Mobile robot positioning algorithm based on Kalman filtering method in network environment

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Abstract. Positioning is the basic link in a multi-mobile robot control system, and is also a problem that must be solved before completing a specified task. The positioning method can be generally divided into relative positioning and absolute positioning. Absolute positioning method refers to that the robot calculates its current position by acquiring the reference information of some known positions in the outside world, calculating the relationship between itself and the reference information. Absolute positioning generally adopts methods based on beacons, environment map matching, and visual positioning. The relative positioning method mainly uses the inertial navigation system INS. The inertial navigation system directly fixes the inertial measurement unit composed of the gyroscope and the accelerometer to the target device, and uses the inertial devices such as the gyroscope and the accelerometer to measure the triaxial angular velocity and The three-axis acceleration information is measured and integrated, and the mobile robot coordinates are updated in real time. Combined with the initial inertial information of the target device, navigation information such as the attitude, speed, and position of the target device is obtained through integral operation [1-2]. The inertial navigation system does not depend on external information when it is working, and is not easily damaged by interference. As an autonomous navigation system, it has the advantages of high data update rate and high short-term positioning accuracy [3]. However, under the long-term operation of inertial navigation, due to the cumulative error of integration, the positioning accuracy is seriously degraded, so it is necessary to seek an external positioning method to correct its position information [4]

1 Introduction

In order to solve the problem of inertial navigation under long-term operation due to the cumulative error of integration, the positioning accuracy is reduced and GPS absolute positioning cannot be used. This paper proposes a WSN / INS combined positioning algorithm combined with wireless sensor network positioning technology. The algorithm first constructs the coordinate system for the mobile robot working environment, provides a working environment for establishing the WSN / INS combined positioning system, and secondly combines the conversion methods of the combined positioning system under different coordinate systems, and uses the motion characteristics of WMR to establish the combined positioning system. The equation of state, and finally according to the linear characteristics of the established state space model, the Kalman filter is used to combine the data. The WSN / INS navigation method uses the sensor data of INS and WSN, and calculates the redundant or complementary information of these data in space or time through the Kalman filter according to the specified method to obtain unified and consistent positioning information. Because the data collected by multi-sensor nodes is redundant and complementary, it can expand the observation scale in time and space, and strengthen the credibility of effective data. This is more robust and effective for mobile robot formation systems in dynamic environments. Reliability and improving working accuracy are very important. The research work in this chapter will provide a theoretical basis for the subsequent navigation and formation control research

2 MOBILE ROBOT CONTROL FRAMEWORK UNDER NETWORK ENVIRONMENT

In the sensor network environment, the control requirements of mobile robots show new characteristics compared with the past [5-7]: In the network environment, mobile robots can perceive information about obstacles in the workspace through WSN. The spatial characteristics of sensor network information are often affected by communication parameters. At the same time, WSN has the characteristics of strong awareness and diversified information resources. In WSN, environment awareness information is obtained through nodes, and awareness information is also stored on the nodes. This poses new challenges to the placement density of nodes, the selection of effective data, and the effectiveness of information dissemination. Therefore, when WMR, as the main performer,

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combines sensor networks, it is no longer only a participant in network communication, but also a provider of partial information.

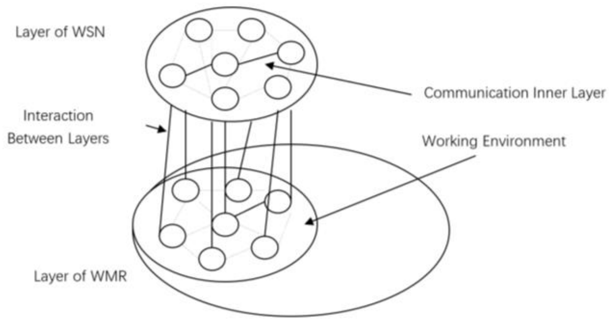


Fig. 1. Mobile formation control method framework based on WSN network.

