Self-Driving Car Beta Testing Nanodegree

Midterm - 3D Object Detection

In this project, we used real-world data from the Waymo Open Dataset and apply an extended Kalman filter for sensor fusion and tracking multiple vehicles. The major tasks accomplished to complete the project:

1. Implement a Kalman filter to track a object
2. Track management, initialize, update and delete tracks to manage tracking
3. Data association
4. Camera sensor fusion, on the basis of lidar fusion, add camera measurement fusion

To run the project, simply run the script loop_over_dataset.py.

Step-1: Extended Kalman Filter

We use ekf to track objects. EKF is implemented in filter.py.

Implementing an ekf includes below work,

- Design system sate [x,y,z,vx,vy,vz]
- Design process model, consent velocity model
- implement predict step, with constant velocity model and process noise increasing with delta time
- implement update step, with lidar measurement model

For the road segment specified in classroom, the following graph was plotted.

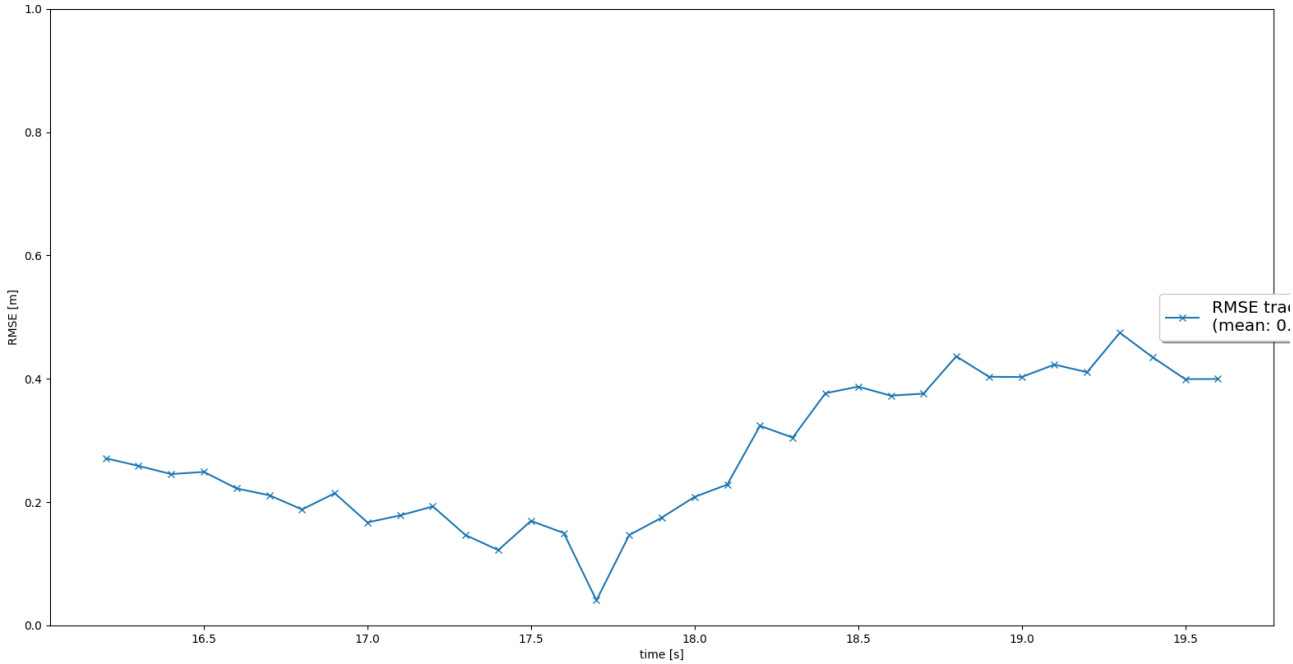


Fig 1

Step-2: Track Management

Track management is implemented in trackmanagement.py.

Below are the key points of track management:

- Track is initialized after receiving an unassigned lidar measurement.
- A track contains scores. Its score will be increased if it's associated with a measurement, and decreased otherwise.
- A track contains state, which will be updated based on its score, 'confirmed' if the confirmed threshold is exceeded.
- A track will be deleted if its score is below a certain threshold.

For the road segment specified in classroom, we can see the track is initialized, confirmed, and then deleted. The following graph is plotted.

