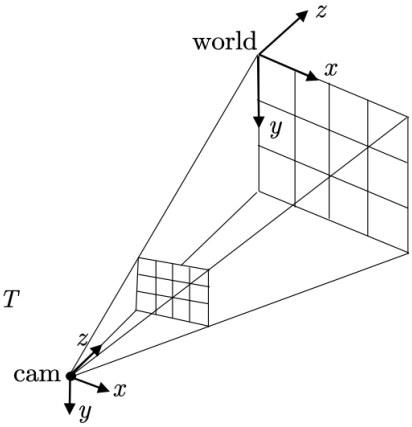
1. PnP 算法简单介绍

PnP(pespective-n-point) , 求解3D-2D点对运动的方法。在已知n个三维空间点坐标（相对于某个指定的坐标系A）及其二维投影位置的情况下，估计相机的位姿（即相机在坐标系A下的姿态）的方法。
PNP 的问题是一致的，不同的就是在已知3D-2D的点对的情况下，怎么求出相机的位姿或者说点对在相机坐标系下的姿态。常见的PNP问题的求解方法，有以下几种:



PnP算法大体分为直接法和优化法
常见的直接法包括：P3P、DLT、EPnP等
优化的算法包括：LHM、Only pos BA

PnP算法的指标主要包括：匹配点数、鲁棒性、速度、精度
P3P：3对匹配点，需要相机内参
DLT：不需要内参，4点法求出单映矩阵，DLT分解出K、R、T
EPnP：最小4个点，性价比高，精度较高，需要内参K
LHM：复杂度较高，具有全局凸性，收敛性好，精度高
（在object坐标系建立误差模型）
only－pos BA：复杂度高，需要初始解，精度高（在image坐标系建立误差模型）

- 直接线性变换DLT
- EPnP ： 利用已知的3d点，通过PCA选择4个控制点，建立新的局部坐标系，从而将3d坐标用新的控制点表示出来。然后，利用相机投影模型和2d点，转换到相机坐标系中，再在相机坐标系中建立和世界坐标系同样关系（每个点在相机坐标系和世界坐标系下控制点处的坐标一致）的4个控制点，求解出相机坐标系下的四个控制点的坐标，进而利用ICP求解pose。
- SDP
- P3P
- UPnP
- 非线性优化方法等.....

2. opencv 函数说明:

solvePnPRansac by opencv doc

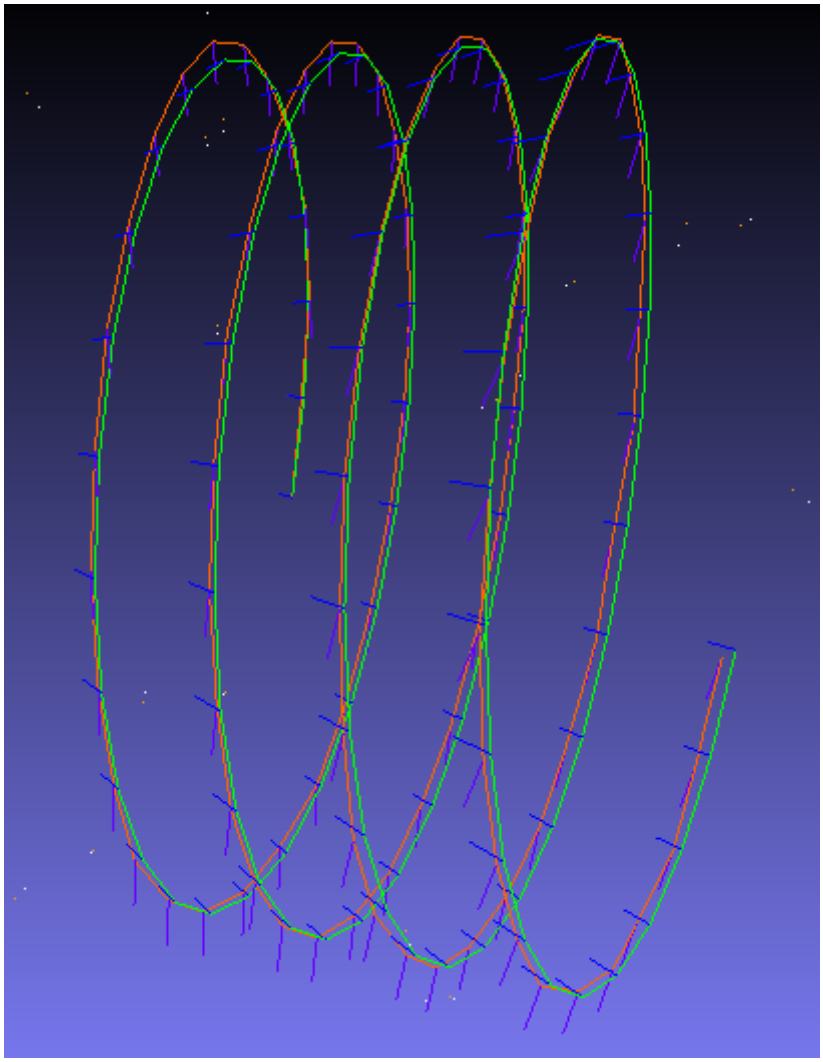
```
bool solvePnPRansac(InputArray _opoints, InputArray _ipoints,
    InputArray _cameraMatrix, InputArray _distCoeffs,
    OutputArray _rvec, OutputArray _tvec, bool useExtrinsicGuess,
    int iterationsCount, float reprojectionError, double confidence,
    OutputArray _inliers, int flags)
```

参数说明：
objectPoints - 世界坐标系下的控制点的坐标，vector<Point3f>的数据类型在这里可以使用
imagePoints - 在图像坐标系下对应的控制点的坐标。vector<Point2f>在这里可以使用
cameraMatrix - 相机的内参矩阵
distCoeffs - 相机的畸变系数
rvec - 输出的旋转向量。使坐标点从世界坐标系旋转到相机坐标系
tvec - 输出的平移向量。使坐标点从世界坐标系平移到相机坐标系

