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The application of extended kalman filtering based on SLAM

Xuwen Cai

School of Electrical and Information Engineering, Hubei University of Automotive Technology, Shiyan, Hubei Province, 442002, China

1811031132@mail.sit.edu.cn

Abstract. EKF (Extended Kalman Filter) is a non-linear state estimation algorithm based on the development of Kalman filtering technology. In SLAM (Simultaneous Localization and Mapping), EKF technology is widely used to realize robots' independent positioning and map construction. EKF technology mainly estimates the state of the robot by using the information provided by the sensor, and then realizes the robot's self-positioning and the environment's map. This paper uses EKF algorithm for testing, and analyses the simulation results, which compared with Kalman filtering technology, the main difference between the two is that EKF can handle non -linear dynamic systems. In SLAM, robots often detect environmental detection through sensors such as laser radar, camera, and then update the position and posture of the robot by the receiving sensor data. In this process, the EKF technology can perform non -linearity by sensor data by sensor data Transformation makes the state of the robot more accurately estimate. Specifically, Extended Kalman Filtering technology can be divided into two steps: prediction and update. In the predicted phase, EKF uses the current robotic status and motion equation to predict the robot status of the next moment; in the update stage, EKF uses sensors to measure data to update the current state of the robot. By repeating the prediction and updating two steps, you can get the trajectory of the robot movement and the map of the environment where the robot is located.

Keywords: extended kalman filter, SLAM, non-linear.

1. Introduction

With the continuous development of robotic technology, the SLAM technology has become a very important research direction in the field of robotics. SLAM comes from the IEEE robot and automation conference held in San Francisco in 1986 [1]. SLAM technology can help robots to achieve autonomous positioning and map construction [2], thereby achieving intelligent and autonomous movement capabilities. In SLAM technology, algorithm applications based on EKF are becoming more and more widespread [3]. SLAM is a concept: the robot will have an unknown place that is never known to the environment. It is positioned by repeated observation maps (such as walls, columns, etc.) in the course of exercise. The formula is constructed to simultaneously achieve the purpose of positioning and map construction [4]. Extended Kalman Filter is a variant of Kalman Filter. It was developed by R. E. Kalman in the 1960s and used to deal with linear systems. EKF can optimize the status estimation problem in the non-linear system equation. It transforms non -linear problems into linear problems by linearly non -linear equations [5]. The non -linear state estimation algorithm can make high -precision prediction and update of the robot state through the information provided by the sensor, and can handle non -linear

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dynamic systems in complex environments [6]. At present, EKF -based SLAM technology has been widely used in the fields of driverless cars, drones and other fields [7], and has achieved remarkable research results. This article will review the research status and development trends of applying SLAM technology based on Extended Kalman Filtering, and summarize the research results and simulation experiments of the predecessors, compare the experimental results and data to verify the feasibility of this idea. It aims to provide reference and reference for researchers using the technology in related fields.

2. The principle of EKF in SLAM

EKF-SLAM principle: The core idea of EKF is to expand non -linear functions once, which is similar to a linear relationship. Specifically, in the EKF, non -linear functions will be carried out at the current point to approach the non -linear measurement [8]. In this way, the non -linear function is converted into a linear function. Specifically, the EKF-SLAM algorithm uses the Extended Kalman Filter algorithm to estimate the robot's state, which includes position, direction, and speed, while updating the robot's state using sensor measurements. In addition, the EKF-SLAM algorithm also uses the robot's sensor data to estimate the state of the environment, including the location and characteristics of landmarks. By estimating the state of the robot and the state of the environment simultaneously using the extended Kalman filter algorithm, the EKF-SLAM algorithm can realize the localization of the robot and the construction of the map at the same time.

In SLAM, EKF is usually used to locate and build maps on robots. Its basic process is as follows: Status variables indicate: the position and direction of the robot in the world coordinate system are used as a state variable, and at the same time, the position of multiple feature points (such as road signs) is used as auxiliary variables to jointly constitute the status vector of the system, as shown in Figure 1.

(1) System model establishment: Establish system models according to the motor model and observation model of the robot [9]. Here, because the robot may have a non -linear situation that changes speed and direction, it is necessary to get a linear relationship through Taylor to get closer.

(2) Status prediction: Based on the control input of the robot and the state estimation obtained in the previous step, the state of the current moment is predicted [10].

