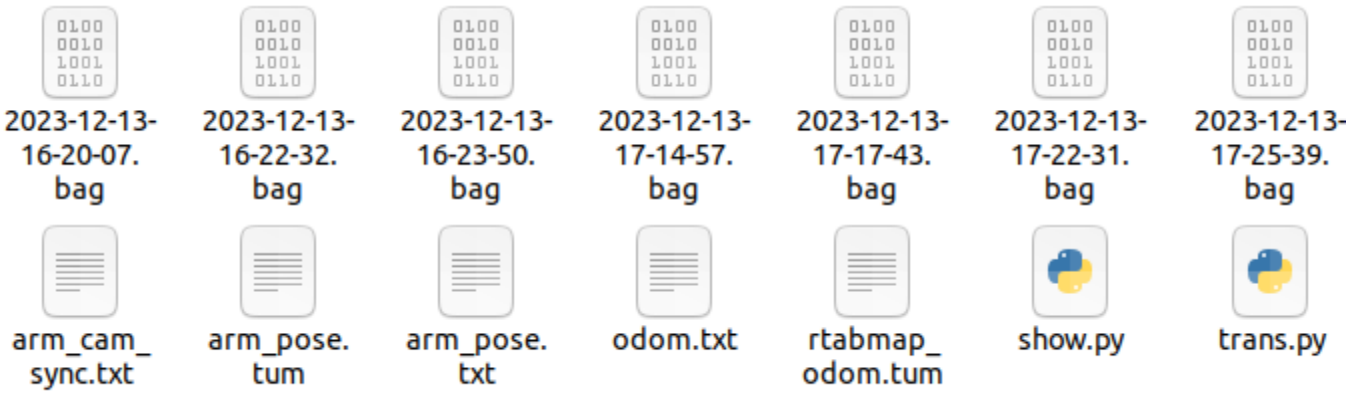
slam轨迹和机械臂轨迹协同标定

实验设备：
jaka5，realsense L515

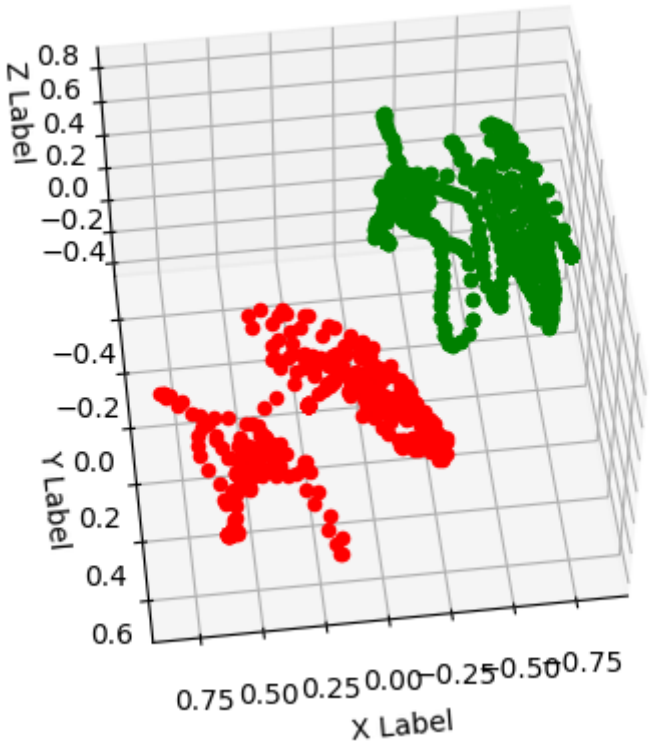
使用方法

```
cd ~/catkin_ws
source ./devel/setup.sh
# 启动jaka的基本底层驱动，启动后需要等待几秒，等控制柜的灯为绿色
roslaunch jaka_ros_driver start.launch
#发布机器人基坐标系下TCP位姿，10HZ发布
roslaunch handeye-calib arm2pose.launch


# 启动RTABMAP
# 略

# 记录数据集
rosbag record /rtabmap/odom /arm_pose

# evo库轨迹可视化与对齐
# https://github.com/MichaelGrupp/evo
# https://zhuanlan.zhihu.com/p/672731463
evo_traj bag 2023-12-13-16-23-50.bag  /rtabmap/odom --ref /arm_pose  -p --
plot_mode=xyz --align --t_max_diff 500 --save_as_tum


evo_traj tum rtabmap_odom.tum --ref arm_pose.tum  -p --plot_mode=xyz  --
align  --t_max_diff 500


#或者 处理数据集
python3 pc_ws/src/application/traj_match/scripts/trans.py
python3 pc_ws/src/application/traj_match/scripts/show.py

#保存的txt位姿为tum 格式，x y z qx qy qz qw
```

