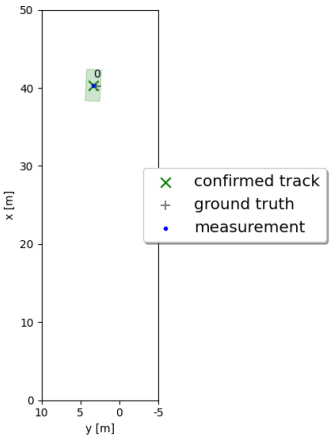
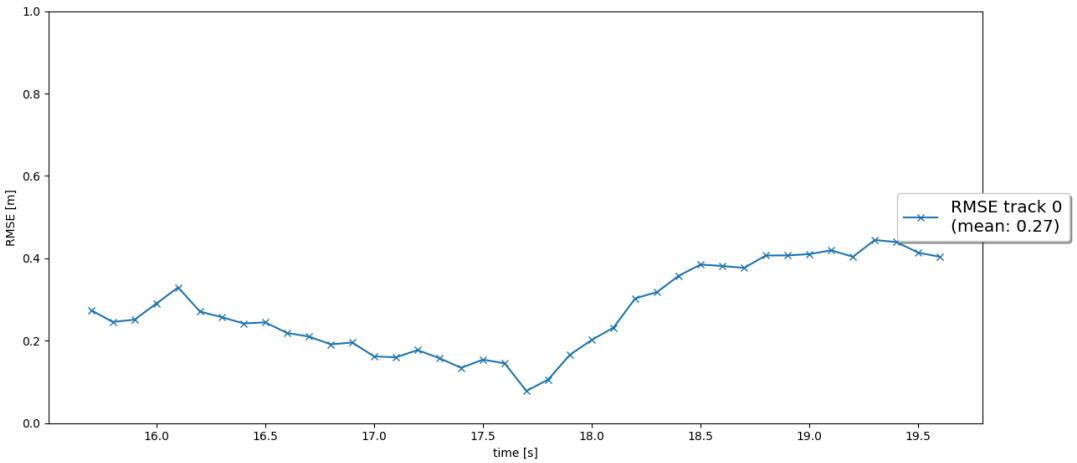
Final Project: Sensor Fusion and Object Tracking

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?**

Project Step 1 - EKF:

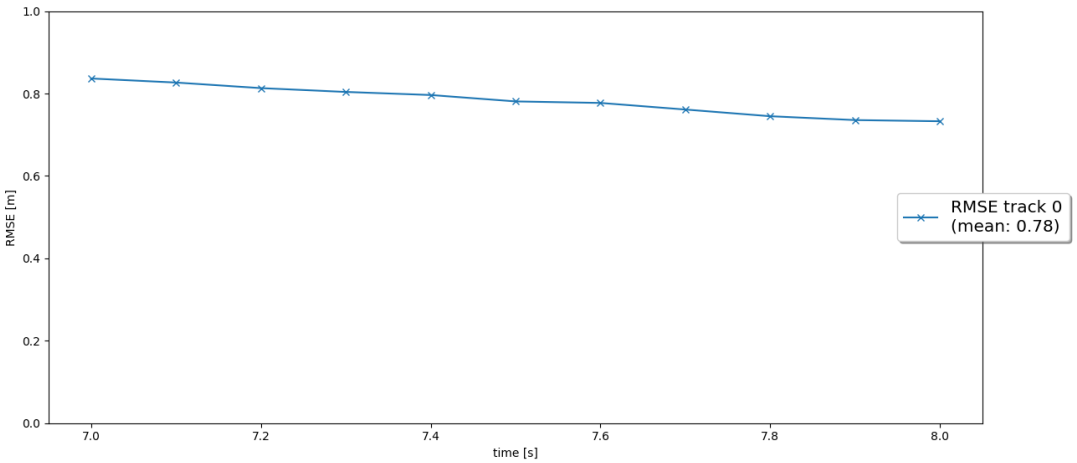
In the first step, the kalman filter 3D was implemented, the implementation of this step is quite simple, the result obtained was RMSE = 0.27 , a value within the expected range. Probably with correct initialization the average value could have been lower.

