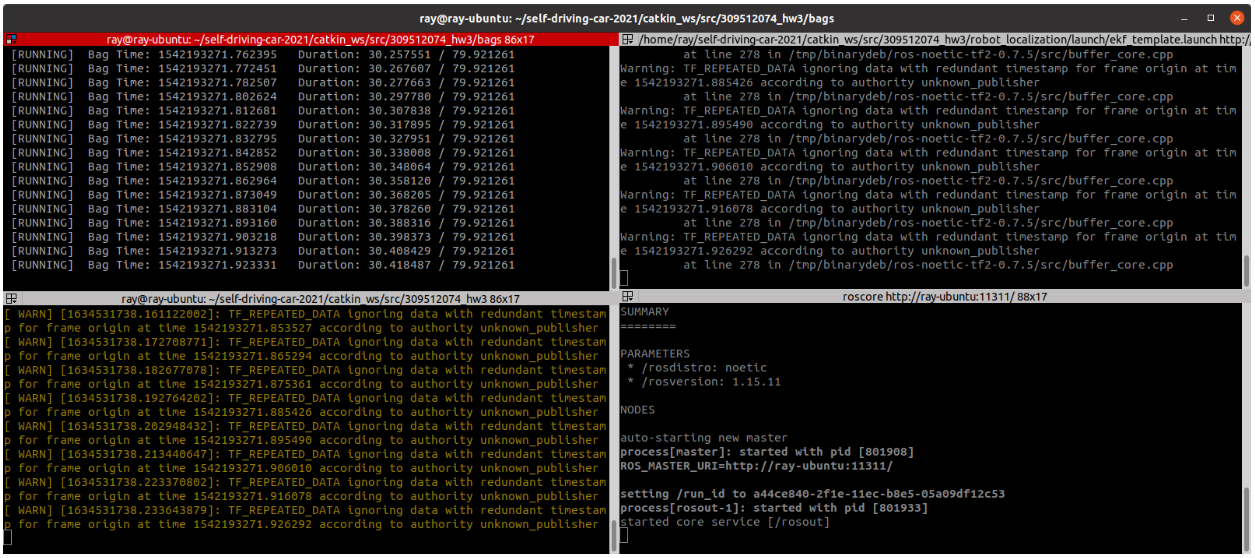
HW3

309512074 電控碩一 黃柏叡



ray@ray-ubuntu: ~/self-driving-car-2021/catkin_ws/src/309512074_hw3/bags

ray@ray-ubuntu: ~/self-driving-car-2021/catkin_ws/src/309512074_hw3/bags 86x17

```
 [RUNNING]  Bag Time: 1542193271.762395   Duration: 30.257551 / 79.921261
 [RUNNING]  Bag Time: 1542193271.772451   Duration: 30.267607 / 79.921261
 [RUNNING]  Bag Time: 1542193271.782507   Duration: 30.277663 / 79.921261
 [RUNNING]  Bag Time: 1542193271.802624   Duration: 30.297780 / 79.921261
 [RUNNING]  Bag Time: 1542193271.812681   Duration: 30.307838 / 79.921261
 [RUNNING]  Bag Time: 1542193271.822739   Duration: 30.317895 / 79.921261
 [RUNNING]  Bag Time: 1542193271.832795   Duration: 30.327951 / 79.921261
 [RUNNING]  Bag Time: 1542193271.842852   Duration: 30.338008 / 79.921261
 [RUNNING]  Bag Time: 1542193271.852908   Duration: 30.348064 / 79.921261
 [RUNNING]  Bag Time: 1542193271.862964   Duration: 30.358120 / 79.921261
 [RUNNING]  Bag Time: 1542193271.873049   Duration: 30.368205 / 79.921261
 [RUNNING]  Bag Time: 1542193271.883104   Duration: 30.378260 / 79.921261
 [RUNNING]  Bag Time: 1542193271.893160   Duration: 30.388316 / 79.921261
 [RUNNING]  Bag Time: 1542193271.903218   Duration: 30.398373 / 79.921261
 [RUNNING]  Bag Time: 1542193271.913273   Duration: 30.408429 / 79.921261
 [RUNNING]  Bag Time: 1542193271.923331   Duration: 30.418487 / 79.921261
```

