtmp(0,2) = -f*r_p*x/(z*z);
Jtmp(1,0) = 0;
Jtmp(1,1) = f*r_p/z;
Jtmp(1,2) = -f*r_p*y/(z*z);

JX = Jtmp * camera_>getPose().rotationMatrix();

```

4、与 g2o 对比

只对比了优化相机坐标，固定 3D 点，如果同时优化 3D 点，内存消耗过大，程序崩溃

```
touchair@touchair-2020T:~/bundle_adjustment/build$ ./bal_g2o ../problem-16-22106-pre.txt
***** Solved by G2O *****
iteration= 0 chi2= 8897877.759774 time= 0.128303 cumTime= 0.128303 edges= 83718 schur= 1 lambda= 227.832660 levenbergIter= 1
iteration= 1 chi2= 1880861.314757 time= 0.119045 cumTime= 0.247348 edges= 83718 schur= 1 lambda= 75.944220 levenbergIter= 1
iteration= 2 chi2= 1282215.336613 time= 0.121327 cumTime= 0.368675 edges= 83718 schur= 1 lambda= 25.944740 levenbergIter= 1
iteration= 3 chi2= 1244048.795190 time= 0.118969 cumTime= 0.487644 edges= 83718 schur= 1 lambda= 8.438247 levenbergIter= 1
iteration= 4 chi2= 1235951.302580 time= 0.118371 cumTime= 0.606015 edges= 83718 schur= 1 lambda= 2.812749 levenbergIter= 1
iteration= 5 chi2= 1233991.731315 time= 0.122274 cumTime= 0.728289 edges= 83718 schur= 1 lambda= 0.937583 levenbergIter= 1
iteration= 6 chi2= 1233450.263831 time= 0.126224 cumTime= 0.854513 edges= 83718 schur= 1 lambda= 0.312528 levenbergIter= 1
iteration= 7 chi2= 1233158.810027 time= 0.121271 cumTime= 0.975784 edges= 83718 schur= 1 lambda= 0.104176 levenbergIter= 1
iteration= 8 chi2= 1232827.068522 time= 0.121051 cumTime= 1.09684 edges= 83718 schur= 1 lambda= 0.069451 levenbergIter= 1
iteration= 9 chi2= 1232634.297081 time= 0.116734 cumTime= 1.21357 edges= 83718 schur= 1 lambda= 0.046300 levenbergIter= 1
iteration= 10 chi2= 1232592.562767 time= 0.115511 cumTime= 1.32908 edges= 83718 schur= 1 lambda= 0.030867 levenbergIter= 1
iteration= 11 chi2= 1232534.022537 time= 0.116121 cumTime= 1.4452 edges= 83718 schur= 1 lambda= 0.020578 levenbergIter= 1
iteration= 12 chi2= 1232228.555772 time= 0.117457 cumTime= 1.56266 edges= 83718 schur= 1 lambda= 0.013719 levenbergIter= 1
iteration= 13 chi2= 1231909.462584 time= 0.118091 cumTime= 1.68075 edges= 83718 schur= 1 lambda= 0.009146 levenbergIter= 1
iteration= 14 chi2= 1230929.517071 time= 0.124128 cumTime= 1.80488 edges= 83718 schur= 1 lambda= 0.009157 levenbergIter= 2
iteration= 15 chi2= 1230441.997968 time= 0.126282 cumTime= 1.93116 edges= 83718 schur= 1 lambda= 0.012210 levenbergIter= 2
iteration= 16 chi2= 1230055.537513 time= 0.123687 cumTime= 2.05485 edges= 83718 schur= 1 lambda= 0.008140 levenbergIter= 2
iteration= 17 chi2= 1230028.170926 time= 0.125612 cumTime= 2.18046 edges= 83718 schur= 1 lambda= 0.010853 levenbergIter= 2
iteration= 18 chi2= 1229812.883436 time= 0.12563 cumTime= 2.30609 edges= 83718 schur= 1 lambda= 0.014471 levenbergIter= 2
iteration= 19 chi2= 1229625.675546 time= 0.123964 cumTime= 2.43005 edges= 83718 schur= 1 lambda= 0.009647 levenbergIter= 2
iteration= 20 chi2= 1229590.987418 time= 0.123795 cumTime= 2.55385 edges= 83718 schur= 1 lambda= 0.012863 levenbergIter= 2
iteration= 21 chi2= 1229476.455502 time= 0.134155 cumTime= 2.688 edges= 83718 schur= 1 lambda= 0.017151 levenbergIter= 2