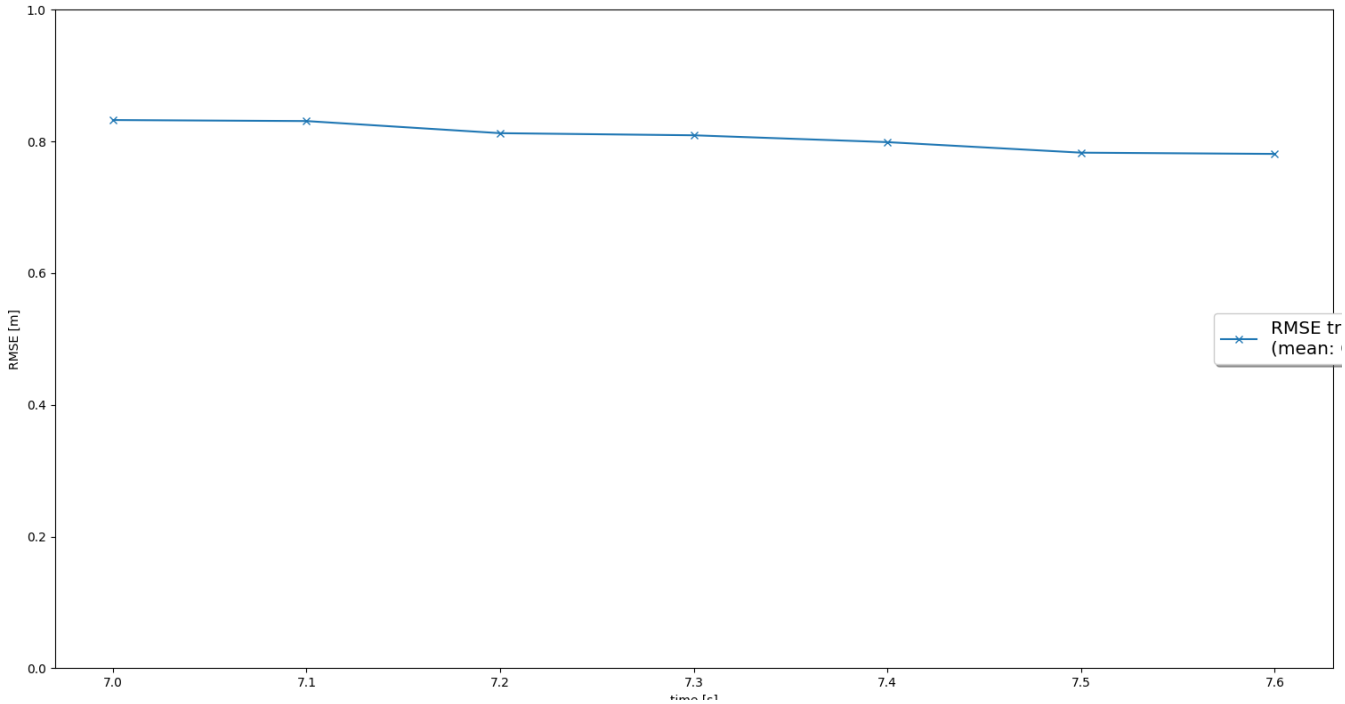


Fig 2

Step-3: Data Association

Data association is implemented in association.py.

Below are the key steps involved in data association,

- Create a matrix for all available tracks and observations.
- Calculate Mahalanobis distance (MHD) for each track measurement pairs.
- Use Chi Square hypothesis test to reject unlikely track measurement pairs.
- Pick out the pair with smallest MHD, perform ekf update step, and then remove corresponding row and column in the association matrix.

For the road segment specified in classroom, we can see the track is initialized, confirmed, and then deleted. The following graph is plotted.