/home/ray/self-driving-car-2021/catkin_ws/src/309512074_hw3/robot_localization/launch/ekf_template.launch http:/

```
         at line 278 in /tmp/binarydeb/ros-noetic-tf2-0.7.5/src/buffer_core.cpp
Warning: TF_REPEATED_DATA ignoring data with redundant timestamp for frame origin at tim
e 1542193271.885426 according to authority unknown_publisher
         at line 278 in /tmp/binarydeb/ros-noetic-tf2-0.7.5/src/buffer_core.cpp
Warning: TF_REPEATED_DATA ignoring data with redundant timestamp for frame origin at tim
e 1542193271.895490 according to authority unknown_publisher
         at line 278 in /tmp/binarydeb/ros-noetic-tf2-0.7.5/src/buffer_core.cpp
Warning: TF_REPEATED_DATA ignoring data with redundant timestamp for frame origin at tim
e 1542193271.906010 according to authority unknown_publisher
         at line 278 in /tmp/binarydeb/ros-noetic-tf2-0.7.5/src/buffer_core.cpp
Warning: TF_REPEATED_DATA ignoring data with redundant timestamp for frame origin at tim
e 1542193271.916078 according to authority unknown_publisher
         at line 278 in /tmp/binarydeb/ros-noetic-tf2-0.7.5/src/buffer_core.cpp
Warning: TF_REPEATED_DATA ignoring data with redundant timestamp for frame origin at tim
e 1542193271.926292 according to authority unknown_publisher
         at line 278 in /tmp/binarydeb/ros-noetic-tf2-0.7.5/src/buffer_core.cpp
```

ray@ray-ubuntu: ~/self-driving-car-2021/catkin_ws/src/309512074_hw3 86x17

```
[ WARN] [1634531738.161122002]: TF_REPEATED_DATA ignoring data with redundant timestam
p for frame origin at time 1542193271.853527 according to authority unknown_publisher
[ WARN] [1634531738.172708771]: TF_REPEATED_DATA ignoring data with redundant timestam
p for frame origin at time 1542193271.865294 according to authority unknown_publisher
[ WARN] [1634531738.182677078]: TF_REPEATED_DATA ignoring data with redundant timestam
p for frame origin at time 1542193271.875361 according to authority unknown_publisher
[ WARN] [1634531738.192764202]: TF_REPEATED_DATA ignoring data with redundant timestam
p for frame origin at time 1542193271.885426 according to authority unknown_publisher
[ WARN] [1634531738.202948432]: TF_REPEATED_DATA ignoring data with redundant timestam
p for frame origin at time 1542193271.895490 according to authority unknown_publisher
[ WARN] [1634531738.213440647]: TF_REPEATED_DATA ignoring data with redundant timestam
p for frame origin at time 1542193271.906010 according to authority unknown_publisher
[ WARN] [1634531738.223370802]: TF_REPEATED_DATA ignoring data with redundant timestam
p for frame origin at time 1542193271.916078 according to authority unknown_publisher
[ WARN] [1634531738.233643879]: TF_REPEATED_DATA ignoring data with redundant timestam
p for frame origin at time 1542193271.926292 according to authority unknown_publisher
```

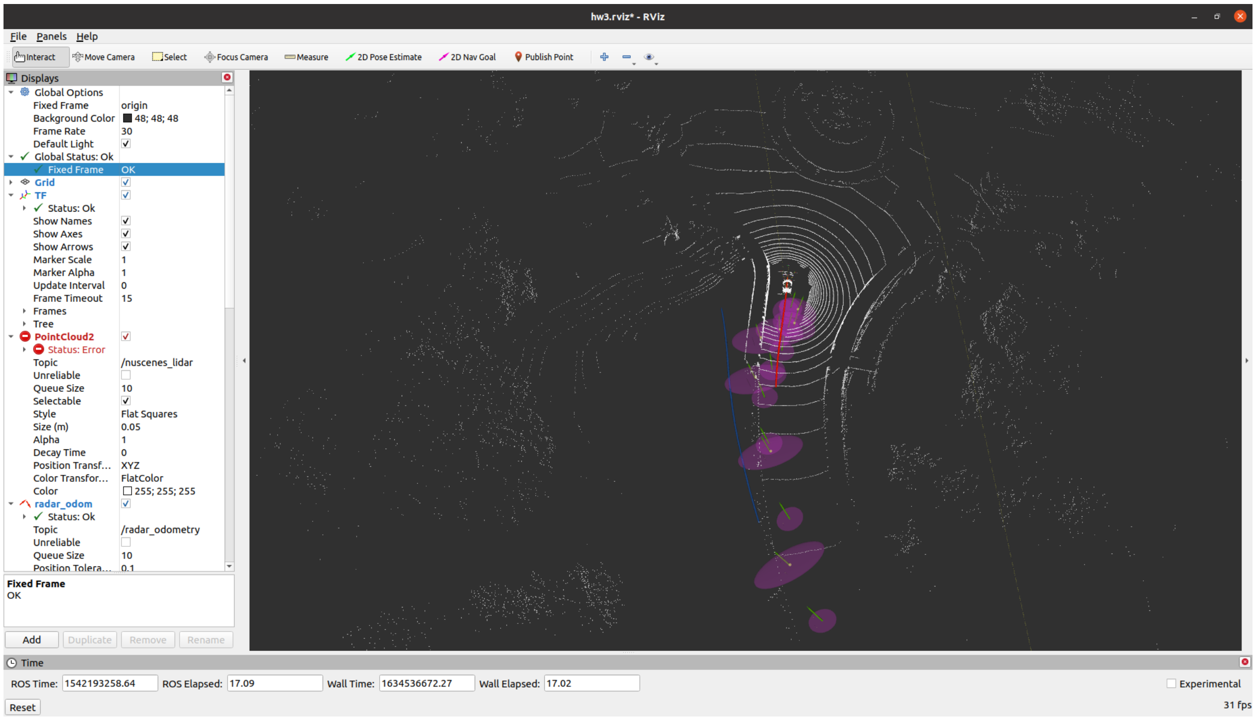
roscore http://ray-ubuntu:11311/ 88x17

```
SUMMARY
========

PARAMETERS
 * /rosdistro: noetic
 * /rosversion: 1.15.11

NODES

auto-starting new master
process[master]: started with pid [801908]
ROS_MASTER_URI=http://ray-ubuntu:11311/

setting /run_id to a44ce840-2f1e-11ec-b8e5-05a09df12c53
process[rosout-1]: started with pid [801933]
started core service [/rosout]
```