iteration= 22 chi2= 1229379.930160 time= 0.127164 cumTime= 2.81517 edges= 83718 schur= 1 lambda= 0.011434 levenbergIter= 2
iteration= 23 chi2= 1229347.977215 time= 0.125134 cumTime= 2.9403 edges= 83718 schur= 1 lambda= 0.015245 levenbergIter= 2
iteration= 24 chi2= 1229283.827426 time= 0.123595 cumTime= 3.06389 edges= 83718 schur= 1 lambda= 0.020327 levenbergIter= 2
Mean rot error: 0.154889 Mean trans error: 1.17547
```

```
touchair@touchair-2020T:~/bundle_adjustment/build$ ./bal_data_test ../problem-16-22106-pre.txt
***** Solved by BA *****
Iter: 1 Cost: 2411309.2949559689 Step: 10.0259200220 Time 0.263 Total time 0.263
Iter: 2 Cost: 1316629.6534588533 Step: 11.6195786262 Time 0.270 Total time 0.533
Iter: 3 Cost: 1315497.3273644391 Step: 0.5580046927 Time 0.273 Total time 0.806
Iter: 4 Cost: 1315497.3273644382 Step: 0.0063708137 Time 0.536 Total time 1.342
Iter: 5 Cost: 1315497.3273644391 Step: 0.0063406018 Time 0.530 Total time 1.872
Iter: 6 Cost: 1315497.3273644377 Step: 0.0061656476 Time 0.536 Total time 2.407
Iter: 7 Cost: 1315497.3273644375 Step: 0.0049262673 Time 0.534 Total time 2.941
Iter: 8 Cost: 1315496.1226943349 Step: 0.0013751490 Time 0.273 Total time 3.214
Iter: 9 Cost: 1315496.1226943356 Step: 0.0019889107 Time 0.529 Total time 3.743
Iter: 10 Cost: 1315496.1226943356 Step: 0.0012500320 Time 0.535 Total time 4.278
Iter: 11 Cost: 1315496.1226943366 Step: 0.0004088770 Time 0.534 Total time 4.812
Iter: 12 Cost: 1315496.1226943356 Step: 0.0000613787 Time 0.534 Total time 5.346
Iter: 13 Cost: 1315496.1226943361 Step: 0.0000040220 Time 0.533 Total time 5.879
Iter: 14 Cost: 1315496.1199328001 Step: 0.0000001263 Time 0.270 Total time 6.149
Iter: 15 Cost: 1315496.1197793041 Step: 0.0000003783 Time 0.270 Total time 6.419
Iter: 16 Cost: 1315496.1197793044 Step: 0.0000011338 Time 0.533 Total time 6.952
Iter: 17 Cost: 1315496.1197793039 Step: 0.0000005672 Time 0.532 Total time 7.484
Iter: 18 Cost: 1315496.1197793051 Step: 0.0000001419 Time 0.535 Total time 8.019
Iter: 19 Cost: 1315496.1197790757 Step: 0.0000000177 Time 0.271 Total time 8.290
Iter: 20 Cost: 1315496.1197790757 Step: 0.0000000128 Time 0.541 Total time 8.832
Iter: 21 Cost: 1315496.1197790750 Step: 0.0000000064 Time 0.534 Total time 9.366
Iter: 22 Cost: 1315496.1197790760 Step: 0.0000000016 Time 0.536 Total time 9.902
Iter: 23 Cost: 1315496.1197790417 Step: 0.0000000002 Time 0.270 Total time 10.172
Iter: 24 Cost: 1315496.1197790422 Step: 0.0000000006 Time 0.532 Total time 10.704
Iter: 25 Cost: 1315496.1197790422 Step: 0.0000000003 Time 0.533 Total time 11.237
Mean rot error: 0.155 Mean trans error: 2.041
```

G2O

1/1

touchair@touchair-2020T:~/bundle_adjustment/build

touchair@touchair-2020T:~/bundle_adjustment/build\$./bal_g2o ../problem-16-22106-pre.txt

***** Solved by G2O *****

iteration= 0 chi2= 8897877.759774 time= 0.121061 cumTime= 0.121061 edges= 83718 schu

iteration= 1 chi2= 1880861.314757 time= 0.117457 cumTime= 0.238518 edges= 83718 schu

iteration= 2 chi2= 1282215.336613 time= 0.120446 cumTime= 0.358964 edges= 83718 schu