录制的数据集:

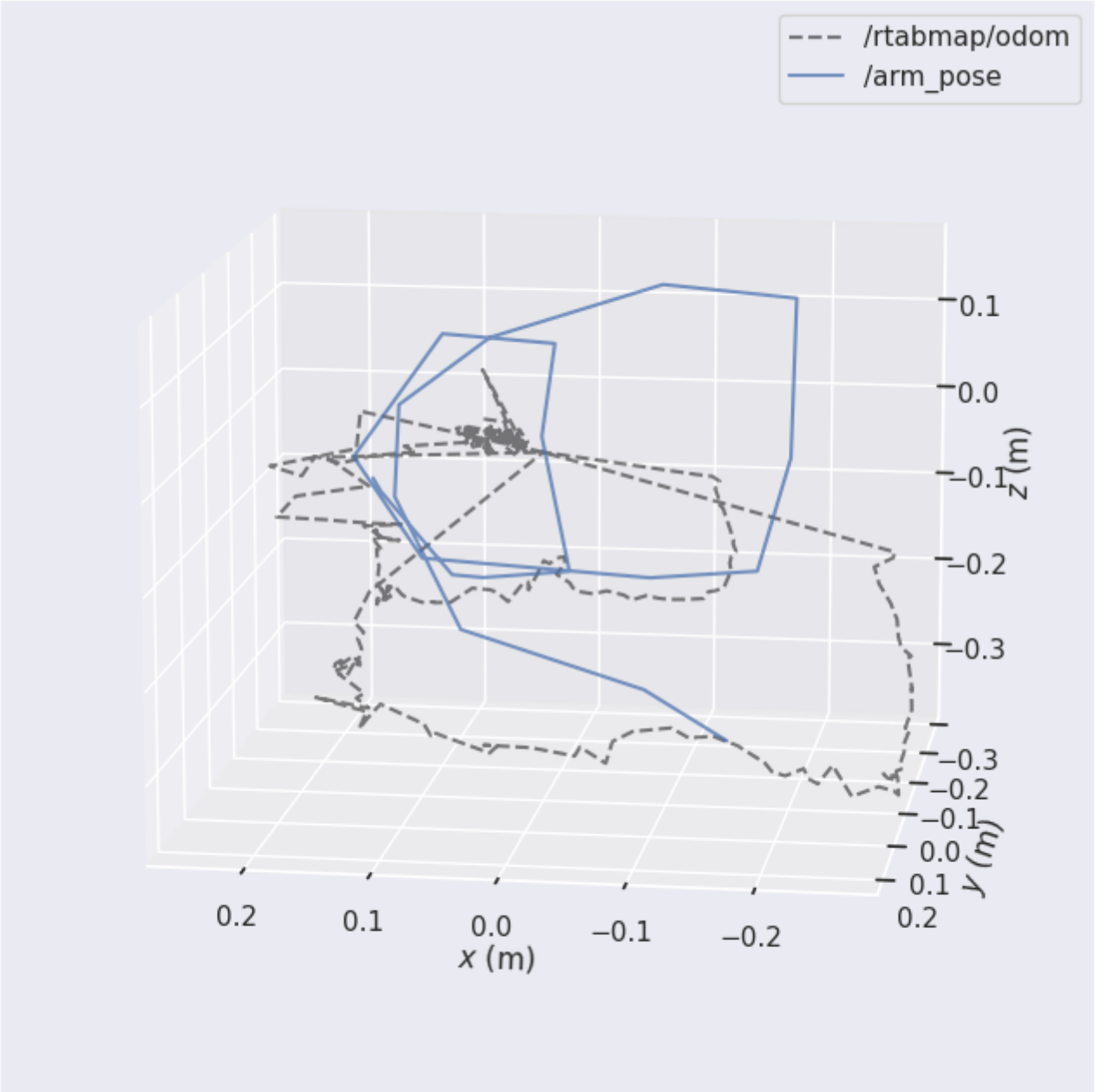


rosbag数据集处理和可视化，红色代表slam里程计，绿色代表机械臂获取的位姿