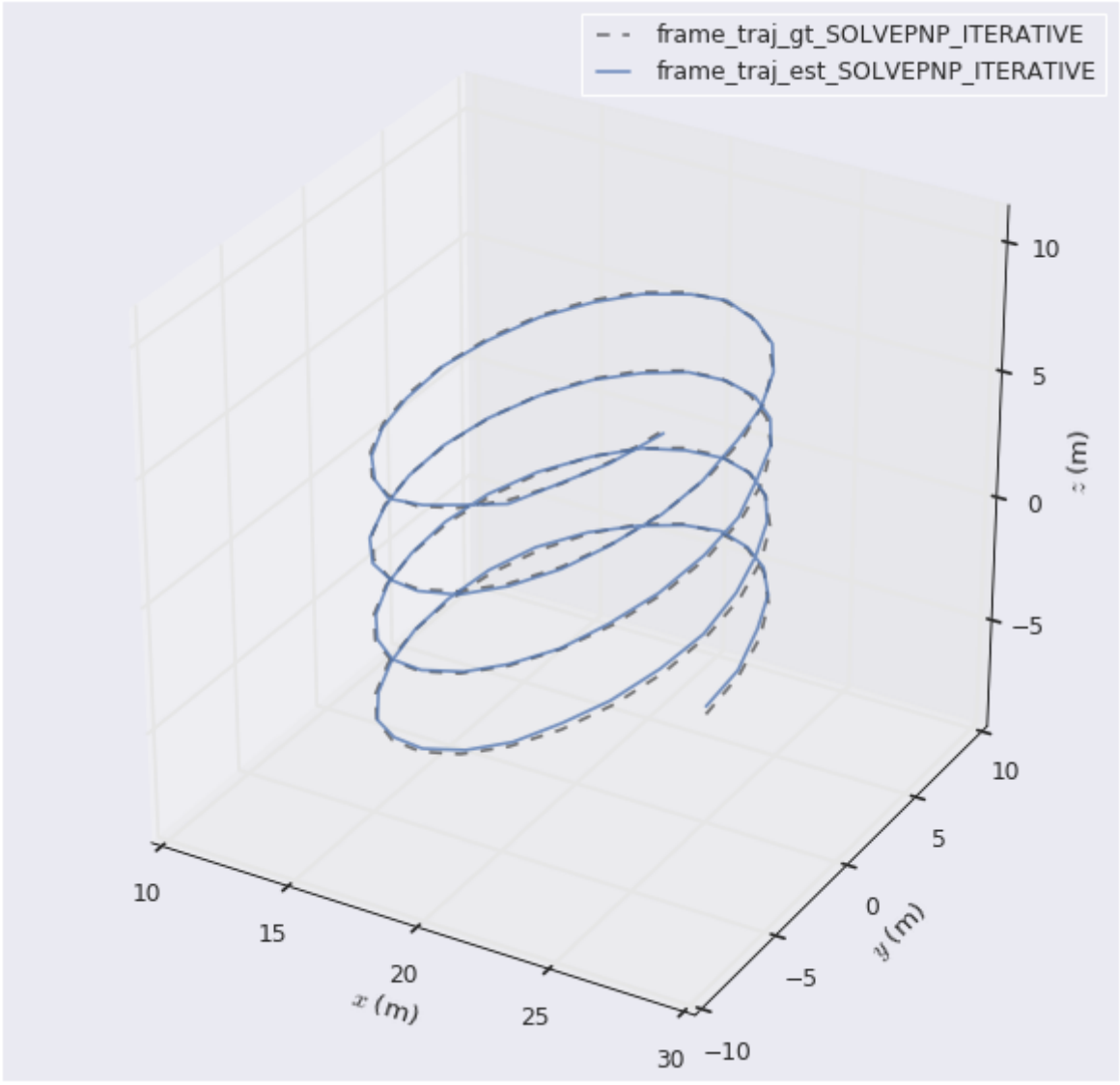
```
flags - 默认使用CV_ITERATIV迭代法
      SOLVEPNP_ITERATIVE(此方案，最小模型用的EPNP，内点选出之后用了一个迭代)；
      SOLVE_P3P(P3P只用在最小模型上，内点选出之后用了一个EPNP)
      SOLVE_AP3P(AP3P只用在最小模型上，内点选出之后用了一个EPNP)
      SOLVE_EPnP(最小模型上&内点选出之后都采用了EPNP)
```

3. 实验数据与结果分析

3.0. SOLVEPNP_ITERATIVE



```
 evo_traj tum frame_traj_est_SOLVEPNP_ITERATIVE.txt --
ref=frame_traj_gt_SOLVEPNP_ITERATIVE.txt -p --plot_mode xyz  --align --
correct_scale
```

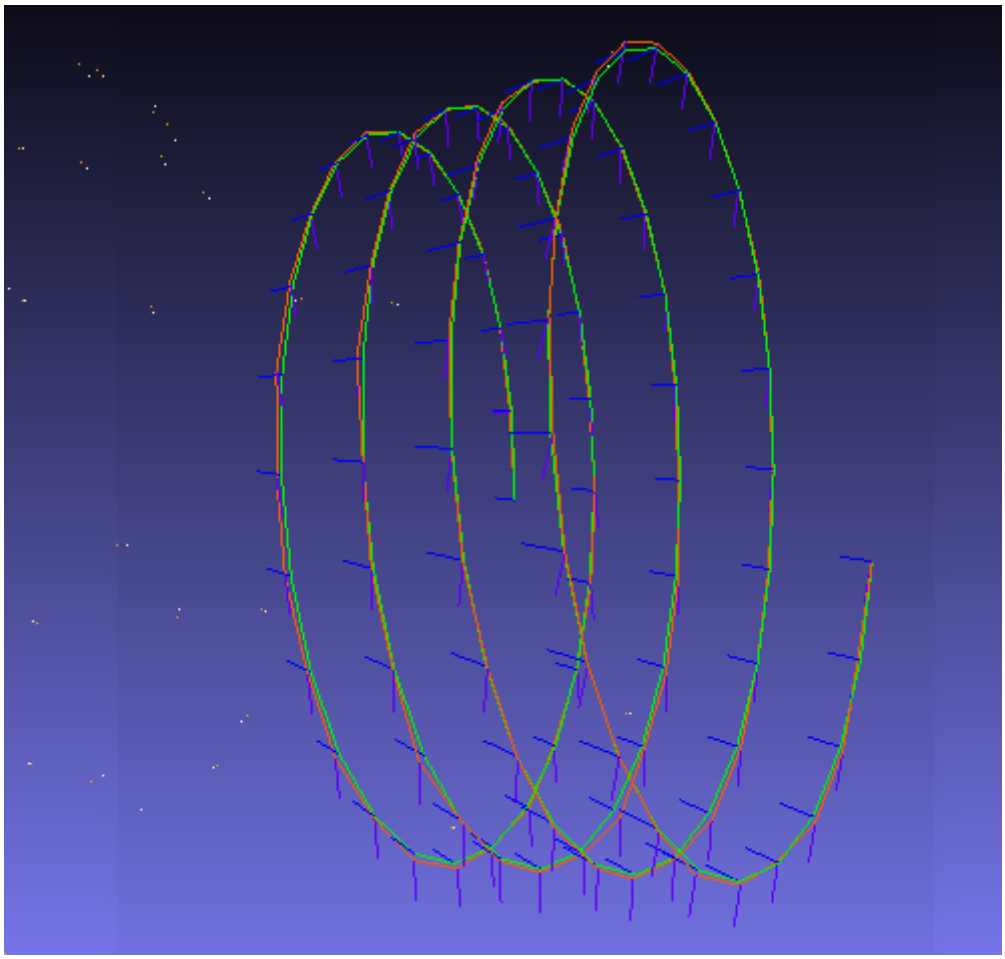



```
evo_ape tum frame_traj_est_SOLVEPNP_ITERATIVE.txt
frame_traj_gt_SOLVEPNP_ITERATIVE.txt  -va --plot --plot_mode xyz --save_results
SOLVEPNP_ITERATIVE_ape.zip
       max  0.434389
      mean  0.178372
    median  0.171207
       min  0.039869
      rmse  0.197632
       sse  3.749621
       std  0.085099
```