EKF Result

RED arrows are ground truth odometry, GREEN arrows are EKF result, BLUE arrows are radar odometry, PURPLE ecllipse represents covariance.

- Screenshot of the result using GPS in EKF

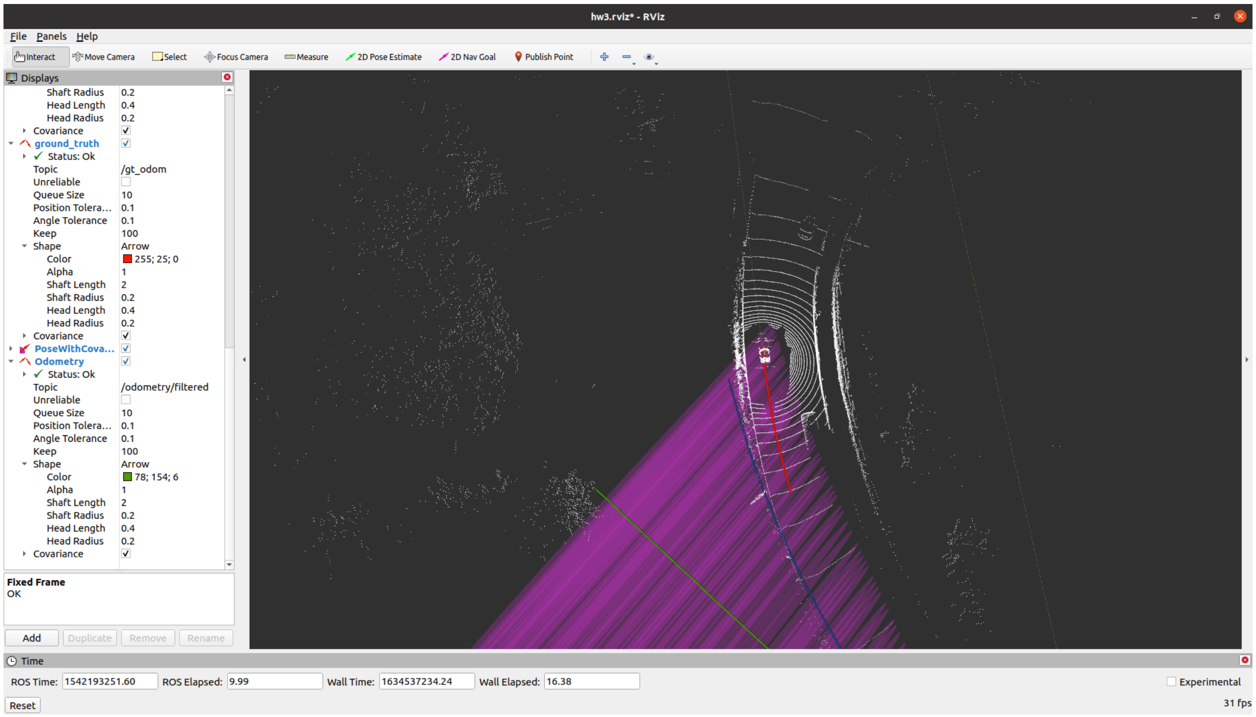


Global Options	
Fixed Frame	origin
Background Color	■ 48; 48; 48
Frame Rate	30
Default Light	☑
✓ Global Status: Ok	
✓ Fixed Frame	OK
Grid	☑
TF	☑
✓ Status: Ok	
Show Names	☑
Show Axes	☑
Show Arrows	☑
Marker Scale	1
Marker Alpha	1
Update Interval	0
Frame Timeout	15
Frames	
Tree	
PointCloud2	☑
Status: Error	
Topic	/nuscenes_lidar
Unreliable	□
Queue Size	10
Selectable	☑
Style	Flat Squares
Size (m)	0.05
Alpha	1
Decay Time	0
Position Transf...	XYZ
Color Transfor...	FlatColor
Color	□ 255; 255; 255
radar_odom	☑
✓ Status: Ok	
Topic	/radar_odometry
Unreliable	□
Queue Size	10
Position Tolera...	0.1