iteration= 3 chi2= 1244048.795190 time= 0.123486 cumTime= 0.491449 edges= 83718 schu

iteration= 4 chi2= 1235951.302580 time= 0.125529 cumTime= 0.616978 edges= 83718 schu

iteration= 5 chi2= 1233991.731315 time= 0.119858 cumTime= 0.736836 edges= 83718 schu

iteration= 6 chi2= 1233450.263831 time= 0.11841 cumTime= 0.855246 edges= 83718 schu

iteration= 7 chi2= 1233158.810027 time= 0.118977 cumTime= 0.974223 edges= 83718 schu

iteration= 8 chi2= 1232827.068522 time= 0.121362 cumTime= 1.09558 edges= 83718 schu

iteration= 9 chi2= 1232634.297081 time= 0.121441 cumTime= 1.21703 edges= 83718 schu

iteration= 10 chi2= 1232592.562767 time= 0.11788 cumTime= 1.3349 edges= 83718 schu

iteration= 11 chi2= 1232534.022537 time= 0.12449 cumTime= 1.4594 edges= 83718 schu

iteration= 12 chi2= 1232228.555772 time= 0.128457 cumTime= 1.58785 edges= 83718 schu

iteration= 13 chi2= 1231909.462584 time= 0.132803 cumTime= 1.72066 edges= 83718 schu

iteration= 14 chi2= 1230929.517071 time= 0.135267 cumTime= 1.85592 edges= 83718 schu

iteration= 15 chi2= 1230441.997968 time= 0.127122 cumTime= 1.98304 edges= 83718 schu

iteration= 16 chi2= 1230055.537513 time= 0.125359 cumTime= 2.1084 edges= 83718 schu

iteration= 17 chi2= 1230028.170926 time= 0.125034 cumTime= 2.23344 edges= 83718 schu

iteration= 18 chi2= 1229812.883436 time= 0.126975 cumTime= 2.36041 edges= 83718 schu

iteration= 19 chi2= 1229625.675546 time= 0.125102 cumTime= 2.48552 edges= 83718 schu

iteration= 20 chi2= 1229590.987418 time= 0.125391 cumTime= 2.61091 edges= 83718 schu

iteration= 21 chi2= 1229476.455502 time= 0.127582 cumTime= 2.73849 edges= 83718 schu

iteration= 22 chi2= 1229379.930160 time= 0.127704 cumTime= 2.86619 edges= 83718 schu

iteration= 23 chi2= 1229347.977215 time= 0.129586 cumTime= 2.99578 edges= 83718 schu

iteration= 24 chi2= 1229283.827426 time= 0.142275 cumTime= 3.13805 edges= 83718 schu

iteration= 25 chi2= 1229283.827426 time= 0.142275 cumTime= 3.13805 edges= 83718 schu

Mean rot error: 0.154889 Mean trans error: 1.17547

touchair@touchair-2020T:~/bundle_adjustment/build\$./bal_data_test ../problem-16-22106-pre.txt

***** Solved by BA *****

Iter: 1 Cost: 2411309.2949559689 Step: 10.0259200220 Time 0.263 Total time 0.263

Iter: 2 Cost: 1316629.6534588533 Step: 11.6195786262 Time 0.270 Total time 0.533

Iter: 3 Cost: 1315497.3273644391 Step: 0.5580046927 Time 0.273 Total time 0.806

Iter: 4 Cost: 1315497.3273644382 Step: 0.0063708137 Time 0.536 Total time 1.342

Iter: 5 Cost: 1315497.3273644391 Step: 0.0063406018 Time 0.530 Total time 1.872

Iter: 6 Cost: 1315497.3273644377 Step: 0.0061656476 Time 0.536 Total time 2.407

Iter: 7 Cost: 1315497.3273644375 Step: 0.0049262673 Time 0.534 Total time 2.941

Iter: 8 Cost: 1315496.1226943349 Step: 0.0013751490 Time 0.273 Total time 3.214

Iter: 9 Cost: 1315496.1226943356 Step: 0.0019889107 Time 0.529 Total time 3.743

Iter: 10 Cost: 1315496.1226943356 Step: 0.0012500320 Time 0.535 Total time 4.278