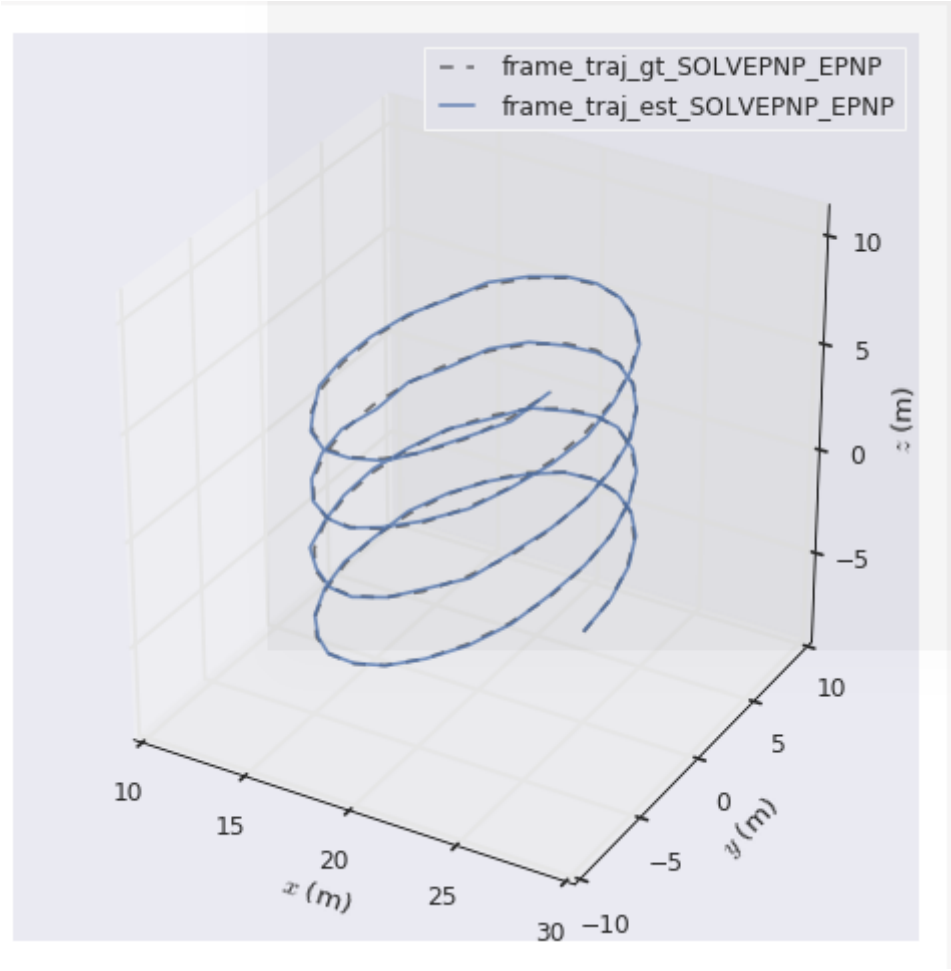
```
 evo_rpe tum frame_traj_est_SOLVEPNP_ITERATIVE.txt
frame_traj_gt_SOLVEPNP_ITERATIVE.txt  -va --plot --plot_mode xyz --save_results
SOLVEPNP_ITERATIVE_rpe.zip

       max  4.377182
      mean  2.601915
    median  2.644808
       min  0.074727
      rmse  2.779581
       sse  733.976471
       std  0.977806
```

```
evo_res SOLVEPNP_ITERATIVE_ape.zip -p --save_table SOLVEPNP_ITERATIVE_table.csv

                           max      mean    median         min      rmse  \
frame_traj_gt_SOL...  0.434389  0.178372  0.171207  0.0398691  0.197632

                           sse       std
frame_traj_gt_SOL...  3.74962  0.0850991
```

3.1. SOLVEPNP_EPNP



```
 evo_traj tum frame_traj_est_SOLVEPNP_EPNP.txt --
ref=frame_traj_gt_SOLVEPNP_EPNP.txt -p --plot_mode xyz  --align --correct_scale
```

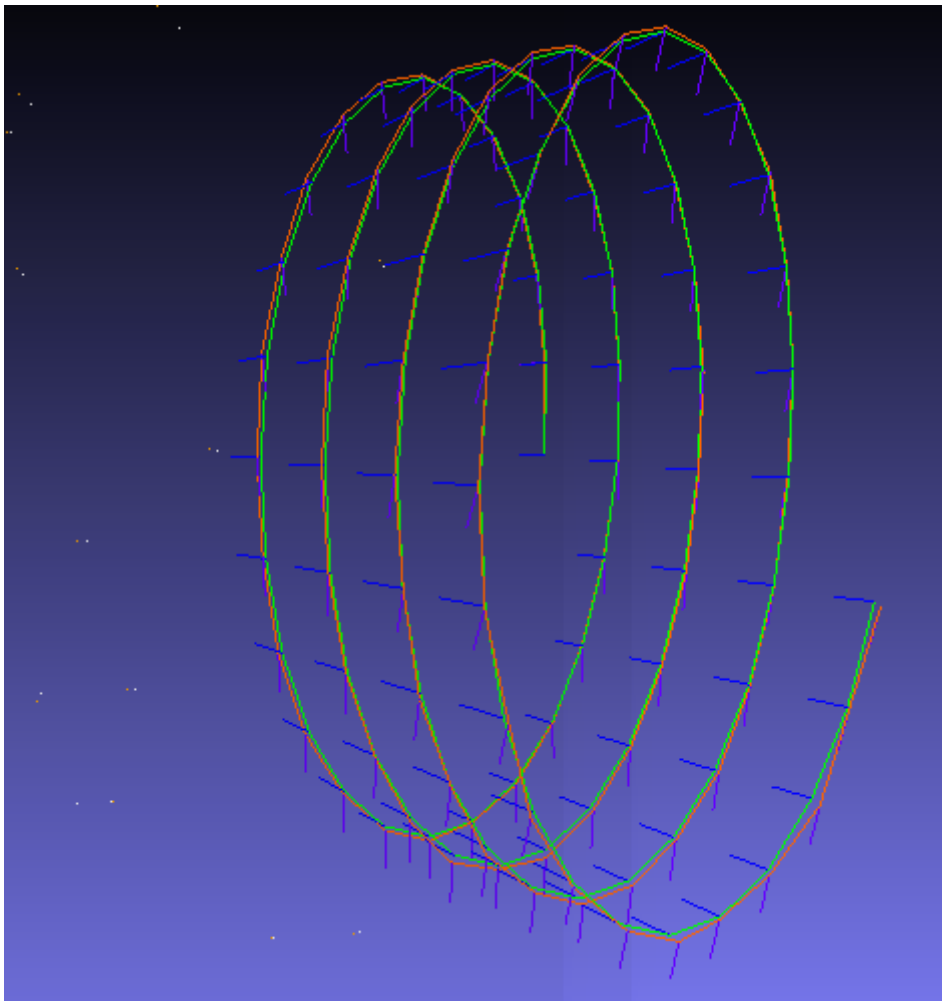



```
evo_ape tum frame_traj_est_SOLVEPNP_EPNP.txt frame_traj_gt_SOLVEPNP_EPNP.txt  -
va --plot --plot_mode xyz --save_results SOLVEPNP_EPNP_ape.zip
       max  0.242836
      mean  0.117471
    median  0.114078
       min  0.017015
      rmse  0.126450
       sse  1.534998
       std  0.046799
```