Fixed Frame
OK

ROS Time: 1542193258.64 ROS Elapsed: 17.09 Wall Time: 1634536672.27 Wall Elapsed: 17.02

- Screenshot of the result using radar odometry in EKF

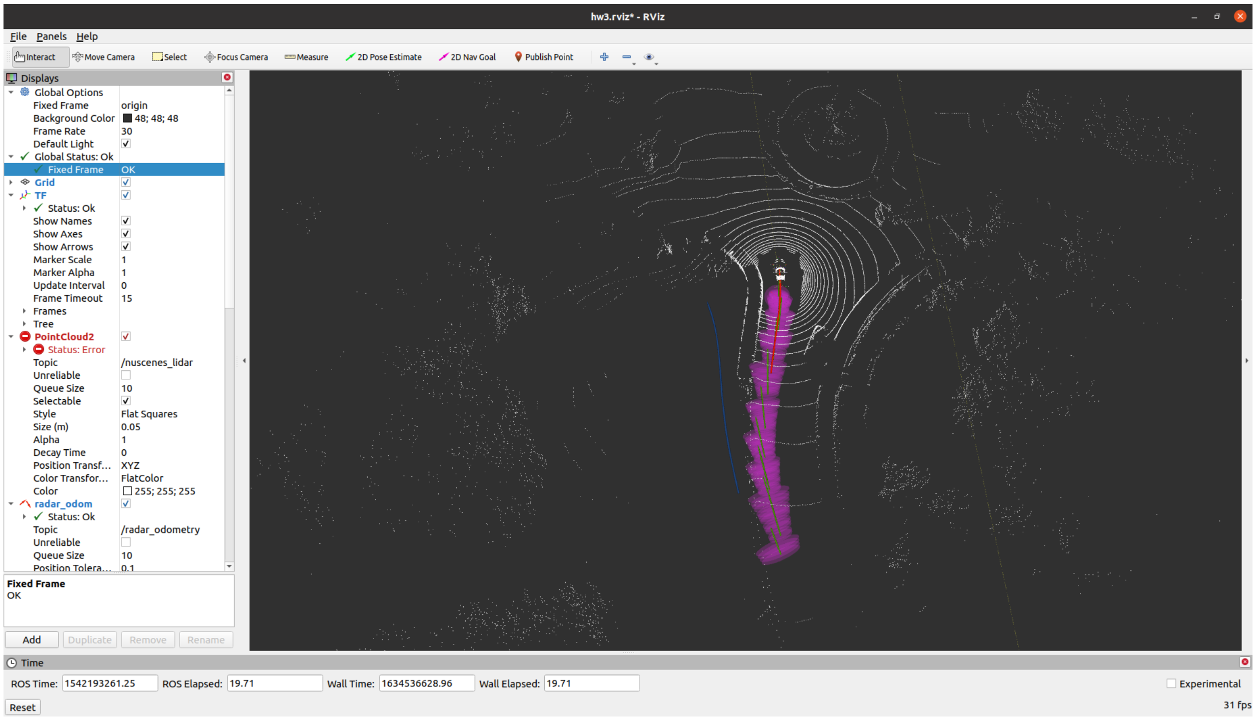


Shaft Radius	0.2
Head Length	0.4
Head Radius	0.2
Covariance	☑
ground_truth	☑
✓ Status: Ok	
Topic	/gt_odom
Unreliable	□
Queue Size	10
Position Tolera...	0.1
Angle Tolerance	0.1
Keep	100
Shape	Arrow
Color	🟥 255; 25; 0
Alpha	1
Shaft Length	2
Shaft Radius	0.2
Head Length	0.4
Head Radius	0.2
Covariance	☑
PoseWithCova...	☑
Odometry	☑
✓ Status: Ok	
Topic	/odometry/filtered
Unreliable	□
Queue Size	10
Position Tolera...	0.1
Angle Tolerance	0.1
Keep	100
Shape	Arrow
Color	🟩 78; 154; 6
Alpha	1
Shaft Length	2
Shaft Radius	0.2
Head Length	0.4
Head Radius	0.2
Covariance	☑

Fixed Frame
OK

ROS Time: 1542193251.60 ROS Elapsed: 9.99 Wall Time: 1634537234.24 Wall Elapsed: 16.38

