Question 1: Write a short recap of the four tracking steps and what you implemented there (EKF, track management, data association, camera-lidar sensor fusion). Which results did you achieve? Which part of the project was most difficult for you to complete, and why?

- The four parts are well discussed and also the exercises cover the whole project so I didn't face any problem working in these four tasks. The most difficult part was the EKF but I solved it directly without and issue cause It's elaborated well in the lessons.
  In the first part, EKF predict and update functions are implemented as what is discussed in the lessons. In predict function, the state X and covariance matrix P is implemented, In update function, the residual is calculated and then the covariance of residual is calculated based on the jacobian matrix H. kalman gain is calculated to update the state X and covariance matrix P.
  in the second part, track management module is created to handle initialization, deletion of the tracks and also updating the track score and state based on the remaining tracks and measurements. This track management includes the association part which is responsible for associate each measurement to a track based on the mahalanobis distance. The fourth and final requirement is for implementing nonlinear camera module and fuse the camera and sensor readings to achieve the tracking task for 200 different Waymo dataset frames.

Question 2: Do you see any benefits in camera-lidar fusion compared to lidar-only tracking (in theory and in your concrete results)?

- Using camera with lidar sensor improves the estimation cause each sensor face some issues while working so taking into consideration different sensors to get an inference about the surrounding environment is for sure a better idea. Fuse sensors readings increase the confidence of the measurement data to be used to take an action for autonomous navigation of the vehicle.

Question 3: Which challenges will a sensor fusion system face in real-life scenarios? Did you see any of these challenges in the project?

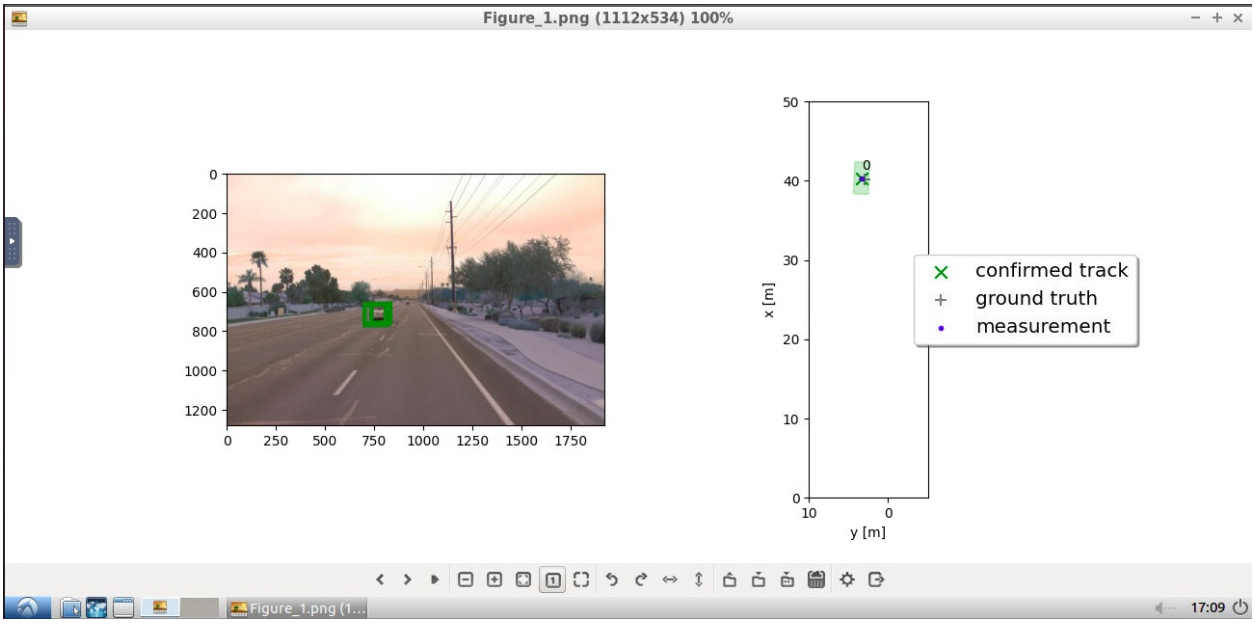
- Computation power required is the main challenge for the sensor fusion system and handling all the transformations between sensors and main vehicle frame. Using different sensors need more effort to customize the data and the behavior of the vehicle software to handle such sensor and the cost also is another factor that came into mind when deciding to work with different sensors.