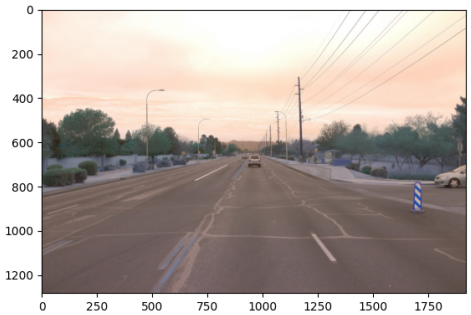


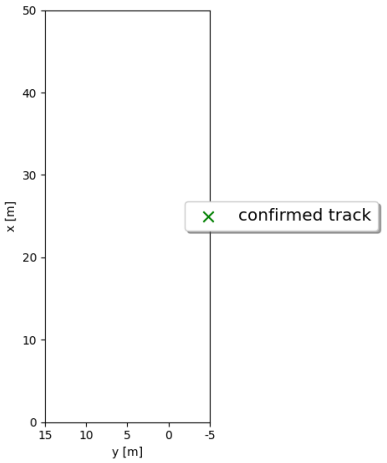


Project Step 2 - Track management

Firstly, the correct initiation of the track was implemented, after that, the management of the state (initiative/attempt/confirmed) and of the track's score was implemented.
This task was the one that demanded greater care so that the model was implemented in a way that it could manage different situations. First, I had implemented a positive increment of the score every time the target was confirmed, and a negative one if it was not detected. But I realized that this could generate infinite scores (very high) and that they would need many frames until the tracking was removed from the list. So I implemented a maximum limit on the score, so that it is always deleted after 5 frames without detection.