(3) Measurement update: processing the information the robot perceives, updating the status vector through observation model, and using the Kalman gain to ensure the system can adapt the state estimation value [11].

(4) Map Construction: According to the state of real -time renewal of the robot, the map is continuously constructed, and at the same time, it is used to optimize and BA and other algorithms to improve the stability and accuracy of the map [12].

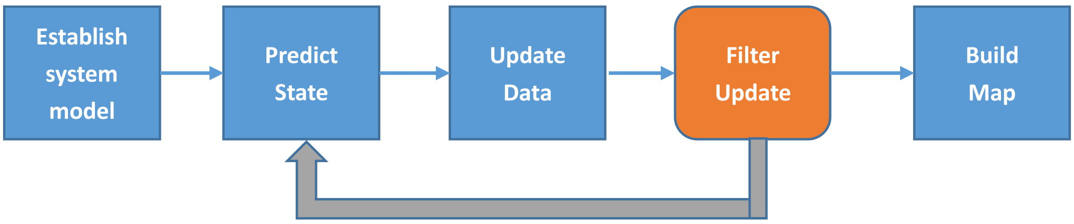

Figure 1. EKF-SLAM operating process.

EKF, as a more classic state estimation method, has a wide range of applications in SLAM. At the same time, it also has some problems, such as the system's dynamic and observation equations in advance. At the same time, accuracy may be reduced due to a large number of linear calculations. Therefore, in practical applications, it can be combined with other algorithms to further improve the performance of SLAM.

3. EKF-SLAM specific application

3.1. SLAM predictive position and actual location gap

The article defines the real location of the robot's motion and road signs by using the EKF-SLAM algorithm [5], so as to simulate the experimental results:

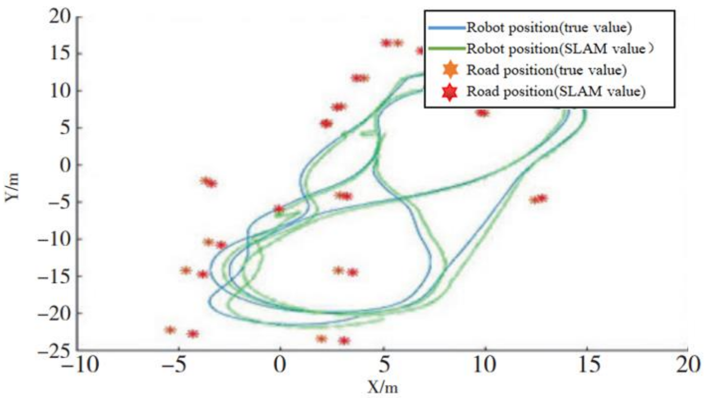

Figure 2. Robot movement location and road sign location [5].

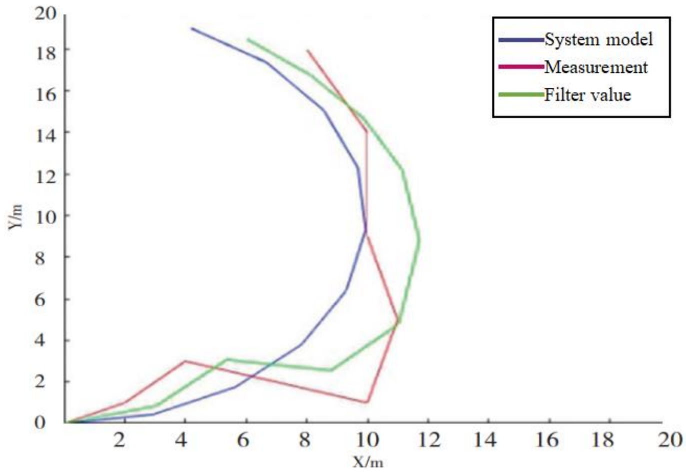

Figure 3. Road signs position error [5].

From the test results, the position of the robot's SLAM position is poor, the position of the position of the SLAN road signs and the real road signs, and the square error of the robot position and the position error of the road signs. It can be seen from the figure 2. and figure 3. that after using EFK-SLAM, the position error of the robot has improved significantly, and the second half of the simulation is getting smaller and smaller. According to the principle of the SLAM problem, in the process of the EFK algorithm, the results of the last estimate will be continuously substituted into the next estimate. After the map construction is completed, the robot will continue to observe the road marking to correct their position, and the map will also be as the computing continues to become more and more complete, theoretically, the entire system will have high accuracy in the later stage of simulation and uncertainty will converge. It can be seen that in the simulation experiment, the EFK-SLAM algorithm has high feasibility, and the effect is fantastic.