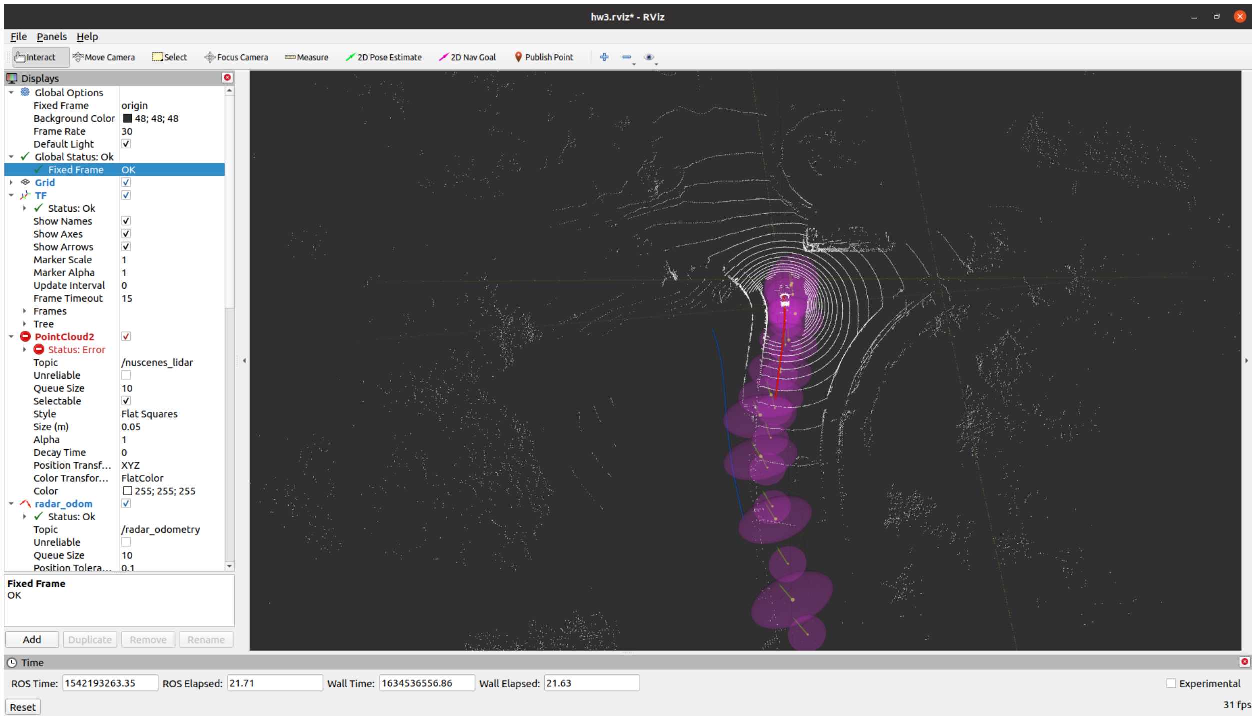
- Screenshot of the result fusing GPS and radar odometry in EKF


hw3.rviz* - RViz
File Panels Help
Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Nav Goal Publish Point
Displays
Add Duplicate Remove Rename
Time
Reset
Experimental
31 fps

```
Global Options
  Fixed Frame          origin
  Background Color     48; 48; 48
  Frame Rate           30
  Default Light        ☑
✓ Global Status: Ok
  ✓ Fixed Frame        OK
Grid                   ☑
TF                     ☑
  ✓ Status: Ok
  Show Names           ☑
  Show Axes            ☑
  Show Arrows          ☑
  Marker Scale         1
  Marker Alpha         1
  Update Interval      0
  Frame Timeout        15
  Frames
  Tree
PointCloud2            ☑
  Status: Error
  Topic                /nuscenes_lidar
  Unreliable           □
  Queue Size           10
  Selectable           ☑
  Style                Flat Squares
  Size (m)             0.05
  Alpha                1
  Decay Time           0
  Position Transf...   XYZ
  Color Transfor...    FlatColor
  Color                255; 255; 255
radar_odom             ☑
  ✓ Status: Ok
  Topic                /radar_odometry
  Unreliable           □
  Queue Size           10
  Position Tolera...   0.1

Fixed Frame
OK

ROS Time: 1542193261.25  ROS Elapsed: 19.71  Wall Time: 1634536628.96  Wall Elapsed: 19.71
```