Question 4: Can you think of ways to improve your tracking results in the future?

- Including other sensors readings from Waymo Open dataset. Tuning the used parameters for initial state, standard deviations and the used kalman filter parameters. Use another data association technique to overcome the used nearest neighbor technique. Use more advance camera model and another performance estimation methods to fine tune the results.

GitHub Repository :
https://github.com/khaledsaad97/sensor-fusion-final-project

Step 1 Figures: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x [m]
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confirmed track
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measurement
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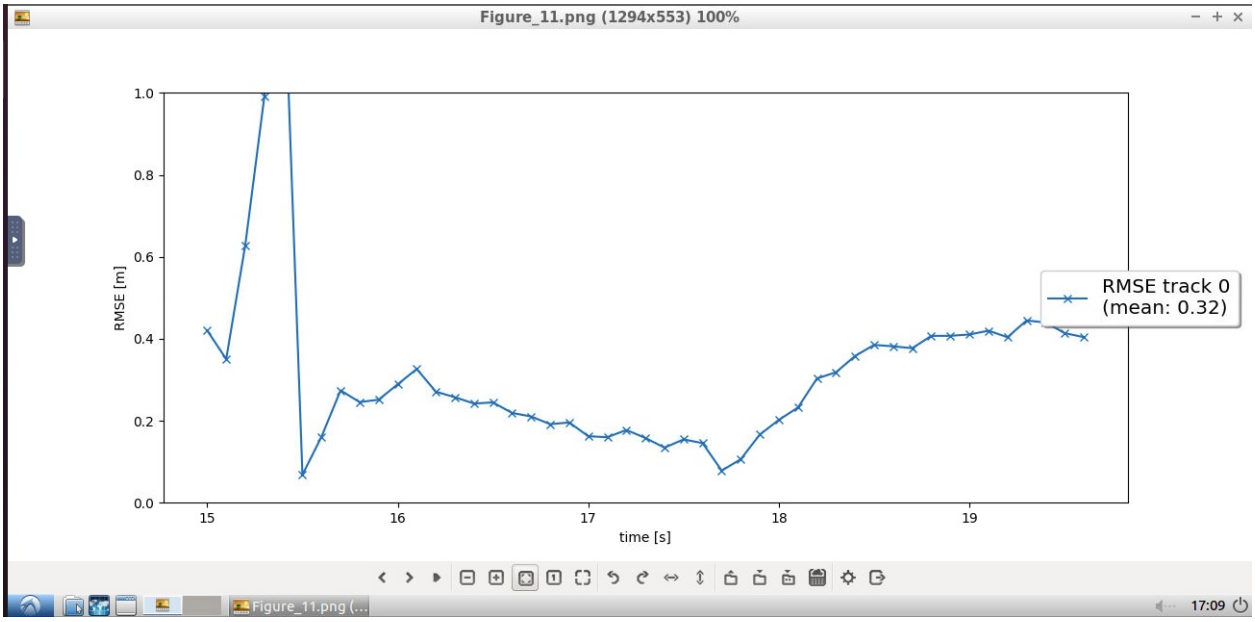