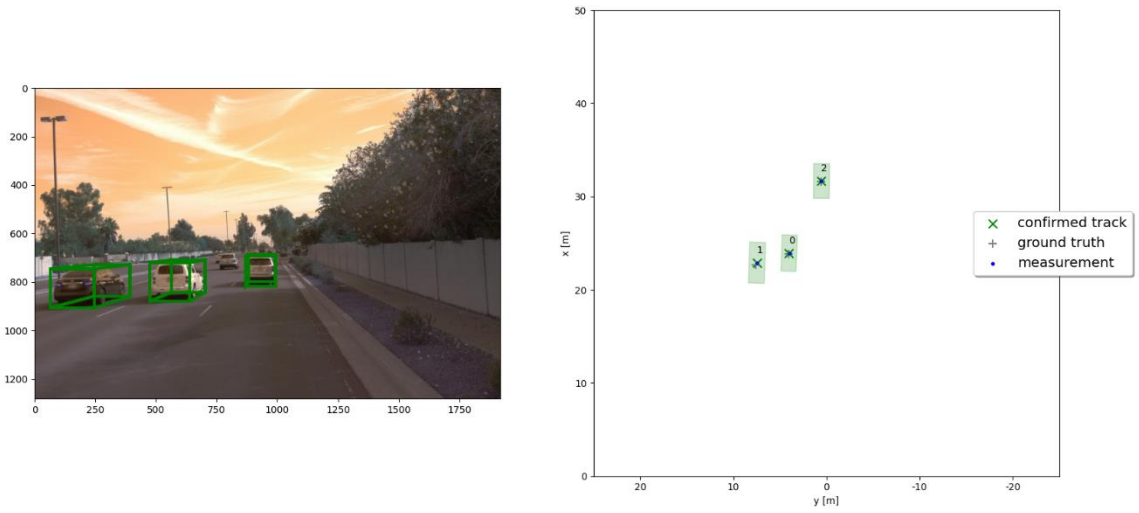


Fig 3

After implementing, we can see that the multiple measurements are properly associated with multiple tracks.

Step-4: Camera Sensor Fusion

In the step, we add camera measurements to the ekf fusion. It is implemented in the measurement.py.

Implementing camera measurement fusion consists of below major aspects,

- measurement model, the projection matrix which transforms points from 3d in space to 2d in image.
- Jacobean for the measurement model, the partial derivative of system state(x,y,z) with respect to measurement(u, v)
- measurement noise R for camera measurement
- check if a track's state is within camera's field of view