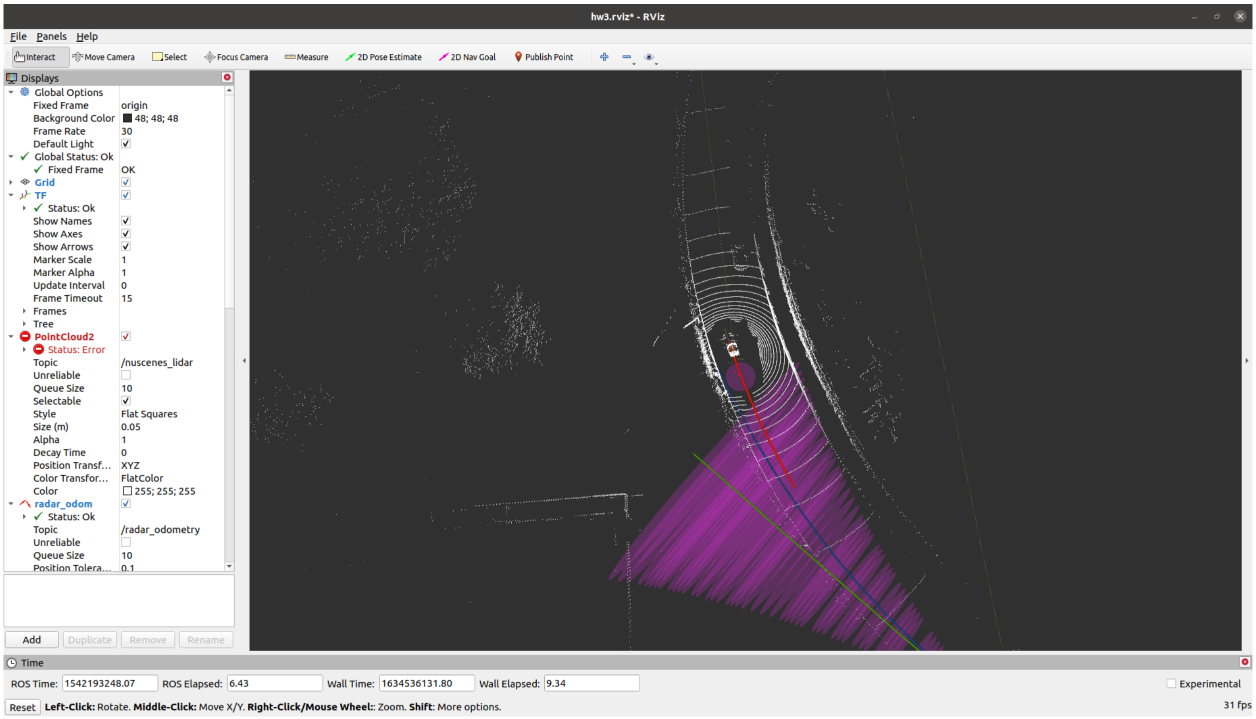
UKF Result

- Screenshot of the result using GPS in UKF


hw3.rviz* - RViz
File Panels Help
Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Nav Goal Publish Point
Displays
Add Duplicate Remove Rename
Time
Reset
Experimental
31 fps

```
Global Options
  Fixed Frame          origin
  Background Color     48; 48; 48
  Frame Rate           30
  Default Light        ☑
✓ Global Status: Ok
  ✓ Fixed Frame        OK
Grid                   ☑
TF                     ☑
  ✓ Status: Ok
  Show Names           ☑
  Show Axes            ☑
  Show Arrows          ☑
  Marker Scale         1
  Marker Alpha         1
  Update Interval      0
  Frame Timeout        15
  Frames
  Tree
PointCloud2            ☑
  Status: Error
  Topic                /nuscenes_lidar
  Unreliable           □
  Queue Size           10
  Selectable           ☑
  Style                Flat Squares
  Size (m)             0.05
  Alpha                1
  Decay Time           0
  Position Transf...   XYZ
  Color Transfor...    FlatColor
  Color                255; 255; 255
radar_odom             ☑
  ✓ Status: Ok
  Topic                /radar_odometry
  Unreliable           □
  Queue Size           10
  Position Tolera...   0.1

Fixed Frame
OK

ROS Time: 1542193263.35  ROS Elapsed: 21.71  Wall Time: 1634536556.86  Wall Elapsed: 21.63
```

- Screenshot of the result using radar odometry in UKF


hw3.rviz* - RViz
File Panels Help
Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Nav Goal Publish Point
Displays
Add Duplicate Remove Rename
Time
Experimental
Reset