3.2. The Kalman filter principle is used to estimate the pose of mobile robots

In this experiment, the state and observation model creation and pose prediction of the mobile robot were completed. The prediction observation calculation was completed, and the matching process of road signs was realized by using the prediction observation and observation measurement. The state update uses the Kalman filter principle to realize the pose estimation of mobile robots, and its essence is to determine the confidence degree of the predicted pose and the pose corresponding to the observation road sign [13]. The following are the simulation results:

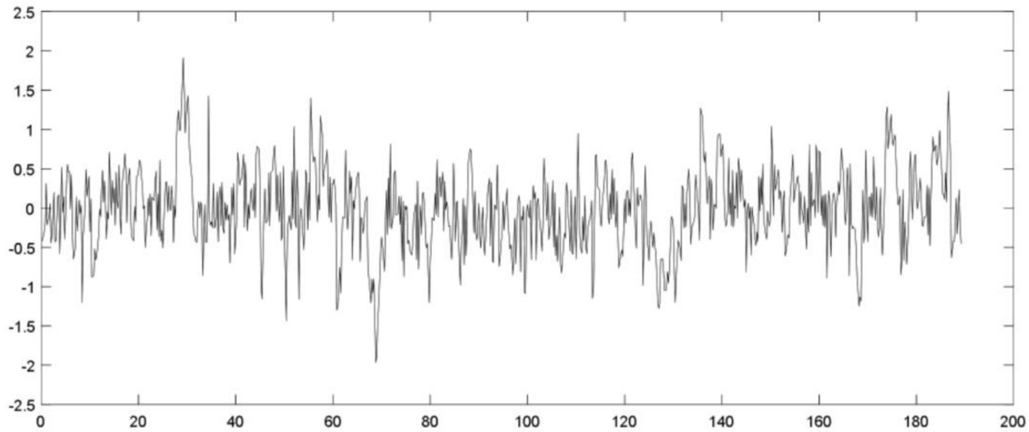

Figure 4. The error of the robot in the x-axis direction [13].

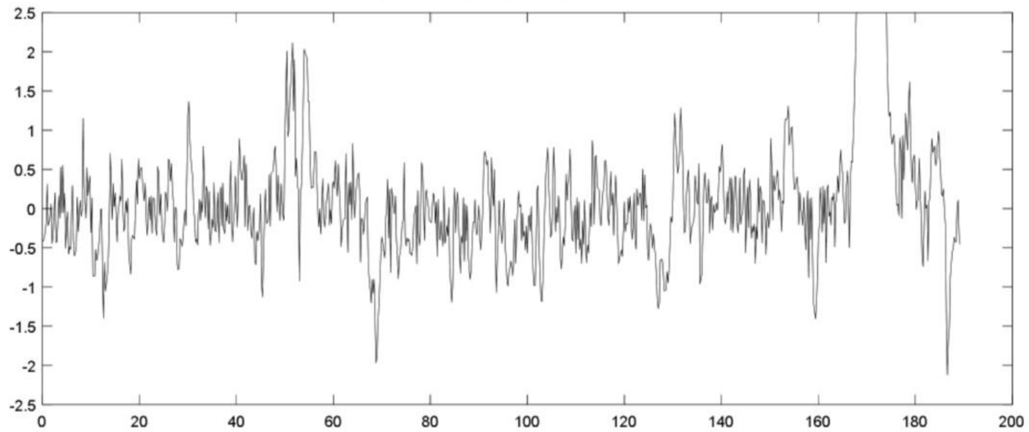

Figure 5. The error of the robot in the y-axis direction [13].