3 WSN / INS combined positioning method under loose coupling

In the combined design of wireless sensor networks and inertial navigation equipment systems, loosely coupled systems are defined as systems in which each component in the WSN / INS system has little or no knowledge of other individual components. The goal of loose coupling is to minimize the dependence of INS on external navigation equipment. The external navigation equipment in the WSN / INS system can be replaced by other similar functional components.

The proposed WSN / INS combined positioning method first constructs the coordinate system for the WMR working environment, and provides a working environment for establishing the WSN / INS combined positioning system. Combining the transformation methods of different coordinate systems of the combined positioning system, the motion equation of the WMR is used to establish the state equation of the combined positioning system. According to the linear characteristics of the established state space model, the Kalman filter is used to combine the data.

The expression of time continuous navigation in the global coordinate system is

$$\begin{cases} \dot{r}^e = v^e \\ \dot{v}^e = R_b^e f^b - 2\Omega_{ie}^e v^e + g^e \\ \dot{R}_b^e = R_b^e \Omega_{eb}^b \end{cases} \quad (1)$$

r^e and v^e represents the position and speed in the respective coordinate system. f^b is the acceleration value measured under the mobile robot coordinate system. The angular marks *e*, b used to indicate which coordinate system in the current navigation system. They are the earth coordinate system, mobile robot coordinates and inertial gyroscope coordinate system. When the acceleration of the earth is known in the global coordinate system, g^e is the position compensation value. R_b^e is a rotation matrix, which can convert the vectors in the mobile robot coordinate system to the global coordinate system. R_b^e has nine elements and it has three degrees of freedom, so R_b^e can be uniquely described by three angular velocities. The matrices Ω_{eb}^b and Ω_{ie}^e are skewed symmetric matrices, which represent the angular rates of ω_{eb}^b and ω_{ie}^e.

$$\begin{cases} a \times \omega_{eb}^b = \Omega_{eb}^b a \\ a \times \omega_{ie}^e = \Omega_{ie}^e a \end{cases} \quad (2)$$

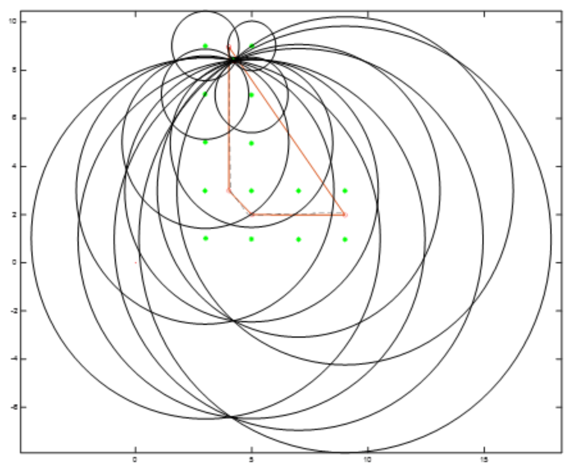
In formular（2）Where a is a 3 × 1 three-dimensional vector, and the matrix Ω_{eb}^b is expressed as follows：

$$\Omega_{eb}^b = \begin{pmatrix} 0 & -\omega_{eb_z}^b & \omega_{eb_y}^b \\ \omega_{eb_z}^b & 0 & -\omega_{eb_x}^b \\ -\omega_{eb_y}^b & \omega_{eb_x}^b & 0 \end{pmatrix} \quad (3)$$