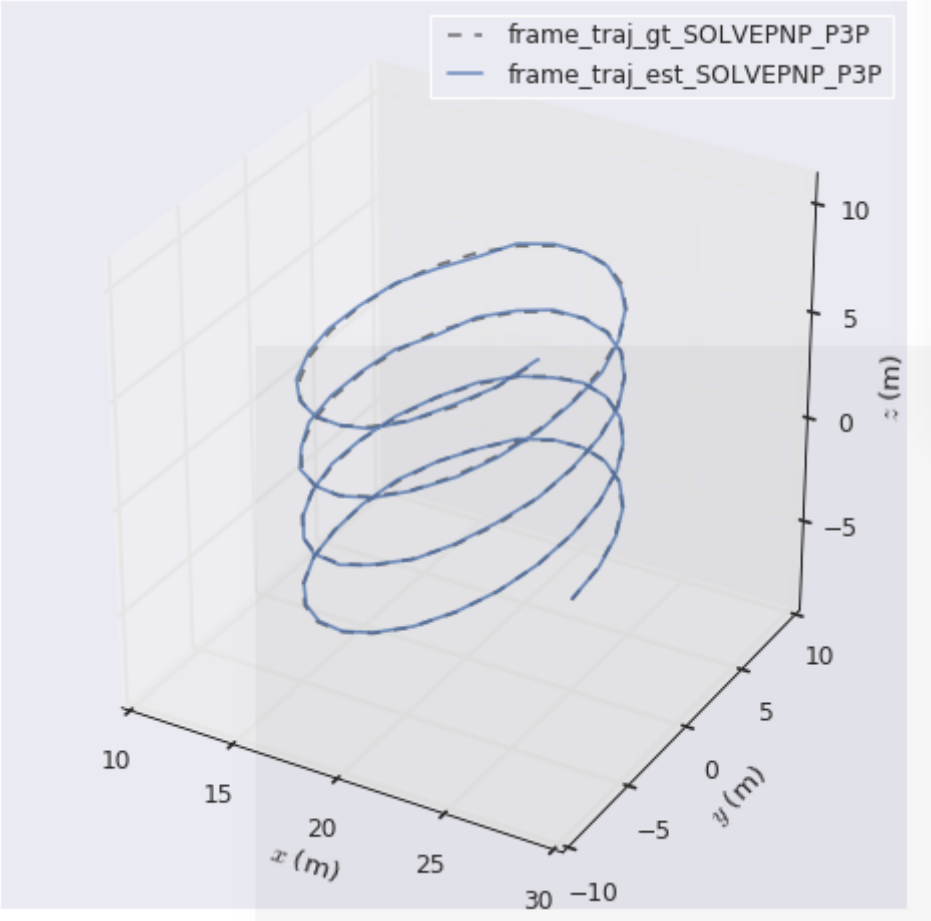
```
 evo_rpe tum frame_traj_est_SOLVEPNP_EPNP.txt frame_traj_gt_SOLVEPNP_EPNP.txt  -
va --plot --plot_mode xyz --save_results SOLVEPNP_EPNP_rpe.zip

       max  4.352881
      mean  2.587162
    median  2.637466
       min  0.074727
      rmse  2.763539
       sse  725.528841
       std  0.971461
```

```
evo_res SOLVEPNP_EPNP_ape.zip -p --save_table SOLVEPNP_EPNP_table.csv

                          max      mean    median        min     rmse    sse  \
frame_traj_gt_SOL...  0.242836  0.117471  0.114078  0.0170151  0.12645  1.535

                           std
frame_traj_gt_SOL...  0.0467992
```

3.2. SOLVEPNP_P3P



```
 evo_traj tum frame_traj_est_SOLVEPNP_P3P.txt --
ref=frame_traj_gt_SOLVEPNP_P3P.txt -p --plot_mode xyz  --align --correct_scale
```



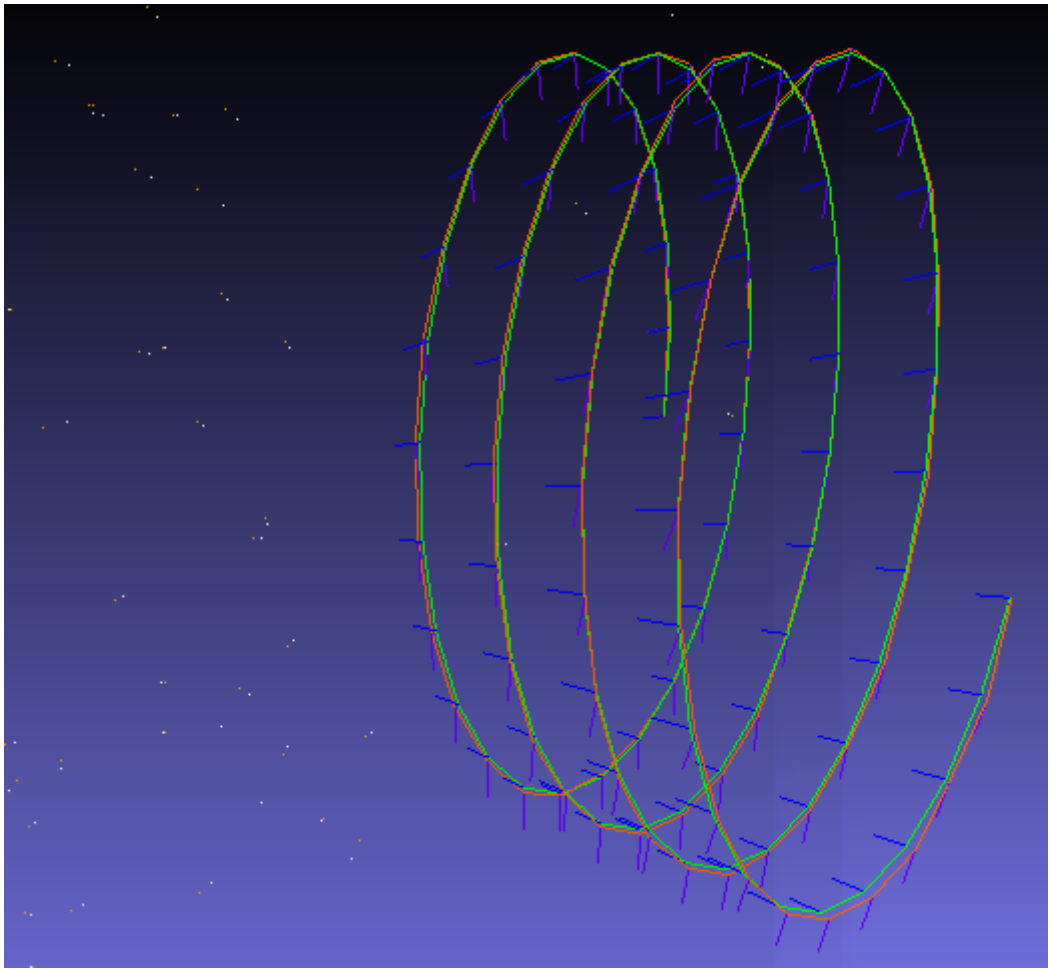

```
evo_ape tum frame_traj_est_SOLVEPNP_P3P.txt frame_traj_gt_SOLVEPNP_P3P.txt  -va
--plot --plot_mode xyz --save_results SOLVEPNP_P3P_ape.zip
       max  0.246748
      mean  0.116399
    median  0.108588
       min  0.040195
      rmse  0.124018
       sse  1.476530
       std  0.042799
```

```
 evo_rpe tum frame_traj_est_SOLVEPNP_P3P.txt frame_traj_gt_SOLVEPNP_P3P.txt  -va
--plot --plot_mode xyz --save_results SOLVEPNP_P3P_rpe.zip

       max  4.376081
      mean  2.589348
    median  2.609933
       min  0.031821
      rmse  2.764878
       sse  726.232326
       std  0.969448
```

