Lab5 - EKF Simultaneous Localization and Mapping

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1 Introduction

EKF SLAM is a popular algorithm in robotics which utilizes the extended Kalman filter (EKF) for simultaneous localization and mapping (SLAM). Typically, EKF SLAM algorithms are feature based, and use the maximum likelihood algorithm for data association. It mainly contains two parts: building the map and localizing the robot itself.

In this lab assignment, the objective is to implement the EKF SLAM with real dataset and fully understand how the algorithm works. The features here we used are lines. So the split and merge algorithm is also used for line extraction.

2 Algorithm and Implementation

For EKF algorithm, there are three steps which are prediction, data association and update for robot state. For EKF with the SLAM, the states of features are taken into account as well. Thus, all the steps we have to add the state of features we sensed along with the robot state.

2.1 Prediction

The initial state of robot is always known. The robot is able to estimate the next state by compounding its odometry since it is a non-linear addition. In the real case there's uncertainty along with the odometry, the estimation of the state contains the prediction of mean and also the uncertainty. The Gaussian distribution of the noise is applied.

Since the states of features have also to be taken into account, they are added into the state vector as well. The size of the state vector turns to be (3+2n) but 3 where n is the number of features we sensed in the map. Consequently the size of the uncertainty turns to be (3+2n)x(3+2n). The jacobian matrices with respect to the robot state and uncertainty are locating at the first 3x3 elements of the coefficient matrices respectively. While robot moving, the size of the state vector and uncertainty is growing since some features are sensed and added in the map.

2.2 Data association

The idea of Data association is the same as the previous lab. The mahalanobis distance between every line the robot sensed and all the lines in the map is computed and compared with the chi-square threshold(In this lab, it is 0.103). For the lines holding less distance than the threshold, we use it to update the state vector and uncertainty of the robot. For the lines whose distances to map lines are greater than the threshold, we consider they are new features and augment them in the state vector.

Different from the last lab, the given format of the lines is not the starting and end coordinates but the index. So every time, if the sensed line is the new feature, we take its index and pass it to the state augmentation step.

The difficulty of data association section is the frame reference transformation. When we compute the distance, we have to transform the lines into robot frame. So the inverse compounding function is used for this purpose. Then when we compute the jacobians, all the lines are supposed to refer to the world frame. The respecting frame should be taken care of in this section.

2.3 Update

After getting the predicted position of robot and the parameters from data association, we can update the state vector and uncertainty of the robot and features. There's one difference from the previous lab is that the innovation uncertainty is not passed from the data association since it is only with respect to one line. We have to recompute the innovation uncertainty before updating.

3 Results

While the robot moving, we observed that the ellipse around the robot which represents the uncertainty of the robot position grows and shrinks from time to time. The new lines are kept adding to the map and their positions are updated along with the robot position.

4 Conclusion

The knowledge of feature-based EKF SLAM is reviewed in this lab and the algorithm is implemented. By also considering the features the robot sensed in the map, it can localize itself more precisely. The thing we should take care of is

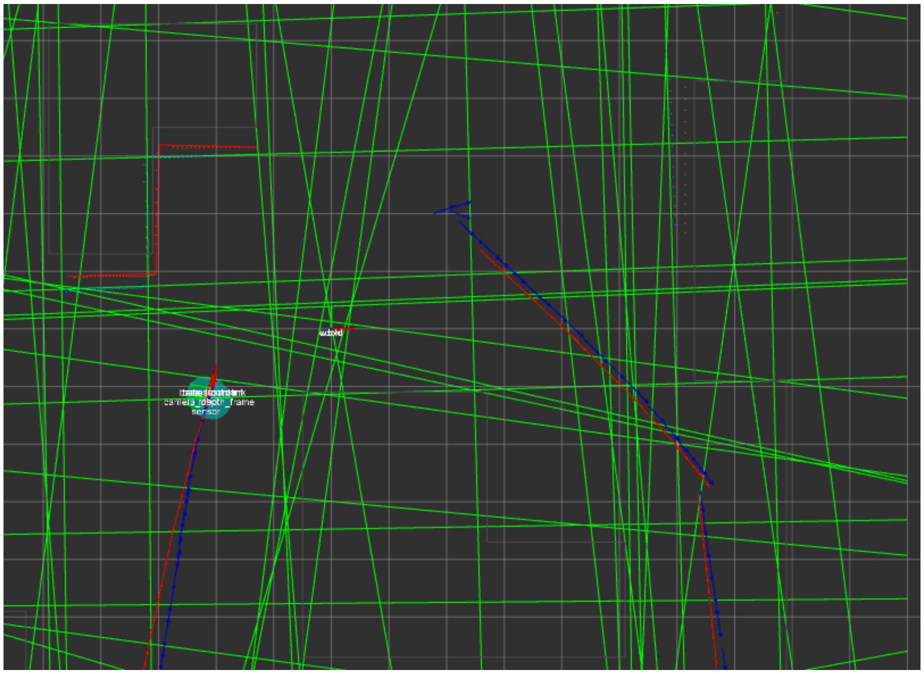

Figure 1: The map after updating the state vector

the frame transformation and the dimension of the state vector and uncertainty matrix when we doing the multiplication.