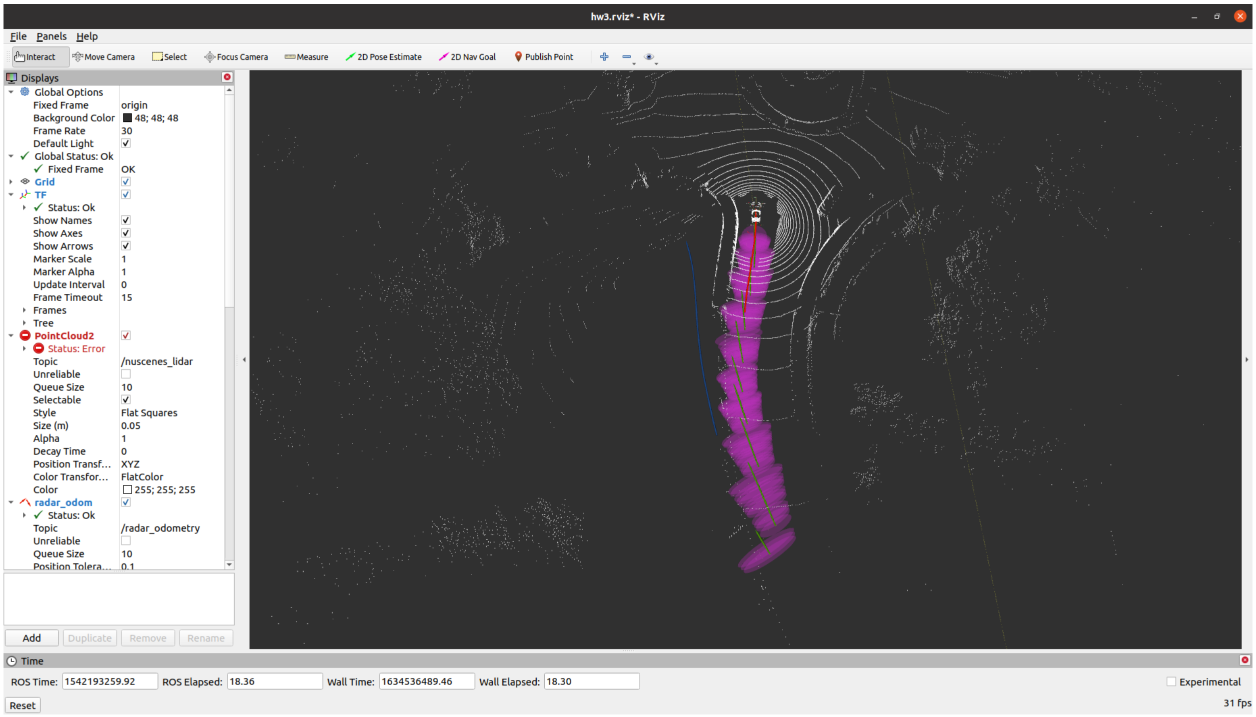
Global Options
Fixed Frame origin
Background Color ■ 48; 48; 48
Frame Rate 30
Default Light ☑
✓ Global Status: Ok
✓ Fixed Frame OK
Grid ☑
TF ☑
✓ Status: Ok
Show Names ☑
Show Axes ☑
Show Arrows ☑
Marker Scale 1
Marker Alpha 1
Update Interval 0
Frame Timeout 15
Frames
Tree
PointCloud2 ☑
Status: Error
Topic /nuscenes_lidar
Unreliable ☐
Queue Size 10
Selectable ☑
Style Flat Squares
Size (m) 0.05
Alpha 1
Decay Time 0
Position Transf... XYZ
Color Transfor... FlatColor
Color □ 255; 255; 255
radar_odom ☑
✓ Status: Ok
Topic /radar_odometry
Unreliable ☐
Queue Size 10
Position Tolera... 0.1

ROS Time: 1542193248.07 ROS Elapsed: 6.43 Wall Time: 1634536131.80 Wall Elapsed: 9.34

Left-Click: Rotate. **Middle-Click:** Move X/Y. **Right-Click/Mouse Wheel:**: Zoom. **Shift**: More options.

31 fps

- Screenshot of the result fusing GPS and radar odometry in UKF


hw3.rviz* - RViz
File Panels Help
Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Nav Goal Publish Point
Displays
Add Duplicate Remove Rename
Time
Experimental
Reset

Global Options
Fixed Frame origin
Background Color ■ 48; 48; 48
Frame Rate 30
Default Light ☑
✓ Global Status: Ok
✓ Fixed Frame OK
Grid ☑
TF ☑
✓ Status: Ok
Show Names ☑
Show Axes ☑
Show Arrows ☑
Marker Scale 1
Marker Alpha 1
Update Interval 0
Frame Timeout 15
Frames
Tree
PointCloud2 ☑
Status: Error
Topic /nuscenes_lidar
Unreliable ☐
Queue Size 10
Selectable ☑
Style Flat Squares
Size (m) 0.05
Alpha 1
Decay Time 0
Position Transf... XYZ
Color Transfor... FlatColor
Color □ 255; 255; 255
radar_odom ☑
✓ Status: Ok
Topic /radar_odometry
Unreliable ☐
Queue Size 10
Position Tolera... 0.1

ROS Time: 1542193259.92 ROS Elapsed: 18.36 Wall Time: 1634536489.46 Wall Elapsed: 18.30