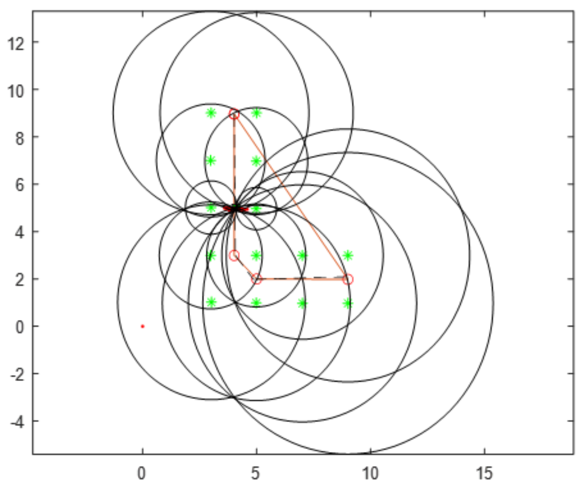
In equation (3), the elements $\omega_{eb_x}^b$ $\omega_{eb_y}^b \omega_{eb_z}^b$ are the angular velocities of the robot coordinate system relative to the earth coordinate system. Solve in the robot coordinate system. The matrix Ω_{ie}^e e is expressed as follows

$$\Omega_{eb}^b = \begin{pmatrix} 0 & -\omega_{eb_z}^b & \omega_{eb_y}^b \\ \omega_{eb_z}^b & 0 & -\omega_{eb_x}^b \\ -\omega_{eb_y}^b & \omega_{eb_x}^b & 0 \end{pmatrix} \quad (4)$$

The input of INS is a three-dimensional value, which is derived from the acceleration measured under the robot coordinate system with respect to the reference value ω_{ib}^b in the inertial coordinate system.



a) trajectory 1



b) trajectory 2

Fig. 2. WSN/INS schematic diagram of navigation trajectory under 14 positioning points

Figures a and b show the comparison between the actual trajectory and the theoretical trajectory of the WSN / INS navigation system when WSN provides 14, 26 anchor nodes for the INS navigation system. The solid black circle is the working area of each anchor node. In the experimental simulation process, WMR takes [4,9] coordinates as the starting point and runs to the end point coordinates [9,2]. As can be seen from Figure 3, the deviation of the WMR actual path (blue dotted line) and the WMR theoretical path (red solid line) becomes smaller as the number of WSN anchor nodes (light green solid points) increases.

Table 1. Comparison of position root mean square error of different positioning methods

Positioning method	East direction error (mm）
INS	1.2
WSN	0.62
WSN/INS filter	0.51
Positioning method	1.2

4 Conclusion

The experimental results show that the WSN / INS integrated navigation system and integrated navigation algorithm designed in this paper are feasible and effective in positioning mobile robots in actual scenarios. Experimental results show that, in terms of network connectivity, under different communication radius conditions, Compared with INS and WSN respectively positioning WMR, the proposed WSN / INS position solution method has a comprehensive positioning accuracy 18% and 59% higher than that of WSN and INS respectively; The goal also lays a theoretical foundation for the establishment of a navigation and formation control system under the network environment.

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References

1. Nepali M M R, Yadav M N, Balasubramaniah M S, et al. A Novel Wall Following Algorithm for Mobile Robots[J]. Computer Science Journals, 2014.
2. Parkinson B W. Global Positioning System: Theory and Applications, Volume II (AIAA)[J]. Aiaa, 1996, 163.
3. Qian C, Liu H, Tang J, et al. An Integrated GNSS/INS/LiDAR-SLAM Positioning Method for Highly Accurate Forest Stem Mapping[J]. Remote Sensing, 2016, 9(1):3.
4. Das A K, Fierro R, Kumar V, et al. A vision-based formation control framework[J]. IEEE Transactions on Robotics & Automation, 2002, 18(5):813-825.
5. These two Army BCTs will be the first to put robotic vehicles in their formations. Todd South. [R/OL].2018. www.armytimes.com
6. Internet of Things: Wireless Sensor Networks[R/OL]. White paper. International Electrotechincal Commission.2014.www.iec.ch
7. Deng X P, Liu Z, Jiang W L, et al. Passive location method and accuracy analysis with phase difference rate measurements[J]. Radar, Sonar and Navigation, IEE Proceedings -, 2001, 148(5):302-307.