Evaluation

Tracking performance is evaluated using RMSE metrics

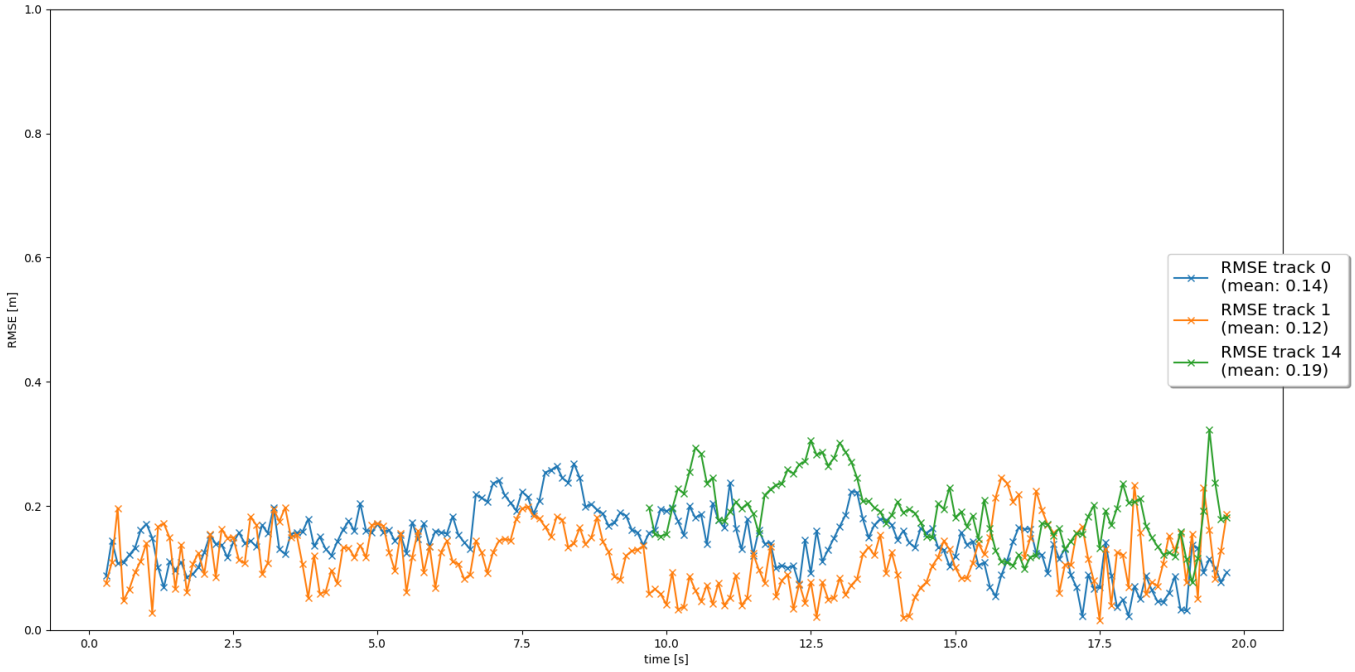
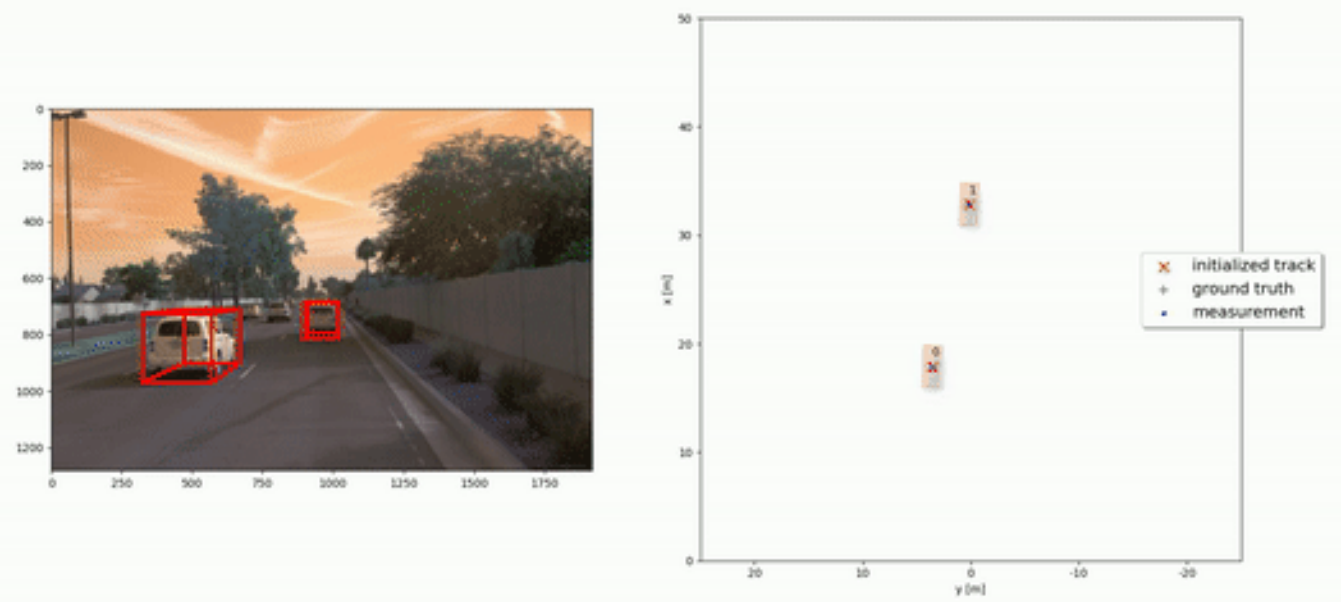


Fig 4

Evaluation

The tracking movie is generated under the directory /result/movies. A sample of the generated movie is included in the directory /video.



Reflection

Most Difficult Part

In my opinion, I faced the most difficulty while implementing the camera measurement model, projecting 3D points to 2D points. Waymo's camera coordinate frame deviates from the z-froward, x-right, and y down coordinate frame, so it is difficult to implement cameara axis transformation.

Benefits of Camera-lidar Fusion Tracking over Lidar-only Tracking

Theoretically, camera-fusion tracking is said to improve the robustness and accuracy of the system.

By including Camera fusion tracking to this project, we can produce a more accurate geometric understanding of the scene and cover a wider area and therefore track more object. This will potentially produce more accurate tracking results than using a single camera Lidar-only Tracking.

Real-life Challenges

A sensor-fusion system can face a number of challenges in real-life. This challenges also exist in this project.

- accurate association between multiple tracks and multiple measures - It is difficult to set a good gating threshold for all scenarios.
- measurement noise configuration - Each measurement should come with its own noise variance rather than a fixed noise variance for the sensor.
- choice of process model - It is important to find a good balance between accuracy and computations.

Improvement Opportunity

Using a multi-camera (camera-lidar fusion) tracking system can significantly improve the system by mitigating the occlusion problems. Using multiple cameras provide a wider area of vision and thus can track more objects. This can eventually improve the tracking accuracy of the system.