Integrated Navigation and Positioning of Mobile Robot Based on EKF

Jinfeng Luo1, Dongli Yuan1*, Pengcheng Zhang2, Zhao Guan1, Shihong Su1

1College of Automation, Northwestern Polytechnical University, Xi’an 710072, China
2Shanghai Investigation Design & Research Institute Co., Ltd, Shanghai, China
yuandongli@nwpu.edu.cn

Abstract

The research work is based on GNSS/IMU integrated positioning, and also odometry data is used for fusion positioning to overcome fluctuations of dynamic data. At the same time, Real-Time Kinematic (RTK) technology is employed to improve positioning accuracy. Combined with the EKF algorithm, multi-sensor measurement information is fused so that much more positioning information that is accurate and continuous is obtained. Based on the Robot Operating System (ROS), hardware-in-the-loop simulation experiments are carried out. The theoretical analysis and experimental results show that the robustness and dynamic accuracy of the mobile robot in the field environment are improved by the method employed in this paper.

Introduction

Based on the research background of dam leakage autonomous detection in the field environment of mobile robots, in order to ensure that mobile robots can complete the leakage detection of dams, an integrated navigation and positioning method is proposed in this paper based on the EKF model. Furthermore, based on the ROS platform, hardware-in-the-loop simulation experiments are carried out to verify the effectiveness of the method employed in this paper.

Main Objectives

1. The problem on low accuracy of positioning for a single sensor is overcome.
2. The multi-sensor fusion positioning method is adopted.
3. The hardware-in-the-loop simulation experiment is accomplished.

Materials and Methods

The sensor data preprocessing: sensor initialization, calibration, spatial registration, and time registration.

A quadruped robot simulation environment is established in the Gazebo by simulating a complex outdoor environment, as shown in Fig. 1. At the same time, a quadruped robot simulation model and the sensor model are established by loading the robot URDF file combined with the robot_state_publisher and joint_state_publisher nodes, as shown in Fig. 2.

Mathematical Section

The pose update equation is shown in Eq.(1).

\[
\begin{bmatrix}
\alpha' \\
\omega' \\
\psi'
\end{bmatrix} =
\begin{bmatrix}
\sin\phi\sin\theta & \cos\gamma\sin\theta & 0 \\
\cos\phi & \cos\theta & \sin\phi \sin\theta \\
0 & \sin\phi & \cos\phi \sin\theta
\end{bmatrix}
\begin{bmatrix}
\alpha \\
\omega \\
\psi
\end{bmatrix}
\]

(1)

The velocity update equation is shown in Eq.(2).

\[v_k = v_{k-1} + \frac{T_{th}v_k + T_{ph}v_{k-1}}{2} - g(t_k - t_{k-1})\]

(2)

The position update equation is shown in Eq.(3).

\[p_k = p_{k-1} + T_{th}v_k + T_{ph}v_{k-1}(t_k - t_{k-1})\]

(3)

The model is established according to the motion of the mobile robot, as shown in Eq.(4).

(4)

Results

Based on the ROS, the pose estimation result of the mobile robot is shown in Fig. 4.

(a) Location information from the odometry. (b) Location information from the GPS. (c) Fusion information

Fig. 4. Mobile robot pose estimation

As can be seen in Fig. 5, the velocity of the x-axis and y-axis based on the EKF are consistent with the integral results. As can be seen in Fig. 6, based on IMU integral information, it is consistent for a short time but there are large errors for a long time. The GPS information is discrete, but it can be consistent with the estimation results. The pose estimation of the mobile robot based on the EKF is continuous and precise.

Fig. 5. Speed estimation comparison. Fig. 6. Location estimation comparison

Conclusion

- Based on the EKF, the multi-sensor fusion positioning method is adopted to generate precise pose transformation and continuous positioning information.
- Based on the ROS, a multi-sensor fusion positioning software package is designed to replace the traditional SLAM map matching positioning system.
- The hardware-in-the-loop simulation experiment is accomplished to verify the effectiveness of the method proposed in this paper.

Forthcoming Research

1. Multi-sensor fusion localization experiment of mobile robot will be carried out in real scene.
2. A better multi-sensor fusion localization method will be adopted, such as Federated Kalman Filter.

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