Iter: 11 Cost: 1315496.1226943366 Step: 0.0004088770 Time 0.534 Total time 4.812

Iter: 12 Cost: 1315496.1226943356 Step: 0.0000613787 Time 0.534 Total time 5.346

Iter: 13 Cost: 1315496.1226943361 Step: 0.0000040220 Time 0.533 Total time 5.879

Iter: 14 Cost: 1315496.1199328001 Step: 0.0000001263 Time 0.270 Total time 6.149

Iter: 15 Cost: 1315496.1197793041 Step: 0.0000003783 Time 0.270 Total time 6.419

Iter: 16 Cost: 1315496.1197793044 Step: 0.0000011338 Time 0.533 Total time 6.952

Iter: 17 Cost: 1315496.1197793039 Step: 0.0000005672 Time 0.532 Total time 7.484

Iter: 18 Cost: 1315496.1197793051 Step: 0.0000001419 Time 0.535 Total time 8.019

Iter: 19 Cost: 1315496.1197790757 Step: 0.0000000177 Time 0.271 Total time 8.290

Iter: 20 Cost: 1315496.1197790757 Step: 0.0000000128 Time 0.541 Total time 8.832

Iter: 21 Cost: 1315496.1197790750 Step: 0.0000000064 Time 0.534 Total time 9.366

Iter: 22 Cost: 1315496.1197790760 Step: 0.0000000016 Time 0.536 Total time 9.902

Iter: 23 Cost: 1315496.1197790417 Step: 0.0000000002 Time 0.270 Total time 10.172

Iter: 24 Cost: 1315496.1197790422 Step: 0.0000000006 Time 0.532 Total time 10.704

Iter: 25 Cost: 1315496.1197790422 Step: 0.0000000003 Time 0.533 Total time 11.237

Mean rot error: 0.155 Mean trans error: 2.041

手写 BA

```
1: touchair@touchair-2020T: ~/bundle_adjustment/build
r=1 lambda= 0.104176 levenbergiter= 1
iteration= 8 chi2= 1232827.068522 time= 0.121362 cunTime= 1.09558 edges= 83718 schu
r=1 lambda= 0.069451 levenbergiter= 1
iteration= 9 chi2= 1232634.297081 time= 0.121441 cunTime= 1.21703 edges= 83718 schu
r=1 lambda= 0.046300 levenbergiter= 1
iteration= 10 chi2= 1232592.562767 time= 0.11788 cunTime= 1.3349 edges= 83718 schu
r=1 lambda= 0.030867 levenbergiter= 1
iteration= 11 chi2= 1232534.022527 time= 0.12449 cunTime= 1.4594 edges= 83718 schu
r=1 lambda= 0.020578 levenbergiter= 1
iteration= 12 chi2= 1232228.555772 time= 0.128457 cunTime= 1.58785 edges= 83718 schu
r=1 lambda= 0.013719 levenbergiter= 1
iteration= 13 chi2= 1231909.462584 time= 0.132803 cunTime= 1.72066 edges= 83718 schu
r=1 lambda= 0.009146 levenbergiter= 1
iteration= 14 chi2= 1230929.517071 time= 0.135267 cunTime= 1.85592 edges= 83718 schu
r=1 lambda= 0.009157 levenbergiter= 2
iteration= 15 chi2= 1230441.997068 time= 0.127122 cunTime= 1.98384 edges= 83718 schu
r=1 lambda= 0.012210 levenbergiter= 2
iteration= 16 chi2= 1230055.537513 time= 0.125359 cunTime= 2.1084 edges= 83718 schu
r=1 lambda= 0.008140 levenbergiter= 2
iteration= 17 chi2= 1230028.170920 time= 0.125034 cunTime= 2.23344 edges= 83718 schu
r=1 lambda= 0.010853 levenbergiter= 2
iteration= 18 chi2= 1229812.883436 time= 0.126975 cunTime= 2.36041 edges= 83718 schu
r=1 lambda= 0.014471 levenbergiter= 2
iteration= 19 chi2= 1229625.075546 time= 0.125102 cunTime= 2.48552 edges= 83718 schu
r=1 lambda= 0.009647 levenbergiter= 2
iteration= 20 chi2= 1229590.987418 time= 0.125391 cunTime= 2.61091 edges= 83718 schu
r=1 lambda= 0.011863 levenbergiter= 2
iteration= 21 chi2= 1229476.455502 time= 0.127582 cunTime= 2.73849 edges= 83718 schu