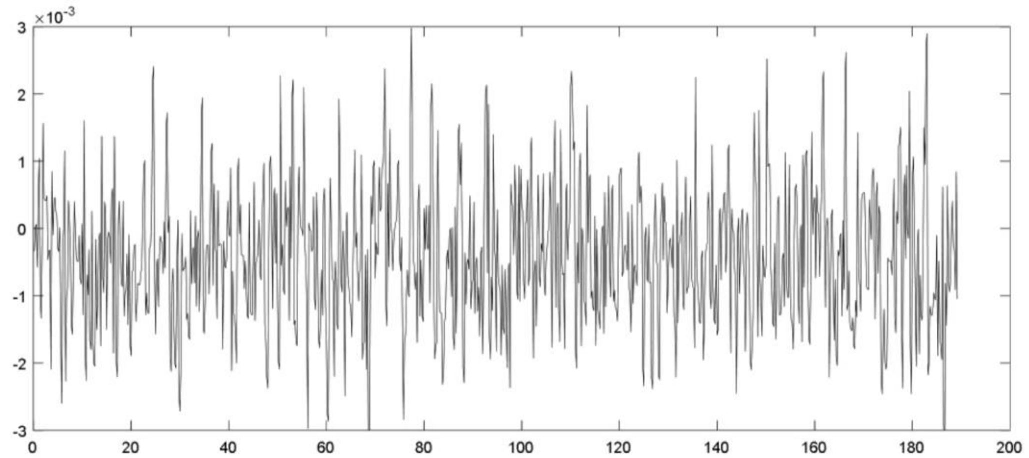

Figure 6. Attitude error of a mobile robot [13].

In view of the precise positioning requirements of mobile robots in the carriage, LiDAR is used to obtain environmental point cloud information to extract and observe straight line features, and then

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match with the straight-line features obtained by using the state model to predict pose, and then complete the estimation process of actual pose by the Kalman filter algorithm. [7] The proposed positioning method using EKF-SLAM based on straight line features shows that the positioning accuracy is high, has good real-time performance, and rapid positioning, which can be used for mobile robot positioning control in a limited area.

4. EKF -SLAM experimental simulation and analysis

This simulation realizes the target tracker that uses the Extended Kalman Filter (EKF) algorithm, which can process radar and lidar measurement data to generate the corresponding trajectory. Among them, EKF plays a role in the following aspects:

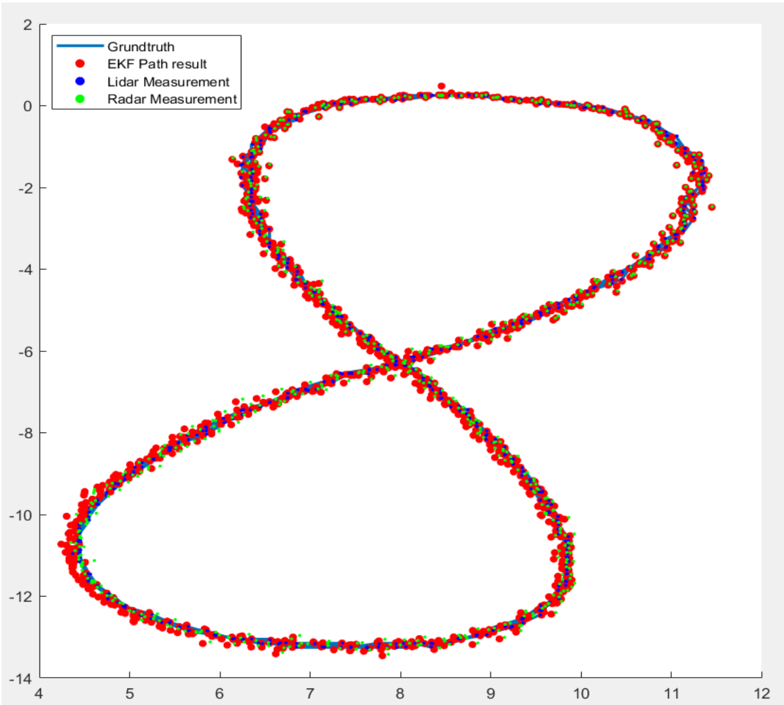

Figure 7. Route plan.

(1) Processing non -linear model: When the system model is non -linear, the conventional Karman filter algorithm fails. However, in the EKF, the Taylor number is carried out by the non -linear function, which can be linearly to be closely solved.

(2) Integrate multiple sensors: This program can simultaneously track the target by using data received from radar and lidar. This is because EKF is not difficult to integrate with multiple sensors, and can adapt to choose the best observation value.

(3) Tracking noise system: Since noise in the system often exists, it must be modelled and considers its impact on the results. By capturing the statistical characteristics of system noise, EKF can more accurately predict and track systems with noise.