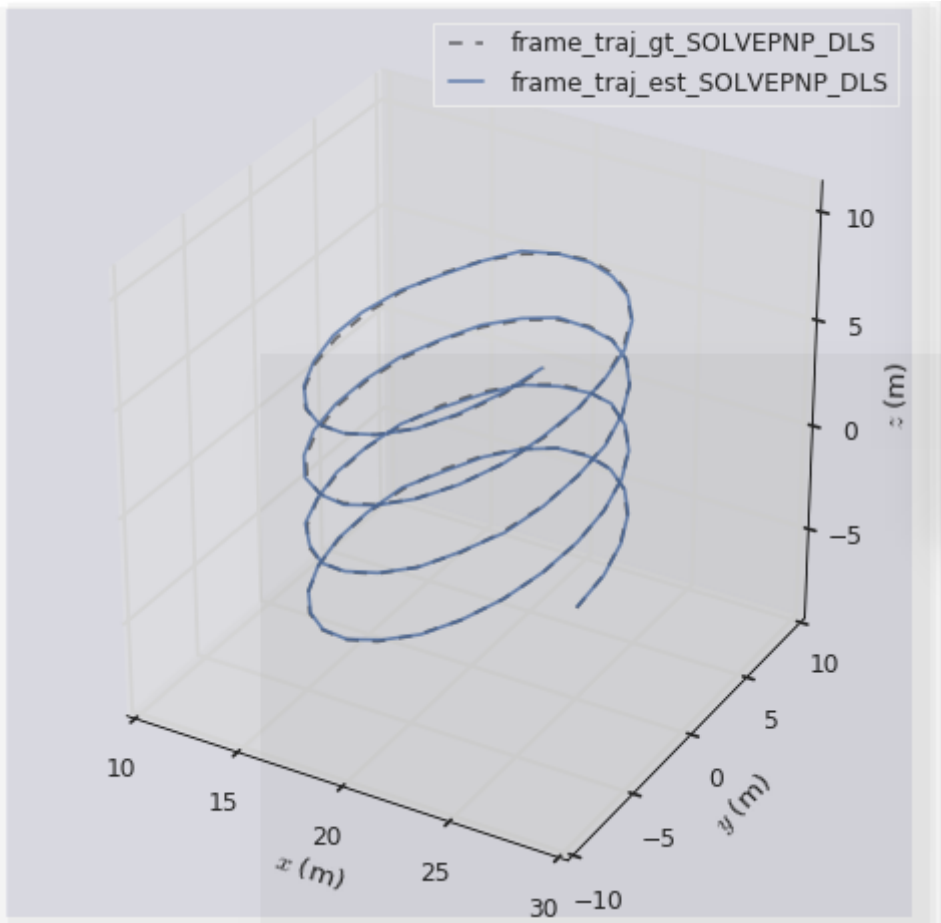
```
evo_res SOLVEPNP_P3P_ape.zip -p --save_table SOLVEPNP_P3P_table.csv

                          max      mean    median        min      rmse  \
frame_traj_gt_SOL...  0.246748  0.116399  0.108588  0.0401949  0.124018

                          sse        std
frame_traj_gt_SOL...  1.47653  0.0427988
```

```
0.246748
0.116399
0.108588
0.0401949
0.124018
1.47653
0.0427988
```

3.3. SOLVEPNP_DLS



```
 evo_traj tum frame_traj_est_SOLVEPNP_DLS.txt --
ref=frame_traj_gt_SOLVEPNP_DLS.txt -p --plot_mode xyz  --align --correct_scale
```

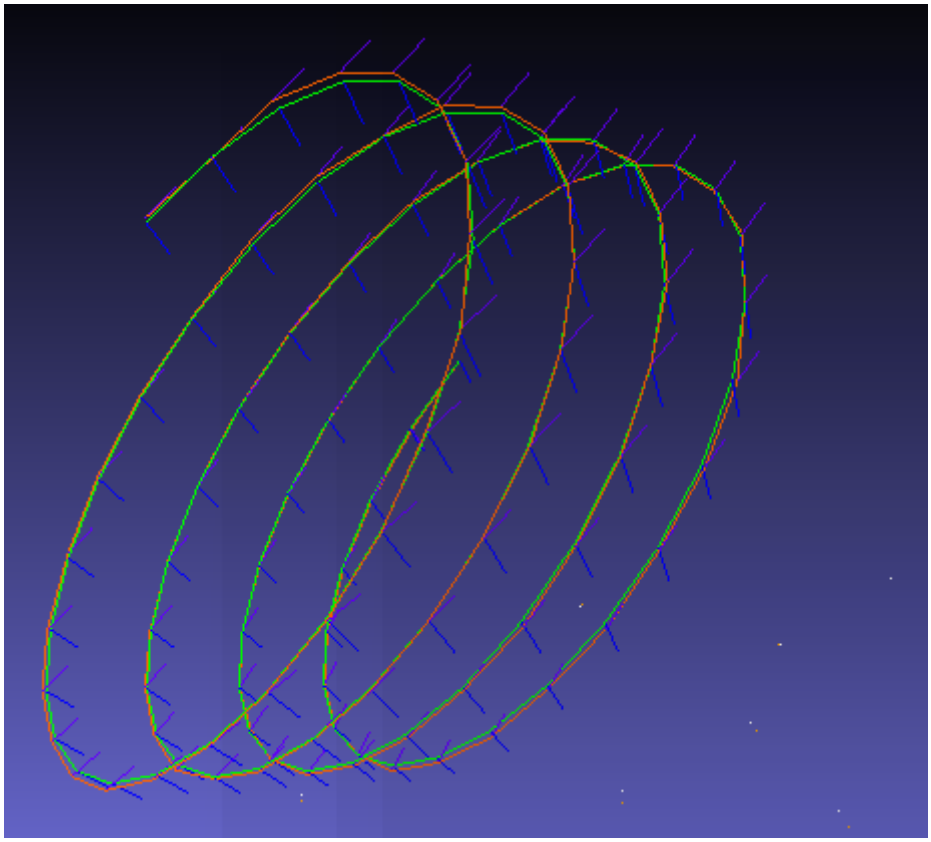



```
evo_ape tum frame_traj_est_SOLVEPNP_DLS.txt frame_traj_gt_SOLVEPNP_DLS.txt  -va
--plot --plot_mode xyz --save_results SOLVEPNP_DLS_ape.zip
       max  0.225975
      mean  0.113513
    median  0.106261
       min  0.035635
      rmse  0.122289
       sse  1.435645
       std  0.045492
```