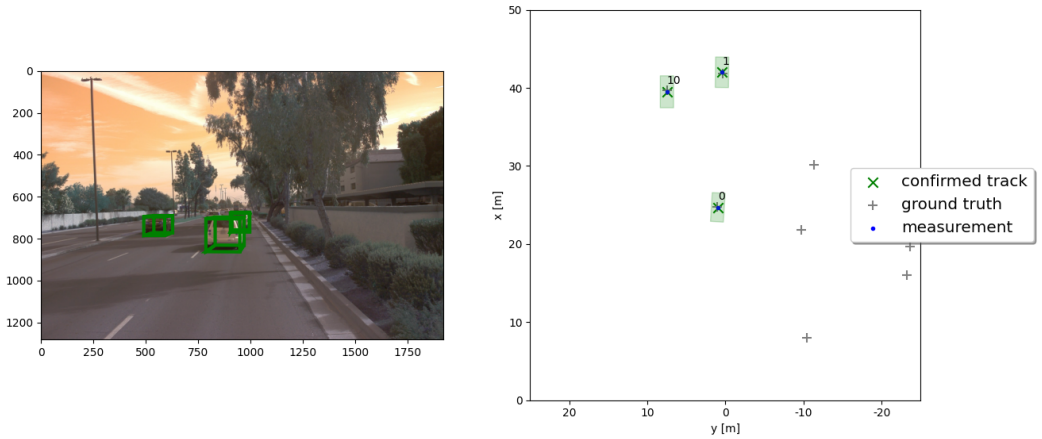


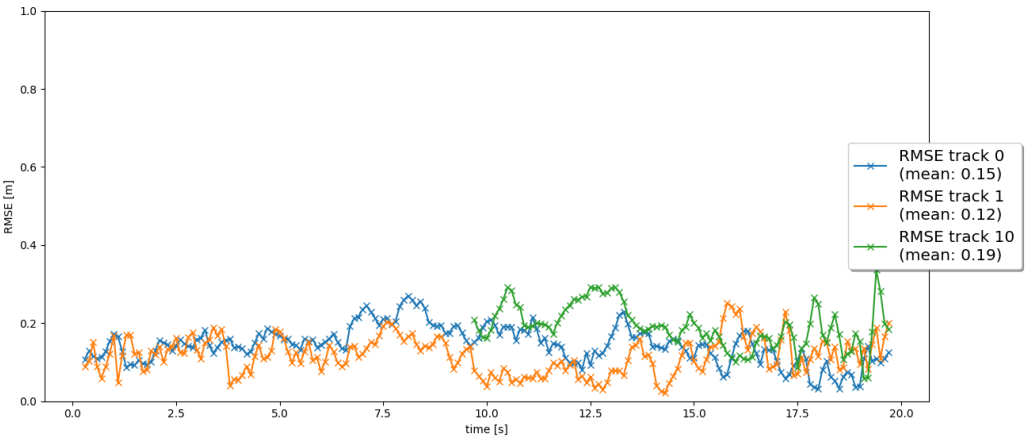




Project Step 3 -data association

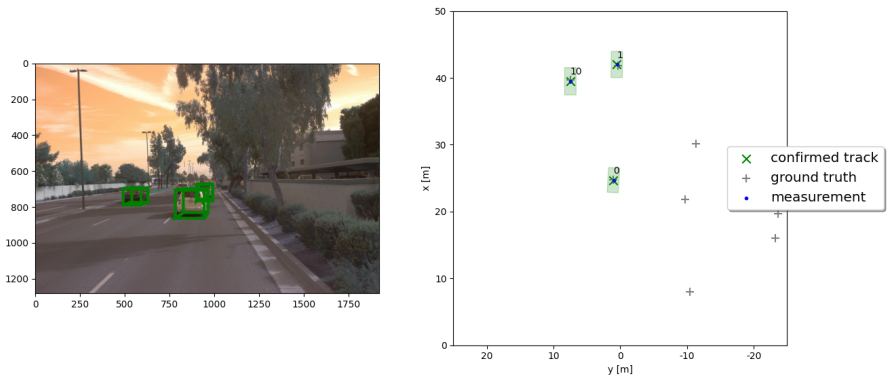
In this step I implemented a nearest neighbor data binding for tracking multiple objects. The Mahalanobis distance presented in the course was used as a criterion by the tracking association. The values obtained from RMSE on this track were acceptable, however many cases of false initiatives from the lidar were seen.

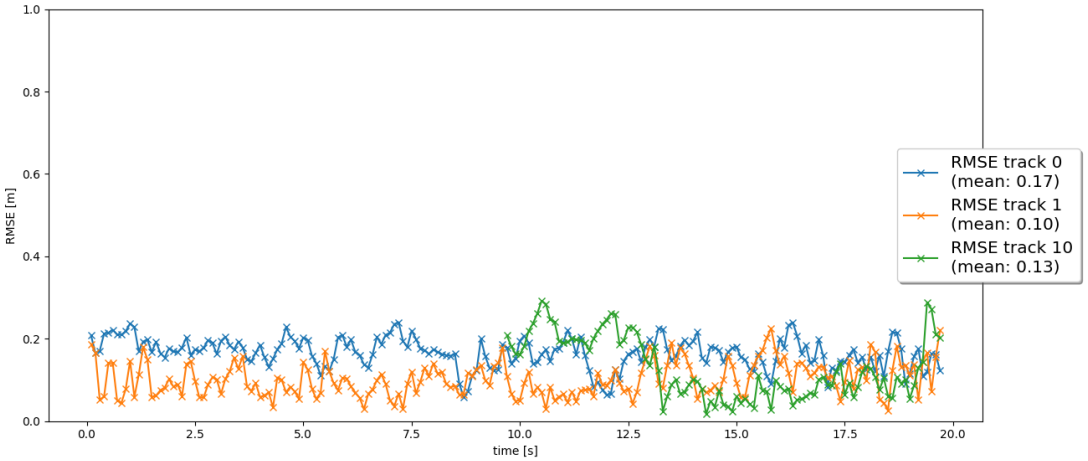




Project Step 4 - camera-lidar sensor fusion

In step 4, camera tracking was added so that the two sensors could be used together. In this was added the non-linear measurement function get_hx(x) for the EKF based on the implementation made in the Jacobian exercise. With the introduction of the camera in the tracking we had an average improvement of the RMSE. we also had a lower average of false initiatives





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

I believe the camera can help a lot with object detection and classification, but I don't think it's the best sensor to use for tracking. The 2D position accuracy of the camera is quite low compared to Lidar or Radar. The camera obtained fewer false positives because at short distances it has a better detection and classification capacity than the lidar. However, lidar has better range estimation accuracy.

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

In the project the ideal scenario to LIDAR and camera was used. Low-density environment (few objects), good lighting, no rain, short-distance evaluation only, low speed... etc. In a real scenario we would have many challenges that would probably need to be supported by other sensors. Like radar and sound sensors.

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

There are many ways to improve tracking. We can for example introduce a non-linear motion model for Kalman (much more realistic with the real movement of objects), we could also add radar measurements, radars can easily distinguish static objects from moving objects, and thus we could reduce the false positives obtained in the LIDAR estimations.