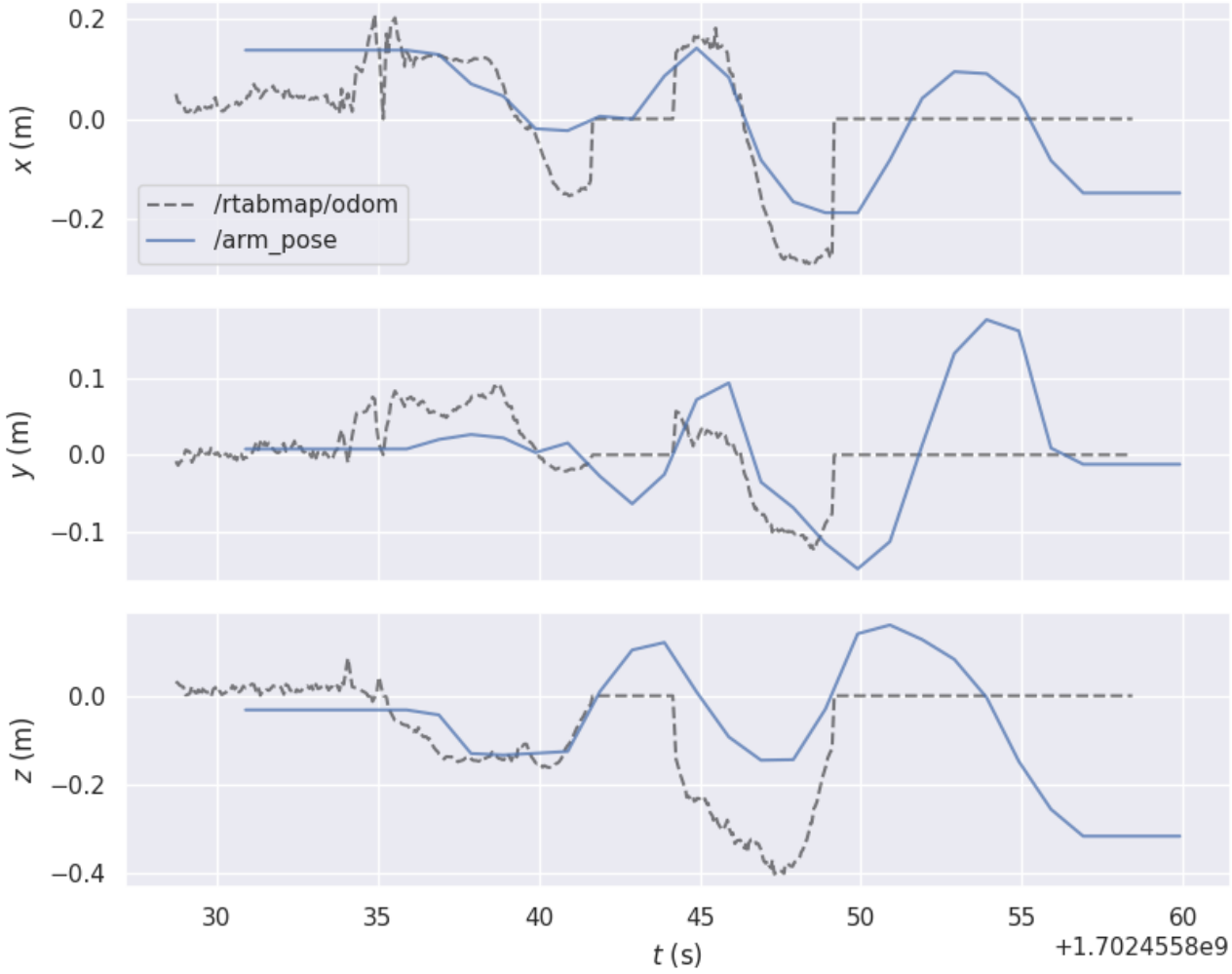


样例1

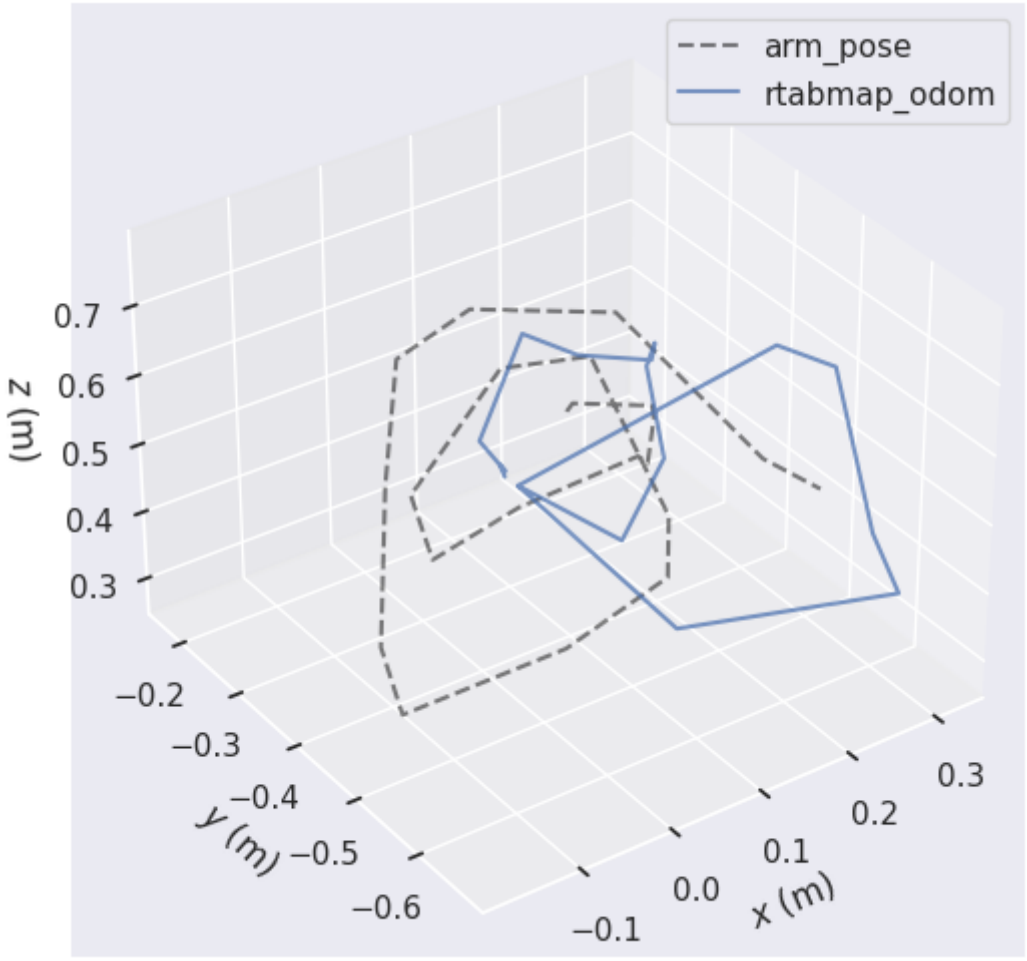
xyz轨迹图


/rtabmap/odom
/arm_pose
0.1
0.0
−0.1
−0.2
−0.3
z (m)
−0.3
−0.2
−0.1
0.0
0.1
y (m)
0.2
0.1
0.0
−0.1
−0.2
0.2
x (m)