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1.0
0.8
0.6
0.4
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RMSE [m]
15
16
17
18
19
time [s]
RMSE track 0
(mean: 0.32)
Figure_11.png (...
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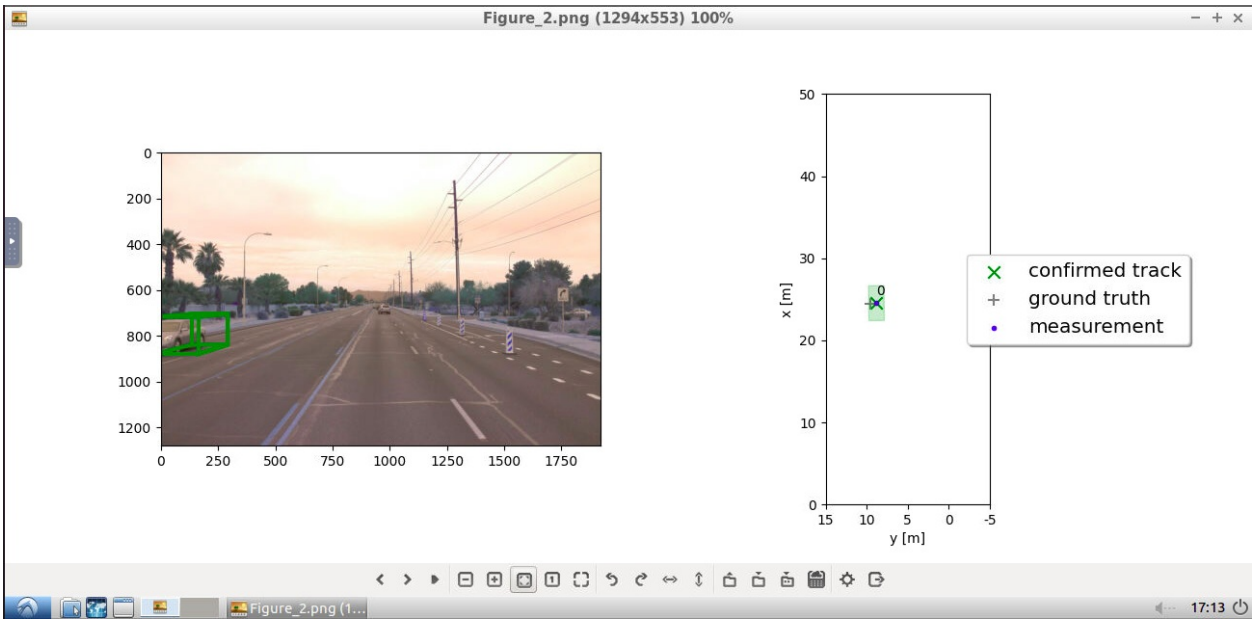
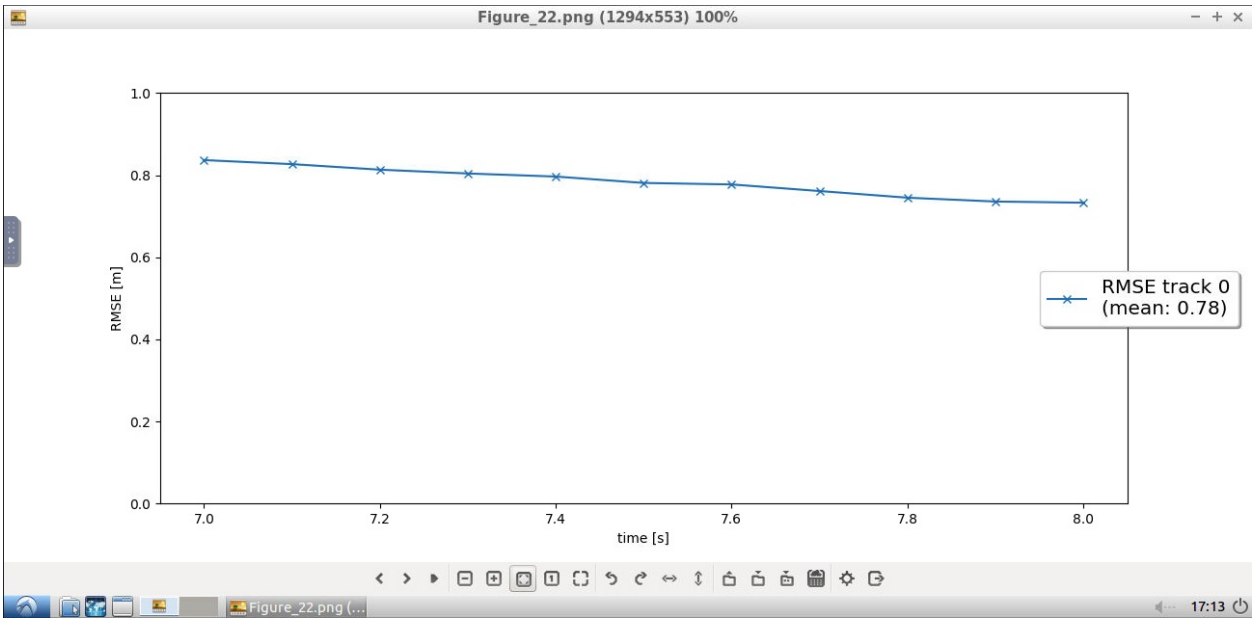
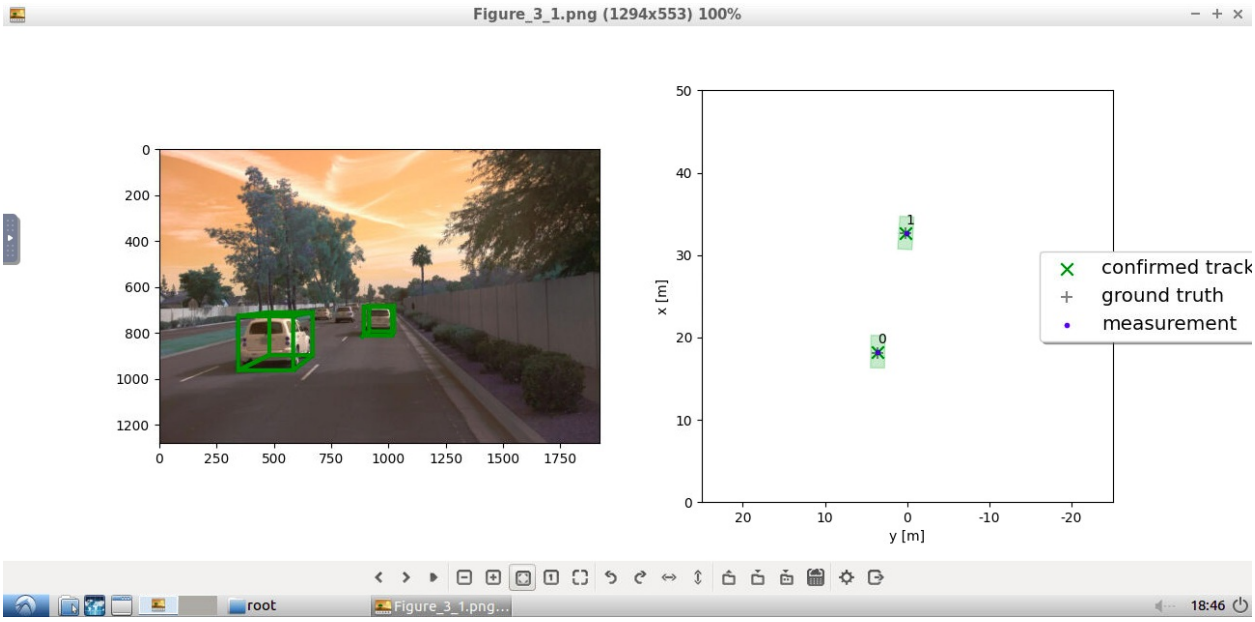
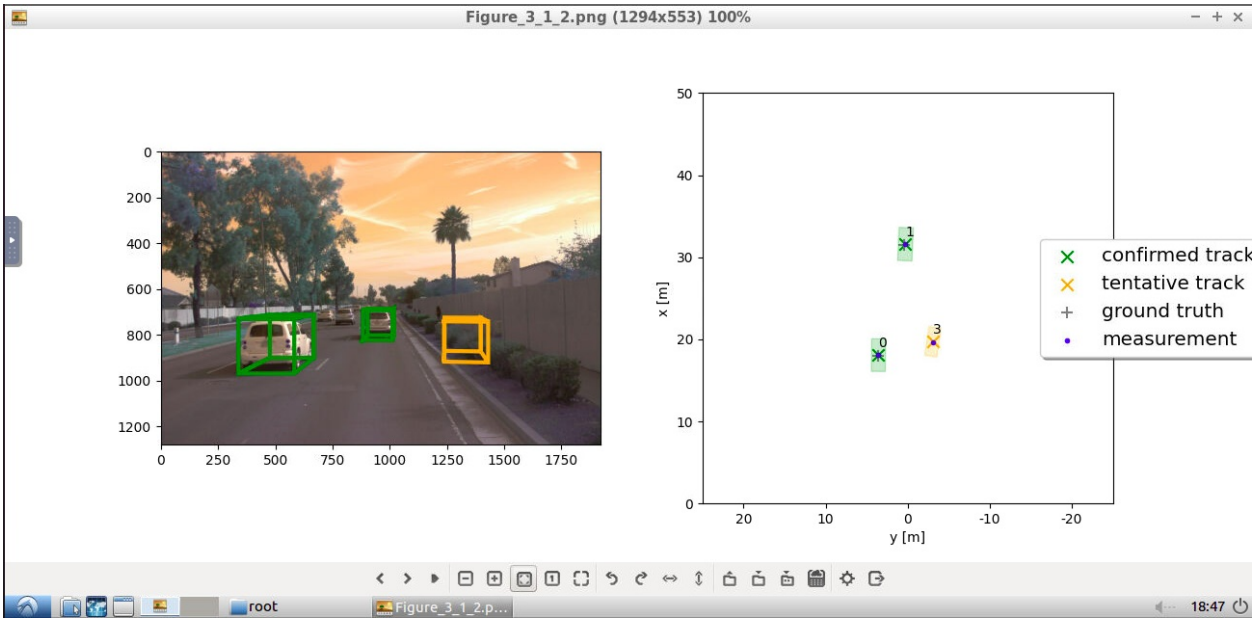
Step 2 Figures:



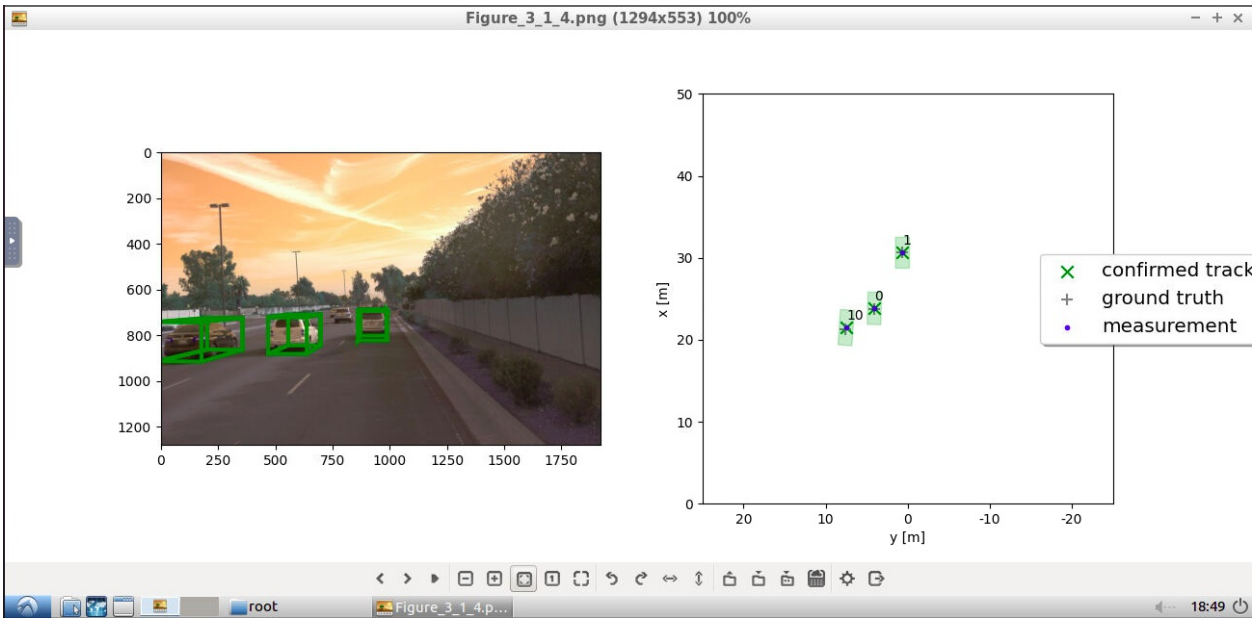


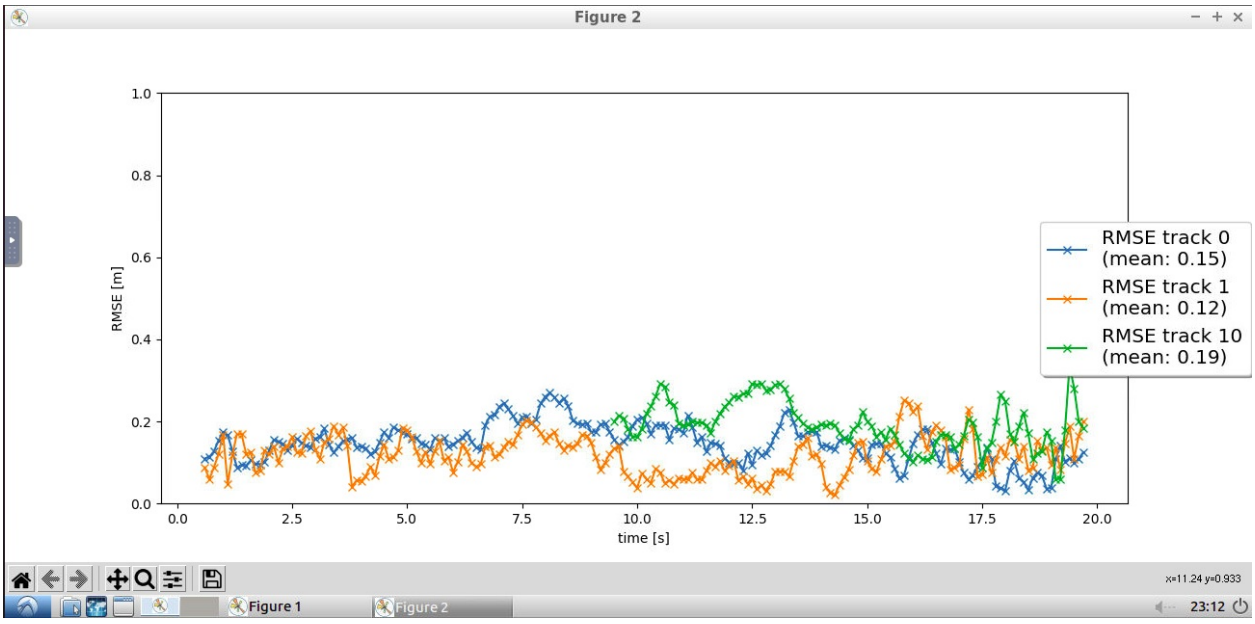
Step 3 Figures:





Step 3 Figures:





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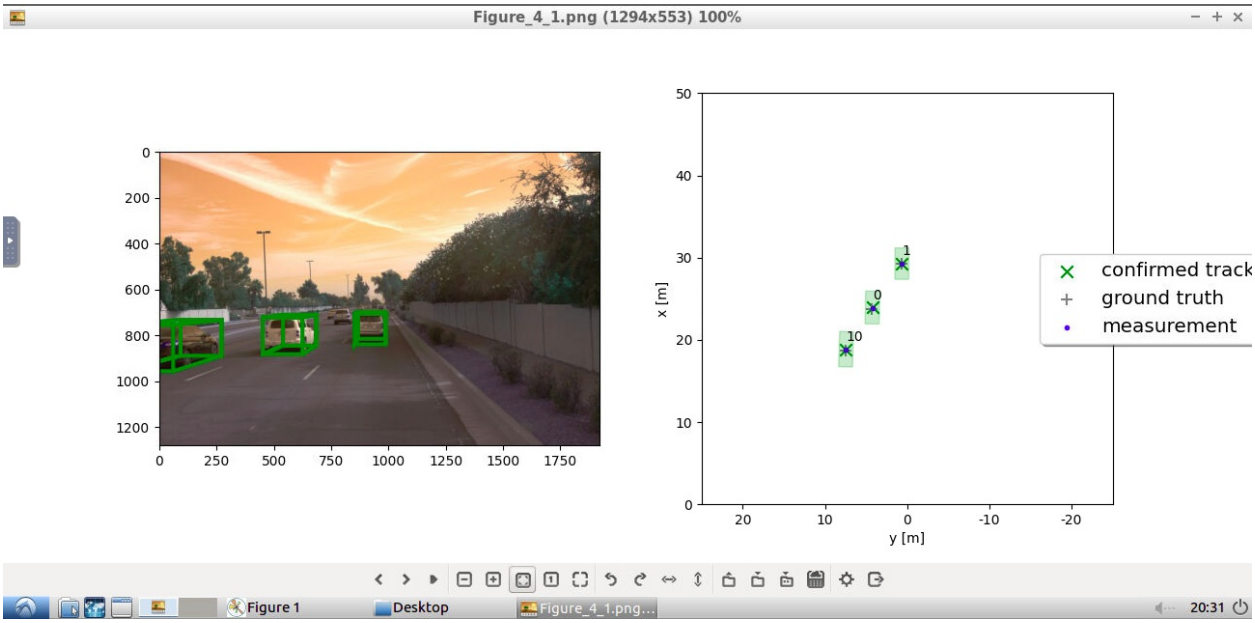