r=1 lambda= 0.017151 levenbergiter= 2
iteration= 22 chi2= 1229379.939168 time= 0.127704 cunTime= 2.86619 edges= 83718 schu
r=1 lambda= 0.011434 levenbergiter= 2
iteration= 23 chi2= 1229347.977215 time= 0.129586 cunTime= 2.99578 edges= 83718 schu
r=1 lambda= 0.015245 levenbergiter= 2
iteration= 24 chi2= 1229283.827426 time= 0.142275 cunTime= 3.13805 edges= 83718 schu
r=1 lambda= 0.020327 levenbergiter= 2
Mean rot error: 0.154889 Mean trans error: 1.17547
touchair@touchair-2020T:~/bundle_adjustment/build$ ./bal_data_test ../problem-16-22106-pre.txt
***** Solved by BA *****
Iter: 1 Cost: 2411309.2949559689 Step: 0.0259200220 Time 0.289 Total_time 0.289
Iter: 2 Cost: 1316620.6534588533 Step: 11.6195786262 Time 0.296 Total_time 0.585
Iter: 3 Cost: 1315497.3273644391 Step: 0.5580040927 Time 0.298 Total_time 0.882
Iter: 4 Cost: 1315497.3273644392 Step: 0.0603708137 Time 0.551 Total_time 1.434
Iter: 5 Cost: 1315497.3273644391 Step: 0.0603406018 Time 0.546 Total_time 1.980
Iter: 6 Cost: 1315497.3273644377 Step: 0.0601656476 Time 0.558 Total_time 2.538
Iter: 7 Cost: 1315497.3273644376 Step: 0.0049262673 Time 0.546 Total_time 3.083
Iter: 8 Cost: 1315496.1226943349 Step: 0.0013751490 Time 0.281 Total_time 3.364
Iter: 9 Cost: 1315496.1226943356 Step: 0.0019889107 Time 0.547 Total_time 3.911
Iter: 10 Cost: 1315496.1226943356 Step: 0.0012500320 Time 0.542 Total_time 4.453
Iter: 11 Cost: 1315496.1226943360 Step: 0.0004089770 Time 0.544 Total_time 4.998
Iter: 12 Cost: 1315496.1226943356 Step: 0.0000613707 Time 0.551 Total_time 5.549
Iter: 13 Cost: 1315496.1226943361 Step: 0.0000040220 Time 0.545 Total_time 6.093
Iter: 14 Cost: 1315496.1199328001 Step: 0.0000001263 Time 0.285 Total_time 6.379
Iter: 15 Cost: 1315496.1197793041 Step: 0.0000003783 Time 0.287 Total_time 6.666
Iter: 16 Cost: 1315496.1197793044 Step: 0.0000011338 Time 0.544 Total_time 7.209
Iter: 17 Cost: 1315496.1197793039 Step: 0.0000005672 Time 0.547 Total_time 7.756
Iter: 18 Cost: 1315496.1197793051 Step: 0.0000001419 Time 0.547 Total_time 8.303

2: touchair@touchair-2020T: ~
1 1 7.2% 5 5.2%
2 1 3.9% 6 4.0%
3 1 2.0% 7 3.9%
4 1 2.0% 8 100.0%
Tasks: 195, 1305 thr; 2 running
Load average: 0.31 0.39 0.64
Uptime: 3 days, 00:46:19

PID USER PRI NI VIRT RES SHR S CPU% MEM% TIME+ Command
336 root 20 0 8101M 2842M 76 S 0.0 17.9 1:22:47 /home/touchair/下载/ubuntu软件包/andro
394 root 20 0 8101M 2842M 76 S 0.0 17.9 0:25:11 /home/touchair/下载/ubuntu软件包/andro
19339 root 20 0 8101M 2842M 76 S 0.0 17.9 0:01:06 /home/touchair/下载/ubuntu软件包/andro
342 root 20 0 8101M 2842M 76 S 0.0 17.9 2:38:15 /home/touchair/下载/ubuntu软件包/andro
337 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:41 /home/touchair/下载/ubuntu软件包/andro
338 root 20 0 8101M 2842M 76 S 0.0 17.9 1:15:32 /home/touchair/下载/ubuntu软件包/andro
339 root 20 0 8101M 2842M 76 S 0.0 17.9 0:06:33 /home/touchair/下载/ubuntu软件包/andro
340 root 20 0 8101M 2842M 76 S 0.0 17.9 4:48:86 /home/touchair/下载/ubuntu软件包/andro
341 root 20 0 8101M 2842M 76 S 0.0 17.9 0:02:78 /home/touchair/下载/ubuntu软件包/andro