31 fps

Discussion

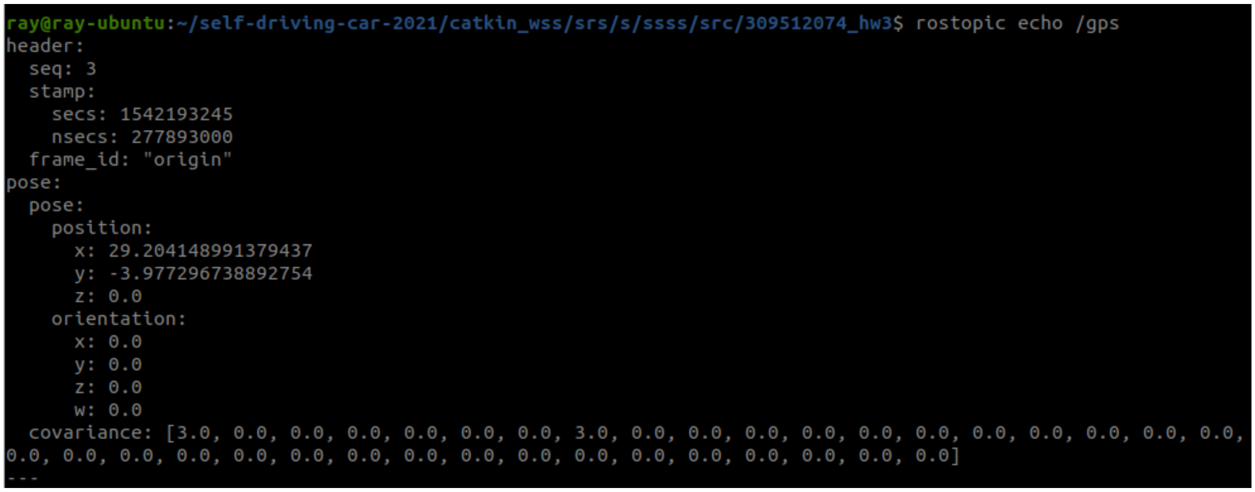
- How do robot_localization package know the covariance matrix of GPS and radar odometry?

By subscriber, the rosbag will publish geometry_msgs/PoseWithCovarianceStamped(/gps) and nav_msgs/Odometry(/radar_odometry) rostopic, therefore the robot_localization package can know the covariance matrix of GPS and radar odometry.

- What is the covariance matrix of GPS and what does it mean?

The covariance matrix is a powerful tool for expressing what remains uncertain about a group of variables that have already been measured many times. This tool can be applied to help make smart decisions about systems which are messy and complex because they have many different kinds of uncertainty piled on top of each other.

covariance matrix of GPS:



```
ray@ray-ubuntu:~/self-driving-car-2021/catkin_wss/srs/s/ssss/src/309512074_hw3$ rostopic echo /gps
header:
  seq: 3
  stamp:
    secs: 1542193245
    nsecs: 277893000
  frame_id: "origin"
pose:
  pose:
    position:
      x: 29.204148991379437
      y: -3.977296738892754
      z: 0.0
    orientation:
      x: 0.0
      y: 0.0
      z: 0.0
      w: 0.0
  covariance: [3.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 3.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
---
```

- In the yaml file, do you set differential parameter of odometry and GPS to true? or false? Why?

differential: When differential mode is enabled, all absolute pose data is converted to velocity data by differentiating the absolute pose measurements. These velocities are then integrated as usual.

In our case, we have two sources with absolute pose information: radar odometry and GPS. If the variances of the input sources are not configured correctly, the measurements may get out of sync and cause oscillations in the filter.

I set differential parameter of odom0(odometry) to true since it odometry message include velocity information(twist), and the differential parameter to pose0(gps) to false since it is not continuous, if not, the covariance of pose will be divergence.

Bonus

- Compare EKF result with UKF result. Describe your findings and explain why.

EKF: In real world, we have non linear equations, because we may be predicting in one direction while our sensor is taking reading in some other direction, so it involves angles and sine cosine functions which are non linear. So EKF takes helps of Taylor Series (and Jacobian Matrix further) to linearly approximate a non linear function around the mean of the Gaussian and then predict the values.

UKF: sigma points, we take some points on source Gaussian and map them on target Gaussian after passing points through some non linear function and then we calculate the new mean and variance of transformed Gaussian, and those sigma points are the representative of whole distribution.

The main difference between EKF and UKF is EKF only take one point(mean) and approximate, but in UKF we take a bunch of points(sigma points) and approximate, the more number of points it take, more precise the approximation will be.

In my case, the outcome of EKF and UKF is similar, but I found out the results of covariance in UKF is more continuous compare to the result of EKF.