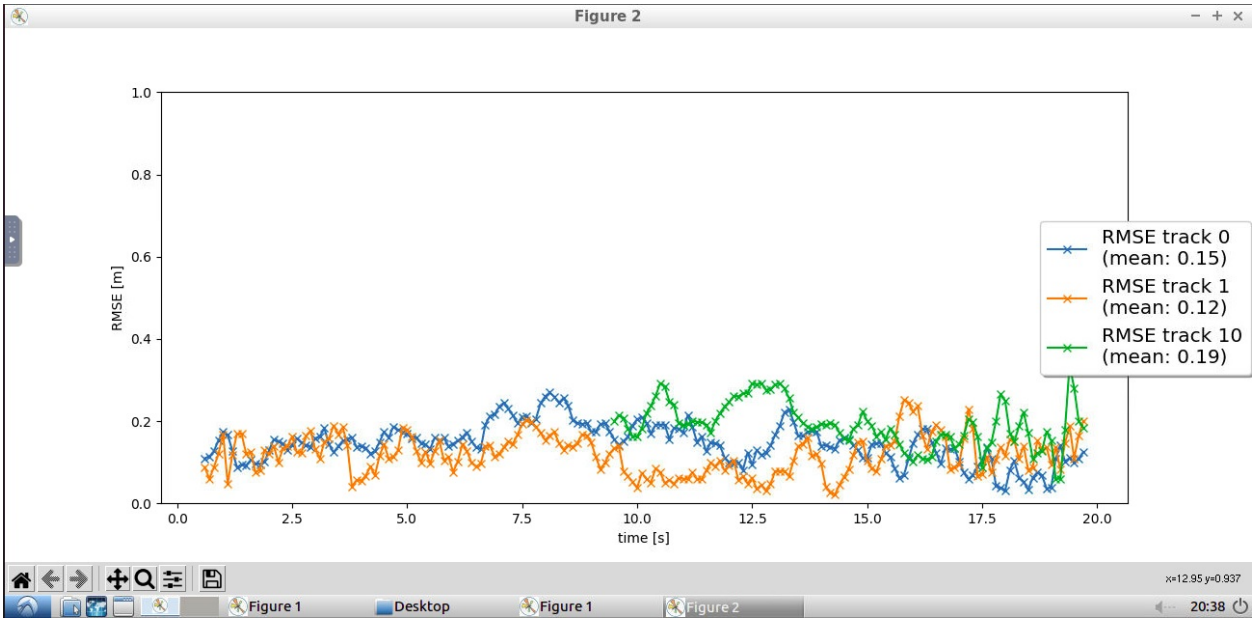
Figure 2
RMSE [m]
time [s]
RMSE track 0
(mean: 0.15)
RMSE track 1
(mean: 0.12)
RMSE track 10
(mean: 0.19)
x=12.95 y=0.937
Figure 1
Desktop
Figure 1
Figure 2
20:38