343 root 20 0 8101M 2842M 76 S 0.0 17.9 0:15:59 /home/touchair/下载/ubuntu软件包/andro
344 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:75 /home/touchair/下载/ubuntu软件包/andro
345 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:02 /home/touchair/下载/ubuntu软件包/andro
346 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
347 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:05 /home/touchair/下载/ubuntu软件包/andro
348 root 20 0 8101M 2842M 76 S 0.0 17.9 0:13:00 /home/touchair/下载/ubuntu软件包/andro
349 root 20 0 8101M 2842M 76 S 0.0 17.9 0:48:08 /home/touchair/下载/ubuntu软件包/andro
350 root 20 0 8101M 2842M 76 S 0.0 17.9 0:02:42 /home/touchair/下载/ubuntu软件包/andro
351 root 20 0 8101M 2842M 76 S 0.0 17.9 1:54:08 /home/touchair/下载/ubuntu软件包/andro
352 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:17 /home/touchair/下载/ubuntu软件包/andro
389 root 20 0 8101M 2842M 76 S 0.0 17.9 1:15:04 /home/touchair/下载/ubuntu软件包/andro
390 root 20 0 8101M 2842M 76 S 0.0 17.9 1:15:57 /home/touchair/下载/ubuntu软件包/andro
391 root 20 0 8101M 2842M 76 S 0.0 17.9 1:15:26 /home/touchair/下载/ubuntu软件包/andro
392 root 20 0 8101M 2842M 76 S 0.0 17.9 1:15:35 /home/touchair/下载/ubuntu软件包/andro
393 root 20 0 8101M 2842M 76 S 0.0 17.9 1:15:75 /home/touchair/下载/ubuntu软件包/andro
401 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
403 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
409 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
411 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
412 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:21 /home/touchair/下载/ubuntu软件包/andro
413 root 20 0 8101M 2842M 76 S 0.0 17.9 1:08:97 /home/touchair/下载/ubuntu软件包/andro
414 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:01 /home/touchair/下载/ubuntu软件包/andro
415 root 20 0 8101M 2842M 76 S 0.0 17.9 0:21:01 /home/touchair/下载/ubuntu软件包/andro
416 root 20 0 8101M 2842M 76 S 0.0 17.9 1:15:52 /home/touchair/下载/ubuntu软件包/andro
417 root 20 0 8101M 2842M 76 S 0.0 17.9 1:15:60 /home/touchair/下载/ubuntu软件包/andro
418 root 20 0 8101M 2842M 76 S 0.0 17.9 4:49:04 /home/touchair/下载/ubuntu软件包/andro
420 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
439 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:14 /home/touchair/下载/ubuntu软件包/andro
441 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
444 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
445 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:11 /home/touchair/下载/ubuntu软件包/andro
446 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
448 root 20 0 8101M 2842M 76 S 0.0 17.9 0:12:76 /home/touchair/下载/ubuntu软件包/andro
449 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
479 root 20 0 8101M 2842M 76 S 0.0 17.9 0:01:85 /home/touchair/下载/ubuntu软件包/andro
559 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
570 root 20 0 8101M 2842M 76 S 0.0 17.9 0:00:00 /home/touchair/下载/ubuntu软件包/andro
```

上面是 G2O 的测试结果，下面是手写 BA 的测试结果，可以看出精度方面，手写 BA 和 G2O 计算的相机位姿旋转误差基本一致，平移误差手写 BA 略高于 G2O，单次迭代时间和总迭代时间手写 BA 均高于 G2O，CPU 占用百分比手写 BA 略低于 G2O