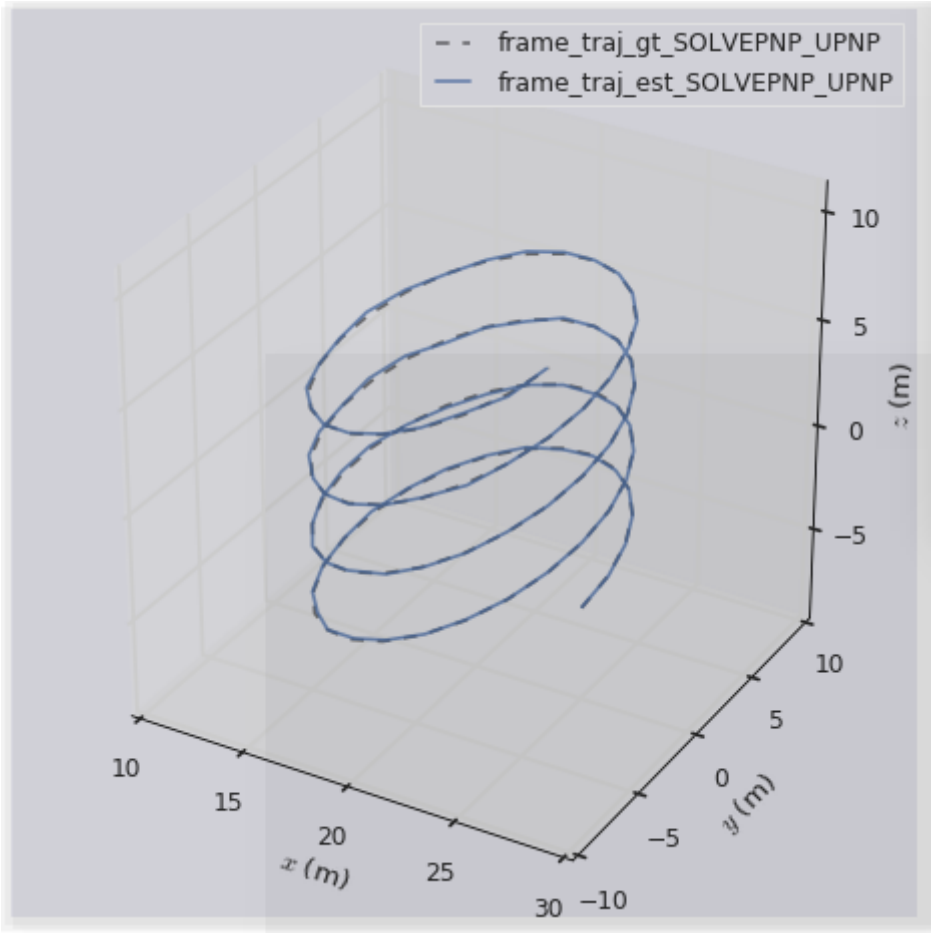
```
 evo_rpe tum frame_traj_est_SOLVEPNP_DLS.txt frame_traj_gt_SOLVEPNP_DLS.txt  -va
--plot --plot_mode xyz --save_results SOLVEPNP_DLS_rpe.zip

       max  4.333318
      mean  2.583120
    median  2.601981
       min  0.017241
      rmse  2.759503
       sse  723.411568
       std  0.970746
```

```
evo_res SOLVEPNP_DLS_ape.zip -p --save_table SOLVEPNP_DLS_table.csv

                           max      mean    median       min      rmse  \
frame_traj_gt_SOL...  0.225975  0.113513  0.106261  0.0356351  0.122289

                          sse       std
frame_traj_gt_SOL...  1.43565  0.0454917
```

3.4. SOLVEPNP_UPNP



```
 evo_traj tum frame_traj_est_SOLVEPNP_UPNP.txt --
ref=frame_traj_gt_SOLVEPNP_UPNP.txt -p --plot_mode xyz  --align --correct_scale
```

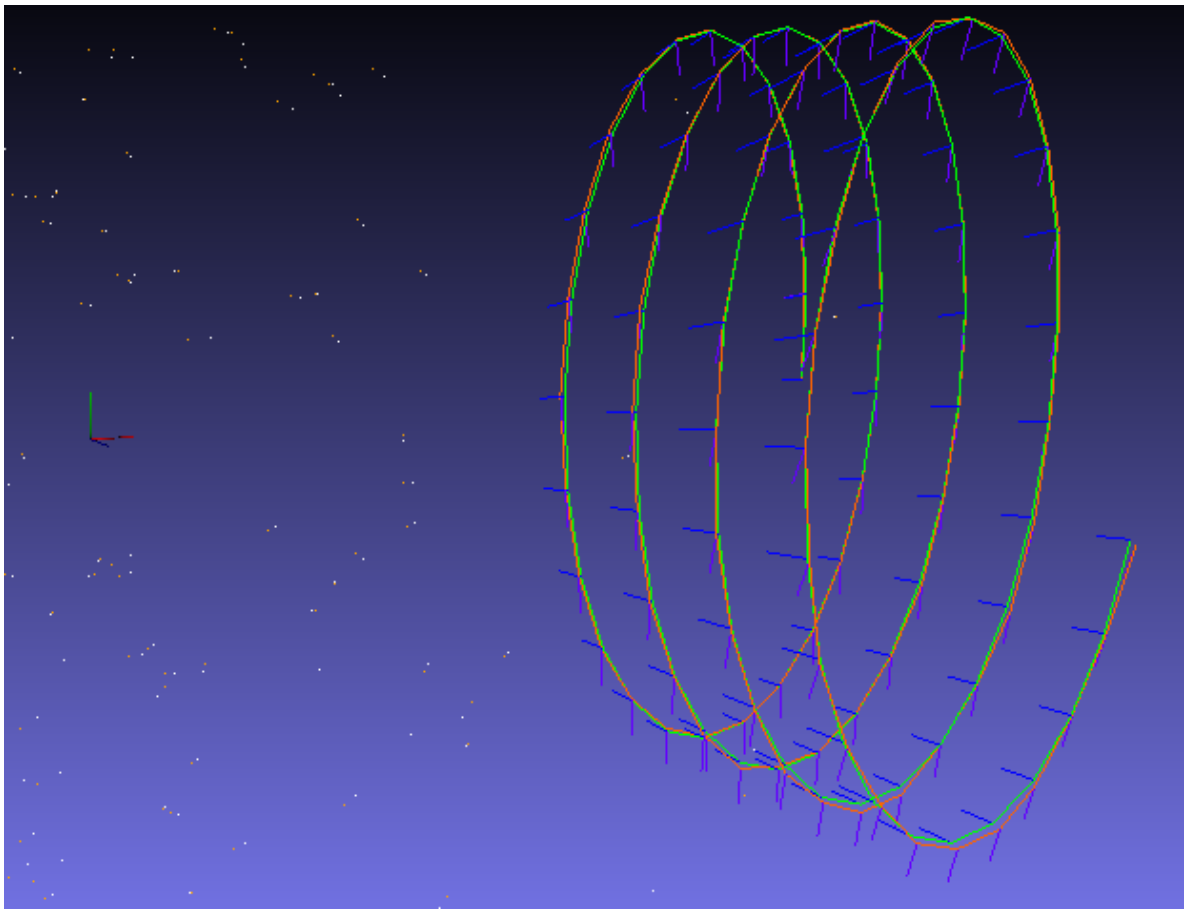



```
evo_ape tum frame_traj_est_SOLVEPNP_UPNP.txt frame_traj_gt_SOLVEPNP_UPNP.txt  -
va --plot --plot_mode xyz --save_results SOLVEPNP_UPNP_ape.zip
       max  0.218468
      mean  0.106990
    median  0.094463
       min  0.033494
      rmse  0.115861
       sse  1.288688
       std  0.044462
```