Read data from radar and laser sensor data files (CSV files). For each time step, determine the type of sensor (radar or laser). The matrices and parameters required in the construction of EKF include state transition matrix (F), process noise covariance matrix (Q), measurement noise covariance matrix (R-l and R-r), state estimation error covariance matrix (P), etc. Predict states for different sensor types and update state estimates and state estimation error covariance matrices. Among them, the laser sensor measurement is directly used for status update, while the radar sensor measurement needs to be converted for status update. The position estimated by the EKF and the position measured by the sensor are displayed as graphs for visualization and evaluation of the results. In summary, the role of EKF in this code is to estimate and track the location of the target through model prediction and measurement

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updates.

5. Conclusion

In the above simulation, the application range of the Kalman filter algorithm is expanded based on the expansion of the Kalman filter algorithm, enabling it to handle non linear transformations such as rotation and translation in the robot state in the robotic state, as well as non linear characteristics such as noise and errors. By applying EKF technology, these problems can be effectively solved and a more accurate robot location and map information can be obtained. In practical applications, the Extended Kalman Filter algorithm needs to consider many factors, such as the degree of nonlinearity of the system, the size of the measurement noise, and the linearization error. In addition, the Extended Kalman Filter algorithm also has its limitations. For example, it may cause instability in the estimation error when dealing with highly nonlinear problems. Therefore, when using the Extended Kalman Filter algorithm, it is necessary to make reasonable selection and parameter adjustment according to specific application scenarios and problem characteristics. Overall, the application of Extended Kalman Filter technology is of great significance for the realization of robot autonomous localization and navigation. By using this technology, robots can more accurately estimate their own state and the state of the environment, and generate more accurate maps and path planning. Therefore, the Extended Kalman Filter algorithm has become an indispensable part in the field of robotics, providing important technical support for solving problems such as autonomous navigation and environmental perception.

References

[1] X. Liu, W.G Zhang, H. Zhong, X. X. Liu, “Study on SLAM -based rotor combination navigation algorithms,” Computer Measurement and Control, vol .2019,27(03),pp. 197-201.

[2] T. Bailey and H. Durrant-Whyte, “Simultaneous localization and mapping (SLAM): part II,” IEEE Robot. Automat. Mag., vol. 13, no. 3, pp. 108–117, Sep. 2006.

[3] B. Zheng and Z. Zhang, “An Improved EKF-SLAM for Mars Surface Exploration,” International Journal of Aerospace Engineering, vol. 2019, pp. 1–9, Feb. 2019.

[4] L. Wei, Z. Z. Lei, M. Z. Qi, J. R. Yang, “Construction of three -dimensional maps of aircraft simulation cockpit based on visual SLAM,” Civil Aircraft Design and Research, vol. 2023, 148(01), pp.128-133.

[5] Z. D. Lin, “Analysis of the SLAM problem based on the Extended Kalman Filter algorithm,” City Building, vol. 2020,17(11), pp.104-106.

[6] T. H. Wu, “Non -linear navigation data processing theory and its application,” Shan Dong University, vol. 2018.

[7] Y. Shi, H. Y. Wu, W. X. Wen, S. Y. Peng, “Study on SLAM research based on the extended Karman filter,” Electronic Design Engineering, vol. 2012,20(01), pp.104-106.

[8] X. T. Wang, Y. L. Cai, H. N. Jiang, “SLAM algorithm based on adaptive and strong tracking EKF,” China Automation Society System Simulation Professional Committee, vol. 2022,05, pp.282-286.

[9] D. F. Shen, G. F. Shang, G. Zhao, “Improve the EKF-SLAM automatic landing car positioning algorithm,” Journal of Xi'an University of Engineering, vol. 2022,36(06), pp.77-85.

[10] P. C. Cao, J. Lu, Q. M. Gao, “SLAM technology research and analysis based on small plots based on EKF algorithm,” Southern Agricultural Machinery, vol. 2021,52(23), pp. 6+1-4.

[11] T. Liu, “The preliminary application and simulation of the EKF-SLAM algorithm in the

[12] asteroid speed measurement,” Scientific and Technological Information, vol. 2015,13(26), pp. 241-242.

[13] Y. Li, “Map construction and path planning of underwater robots,” Nanjing Information Engineering University, vol. 2018.

[14] Y. H. Cai, J. Tan, G. Wang, “Car Positioning Based on Lidar of Extended Kalman Filter Algorithm and Simultaneous Localization and Mapping,” Industrial Control Computer, vol. 2019,32(12), pp. 12-14.