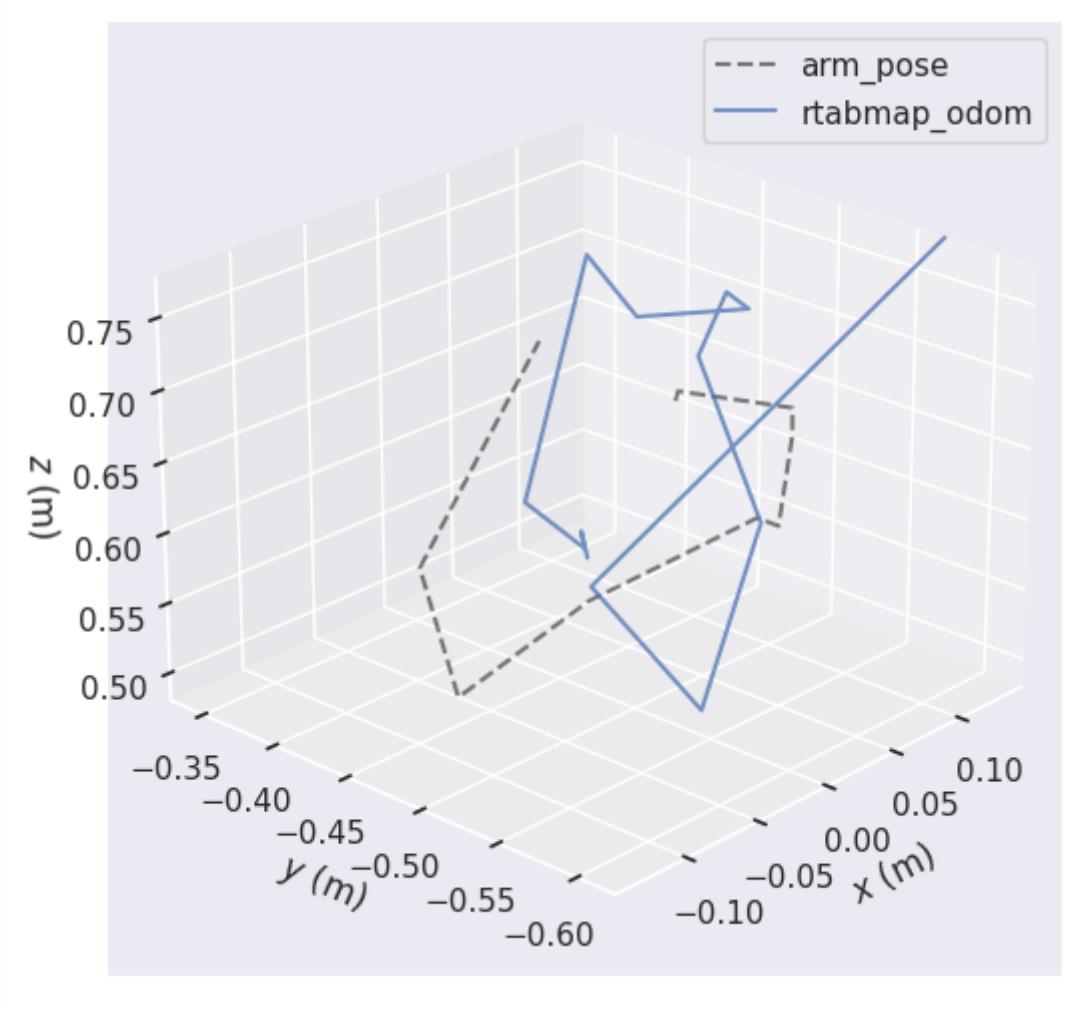
xyz分表显示，slam里程计精度不足，无法很好跟随机械臂关节位姿

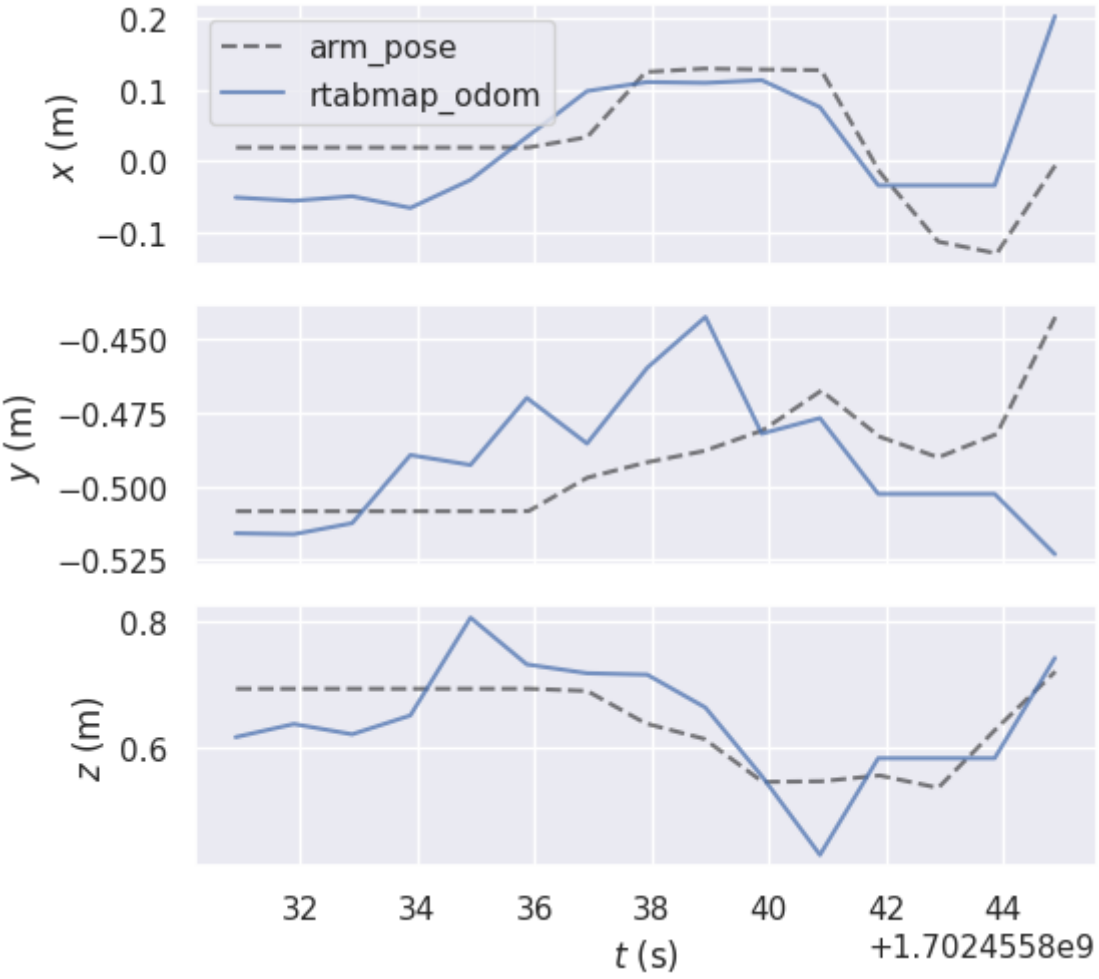


样例2


arm_pose
rtabmap_odom
z (m)
0.7
0.6
0.5
0.4
0.3
−0.2
−0.3
−0.4
−0.5
−0.6
y (m)
−0.1
0.0
0.1
0.2
0.3
x (m)

对上图处理异常值后


arm_pose
rtabmap_odom
z (m)
0.75
0.70
0.65
0.60
0.55
0.50
−0.35
−0.40
−0.45
−0.50
−0.55
−0.60
y (m)
0.10
0.05
0.00
−0.05
−0.10
x (m)



视觉slam定位精度

结论：通常情况下，视觉SLAM的精度可能不满足slam和机械臂轨迹融合标定问题

均方根误差(**RMSE**:Root Mean Square Error): 是观测值与真值偏差的平方和与观测次数m比值的平方根。 是用来衡量观测值同真值之间的偏差。表达式为：

$$RMSE(X,h) = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(h(x^{(i)}) - y^{(i)})^2}$$