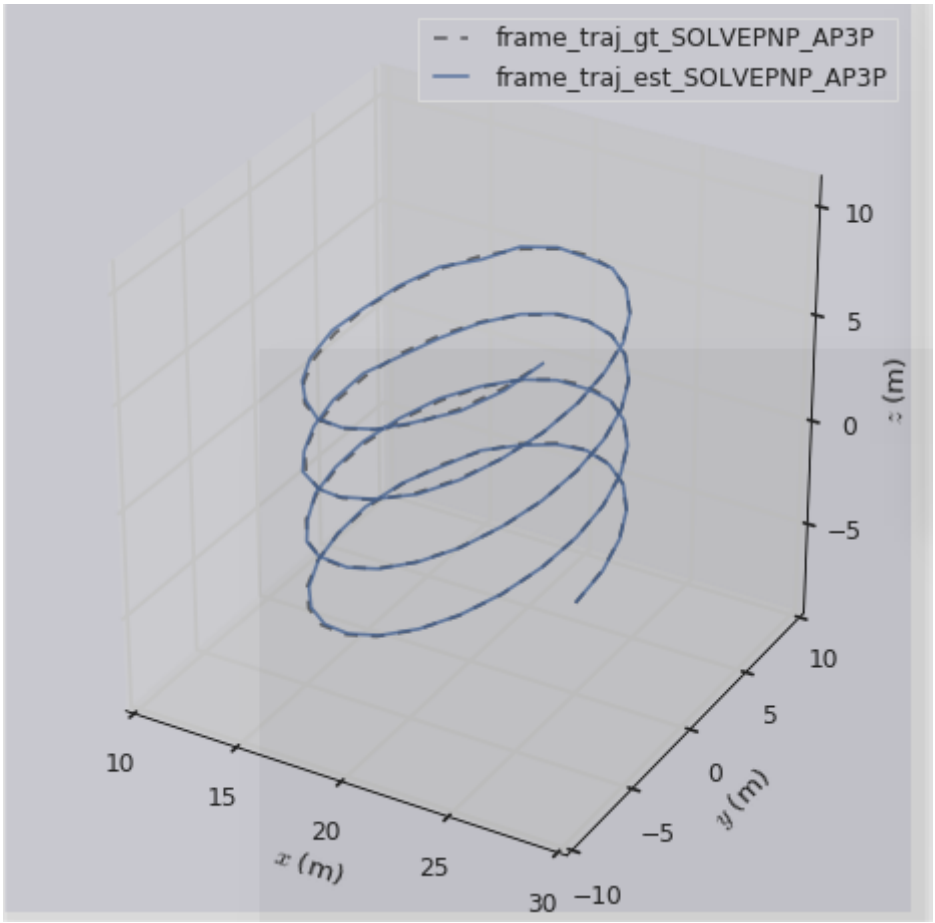
```
 evo_rpe tum frame_traj_est_SOLVEPNP_UPNP.txt frame_traj_gt_SOLVEPNP_UPNP.txt  -
va --plot --plot_mode xyz --save_results SOLVEPNP_UPNP_rpe.zip

       max  4.361522
      mean  2.585335
    median  2.631826
       min  0.016013
      rmse  2.760945
       sse  724.167897
       std  0.968950
```

```
evo_res SOLVEPNP_UPNP_ape.zip -p --save_table SOLVEPNP_UPNP_table.csv

                          max      mean      median         min      rmse  \
frame_traj_gt_SOL...  0.218468  0.10699  0.0944627  0.0334936  0.115861

                          sse        std
frame_traj_gt_SOL...  1.28869  0.0444622
```

3.5. SOLVEPNP_AP3P



```
 evo_traj tum frame_traj_est_SOLVEPNP_AP3P.txt --
ref=frame_traj_gt_SOLVEPNP_AP3P.txt -p --plot_mode xyz  --align --correct_scale
```



```
evo_ape tum frame_traj_est_SOLVEPNP_AP3P.txt frame_traj_gt_SOLVEPNP_AP3P.txt  -
va --plot --plot_mode xyz --save_results SOLVEPNP_AP3P_ape.zip
       max  0.236128
      mean  0.105609
    median  0.097849
       min  0.034734
      rmse  0.116205
       sse  1.296356
       std  0.048481
```

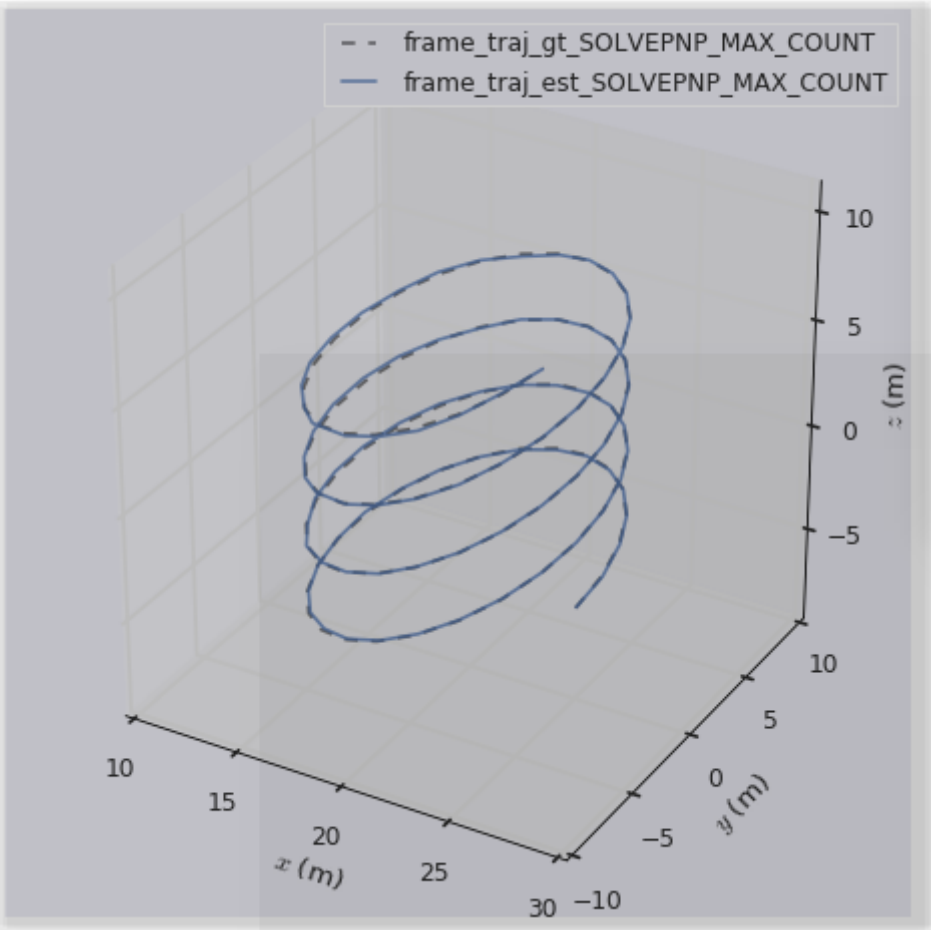
```
 evo_rpe tum frame_traj_est_SOLVEPNP_AP3P.txt frame_traj_gt_SOLVEPNP_AP3P.txt  -
va --plot --plot_mode xyz --save_results SOLVEPNP_AP3P_rpe.zip

       max  4.316022
      mean  2.581949
    median  2.619087
       min  0.016013
      rmse  2.758708
       sse  722.994698
       std  0.971603
```

```
evo_res SOLVEPNP_AP3P_ape.zip -p --save_table SOLVEPNP_AP3P_table.csv

                          max      mean     median       min      rmse  \
frame_traj_gt_SOL...  0.236128  0.105609  0.0978492  0.034734  0.116205

                         sse        std
frame_traj_gt_SOL...  1.29636  0.0484811
```

3.6. SOLVEPNP_MAX_COUNT

```
  ![image-20200301134951151](/home/robot/tmp/github/hw/hw3/result.assets/image-
20200301134951151.png)
```

```
 evo_traj tum frame_traj_est_SOLVEPNP_MAX_COUNT.txt --
ref=frame_traj_gt_SOLVEPNP_MAX_COUNT.txt -p --plot_mode xyz  --align --
correct_scale
```




```
evo_ape tum frame_traj_est_SOLVEPNP_MAX_COUNT.txt
frame_traj_gt_SOLVEPNP_MAX_COUNT.txt  -va --plot --plot_mode xyz --save_results
SOLVEPNP_MAX_COUNT_ape.zip
       max  0.262875
      mean  0.090947
    median  0.078453
       min  0.025371
      rmse  0.101519
       sse  0.989395
       std  0.045109
```

```
 evo_rpe tum frame_traj_est_SOLVEPNP_MAX_COUNT.txt
frame_traj_gt_SOLVEPNP_MAX_COUNT.txt  -va --plot --plot_mode xyz --save_results
SOLVEPNP_MAX_COUNT_rpe.zip

       max  4.313694
      mean  2.582501
    median  2.616074
       min  0.016013
      rmse  2.758629
       sse  722.953111
       std  0.969907
```

```
evo_res SOLVEPNP_MAX_COUNT_ape.zip -p --save_table SOLVEPNP_MAX_COUNT_table.csv

                           max       mean     median        min      rmse  \
frame_traj_gt_SOL...  0.262875  0.0909472  0.0784525  0.0253707  0.101519

                           sse        std
frame_traj_gt_SOL...  0.989395  0.0451088
```

3.7 结果分析

```
method: 0~6 依次代表以下方法：
SOLVEPNP_ITERATIVE
SOLVEPNP_EPNP
SOLVEPNP_P3P
SOLVEPNP_DLS
SOLVEPNP_UPNP
SOLVEPNP_AP3P
SOLVEPNP_MAX_COUNT
```

evo_ape(计算绝对位姿误差)

param	**0**	**1**	**2**	**3**	**4**	**5**	**6**
max	0.434389	0.242836	0.246748	0.225975	0.218468	0.236128	0.262875
mean	0.178372	0.117471	0.116399	0.113513	0.10699	0.105609	**0.090947**
median	0.171207	0.114078	0.108588	0.106261	0.094463	0.097849	0.078453
min	0.039869	0.017015	0.040195	0.035635	0.033494	0.034734	0.025371
rmse	0.197632	0.12645	0.124018	0.122289	0.115861	0.116205	0.101519
sse	3.749621	1.534998	1.47653	1.435645	1.288688	1.296356	**0.989395**
std	0.085099	0.046799	0.042799	0.045492	**0.044462**	0.048481	0.045109

evo_rpe(计算相对位姿误差)

param	**0**	**1**	**2**	**3**	**4**	**5**	**6**
max	4.377182	4.352881	4.376081	4.333318	4.361522	4.316022	4.313694
mean	2.601915	2.587162	2.589348	2.58312	2.585335	2.581949	2.582501
median	2.644808	2.637466	2.609933	2.601981	2.631826	2.619087	**2.616074**
min	0.074727	0.074727	0.031821	0.017241	0.016013	0.016013	0.016013
rmse	2.779581	2.763539	2.764878	2.759503	2.760945	2.758708	**2.758629**
sse	733.976471	725.528841	726.232326	723.411568	724.167897	722.994698	722.953111
std	0.977806	0.971461	0.969448	0.970746	**0.96895**	0.971603	0.969907

evo_res(结果比较)

param	0	1	2	3	4	5	6
max	0.434389	0.242836	0.246748	0.225975	0.218468	0.236128	0.262875
mean	0.178372	0.117471	0.116399	0.113513	0.10699	0.105609	**0.0909472**
median	0.171207	0.114078	0.108588	0.106261	0.0944627	0.0978492	0.0784525
min	0.0398691	0.0170151	0.0401949	0.0356351	0.0334936	0.034734	0.0253707
rmse	0.197632	0.12645	0.124018	0.122289	0.115861	0.116205	**0.101519**
sse Std	3.74962	1.535	1.47653	1.43565	1.28869	1.29636	0.989395
	0.0850991	0.0467992	0.0427988	0.0454917	**0.0444622**	0.0484811	0.0451088

整个轨迹估计时间消耗（ms）, 基本都在4 sec左右

param	0	1	2	3	4	5	6
time	4087322	4007796	3819130	3435533	3819258	3712575	3041394

综合比较， SOLVEPNP_MAX_COUNT 方法估计的精度更加准确可靠，整体方法比对相差不大.

4. 注意点

1. solvePnPRansac 求得的R.t 为 相机的世界坐标在相机坐标系下的表示。