标准差（**SD**: Standard Deviation ）: 是方差的算数平方根.是用来衡量一组数自身的离散程度
SSE(和方差、误差平方和)：The sum of squares due to error ,该统计 参数计算的是拟合 数据和原始数据对应点的误差的平方和
STD(标准差） Standard Deviation:一种量度数据分布的分散程度之标准，用以衡量数据值偏离算术平均值的程度。标准偏差越小，这些值偏离平均值就越少

以专注于定位且可复现性最佳的视觉SLAM，vins作为误差评估，比rtabmap精度更高,,更具代表性

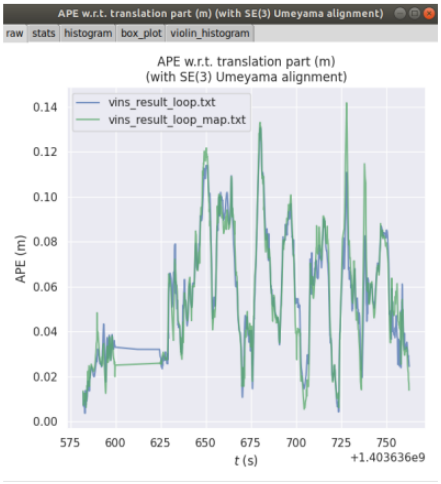
精度分析

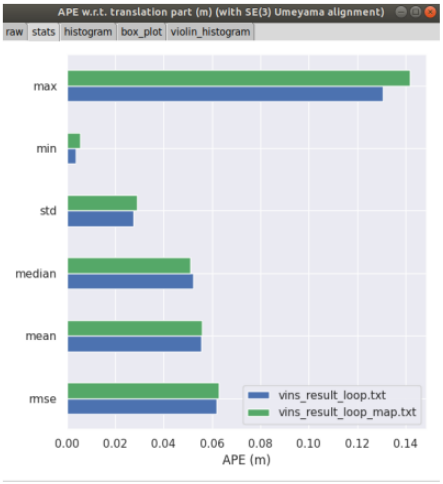
基于数据集Euroc MH_01_easy.bag数据集进行测试
未启动回环
最低误差为3cm，均值14厘米

```
#未启动回环
APE w.r.t. translation part (m)
(with SE(3) Umeyama alignment)

       max      0.349640
      mean      0.144082
    median      0.140714
       min      0.034372
      rmse      0.154602
       sse      43.429475
       std      0.056053
```

启动回环

```
#未启动回环
APE w.r.t. translation part (m)
(with SE(3) Umeyama alignment)

       max      0.141669
      mean      0.055870
    median      0.051059
       min      0.005496
      rmse      0.062941
       sse      4.163599
       std      0.028984
```





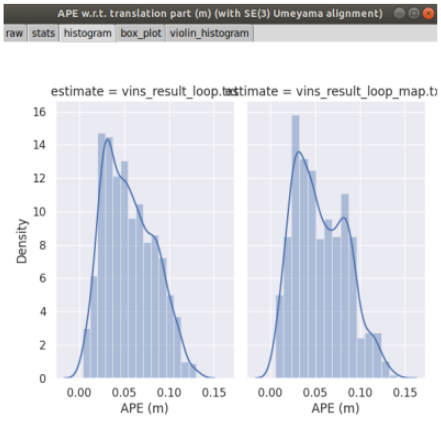


TABLE I

RMSE [43] IN EUROC DATASETS IN METERS

论文中轨迹误差数据

Sequence	OKVIS	VINS	VINS_loop
MH_01_easy	0.33	0.15	**0.12**
MH_02_easy	0.37	0.15	**0.12**
MH_03_medium	0.25	0.22	**0.13**
MH_04_difficult	0.27	0.32	**0.18**
MH_05_difficult	0.39	0.30	**0.21**
V1_01_easy	0.094	0.079	**0.068**
V1_02_medium	0.14	0.11	**0.084**
V1_03_difficult	0.21	**0.18**	0.19
V2_01_easy	0.090	**0.080**	0.081
V2_02_medium	0.17	0.16	**0.16**
V2_03_difficult	0.23	0.27	**0.22**