Design and Realization of A Mobile Seamless Navigation and Positioning System Based on Bluetooth Technology

Xiaoxue Zhang, Qinghua Zeng, Qian Meng, Zhi Xiong, Weixing Qian

***Abstract*—To address the problem of low precision and easy divergence of the intelligent mobile phone sensors, a dual IMU wearable mobile seamless navigation and positioning system based on Bluetooth technology is proposed. The whole system is divided into foot inertial data acquisition module (IMU), mobile phone self-contained sensor data acquisition module (IMU) and mobile phone positioning module for navigation information solution and display. Foot IMU takes STM32 microcontroller as the core, which is responsible for the timing acquisition of the inertial data, A/D conversion and Bluetooth transmission function. A seamless navigation and positioning application is also be programmed which can run on any android platform. Multiple experimental results show that the system can effectively complete the pedestrian navigation.**

I. Introduction

With the development of intelligent mobile phone and its rich Micro-electromechanical Systems (MEMS) sensors inside it, pedestrian navigation and positioning technology based on the mobile phone becomes an important emerging branch in the field of navigation [1]. Mobile phone navigation system can calculate the position of pedestrians and monitor the human body motion, thus it can be used to improve the military operations, the rapid response ability and the task execution efficiency of emergency rescue workers. The technology can also be applied in civilian field to ensure the safety of pedestrians. Therefore it has broad prospect of applications in military and civilian [2]. Mobile pedestrian navigation technology has become one of the current research highlights in the field of navigation.

The navigation algorithms applied on mobile phone are mainly divided into following four categories: 1) GPS, AGPS (assisted GPS), SGPS(Simultaneous GPS); 2) wireless positioning and navigation technology; 3) the cellular-based station positioning technology which is the most mature technology and its basic fixed base station location.4) the inertial positioning technology which is usually adopted in two ways, pedestrian navigation calculation (PDR) and strap-down decoding (SINS).

There were some research on the mobile positioning technology earlier in abroad, and a lot of remarkable achievements have been made. The researchers of German Aerospace Center use WIFI device in the mobile phone to correct the inertial navigation sensor device on the foot [3]. The researchers of Brigham Young University combine inertial sensor system in the phone and WIFI for indoor pedestrian navigation [4]. Abdulrahim from Nottingham institute of engineering survey and space geodesy, applied extended kalman filter for personal positioning, by combining satellite navigation and inertial combination, then bring in the street information as auxiliary to correct the movement direction of the pedestrian which number is limited [5]. Many domestic units have done a lot of researches in mobile navigation [6]–[7], such as Nanjing University of Aeronautics and Astronautics, Beijing University of Aeronautics and Astronautics, NPU etc. Their research focuses on pedestrian navigation algorithm base on information fusion which center is inertial sensor in mobile.

Since 2005, Navigation Research Center of NUAA, has cooperated with the Hong Kong Polytechnic University and the University of Leeds in the research of pedestrian navigation system [8]. The wearable seamless navigation and positioning system realized in this paper which is composed of the foot measurement device and smart phone, is the prototype of the second generation pedestrian navigation system of Navigation Research Center.

II. Principle of Seamless Navigation and Positioning System

A. System principle introduction

As shown in Fig.1, the whole system is divided into three parts, micro inertial data acquisition module, Bluetooth serial port module and intelligent mobile phone terminal. Foot IMU takes STM32 microcontroller as the core, which is responsible for the timing acquisition of the inertial data, A/D conversion and Bluetooth transmission function. Micro inertial data acquisition module communicates with the mobile terminal through hc05 master-slave integrated Bluetooth serial module, of which baud rate is 115200bps.

Bluetooth module is connected with STM32 internal UART interface. STM32 monitors and controls the Bluetooth module working mode, in response to the control word from intelligent mobile phone terminal transmitted by Bluetooth

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wireless in interrupt mode. The seamless navigation and positioning application which can run on any android platform respond to receive foot IMU data, and fuse with the phone IMU data and GPS data by Kalman filter algorithm, the application can also save and display navigation information (position, velocity and attitude). Users can save the dual IMU original sensor data and navigation information to send directly to the integrated monitoring server through the network for collaborative scheduling and sports management.

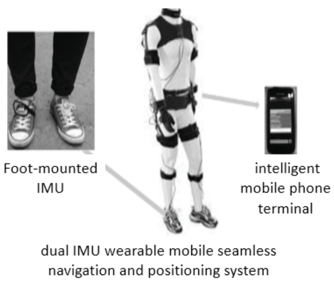

Figure 1. Seamless navigation system schematic

B. Structure design of integrated navigation algorithm

Due to the low precision and easy divergence of the MEMS sensors, the traditional strap-down inertial navigation algorithm can't be applied to the pedestrian inertial navigation system very well, thus zero velocity correction technology is added [9].

Kalman filter algorithm is widely used in engineering, and it is one of the most effective methods of data fusion. In this paper, a variety of data filtering methods has been tried, but finally taking into account the effectiveness of data fusion and the calculation of the algorithm, the basic linear Kalman filter is chosen still.

The state of the system filter is listed as follows:

$$\boldsymbol{X}=[\varphi_E \quad \varphi_N \quad \varphi_U \quad \delta v_E \quad \delta v_N \quad \delta v_U \quad \delta L \quad \delta\lambda \quad \delta h \quad \delta K_{gx} \quad \delta K_{gy} \quad \delta K_{gz} \quad \delta K_{ax} \quad \delta K_{ay} \quad \delta K_{az}]^T$$

Where $\varphi_E \quad \varphi_N \quad \varphi_U$ are the initial alignment errors of mathematical platform, $\delta v_E, \delta v_N, \delta v_U$ are velocity errors, $\delta L, \delta\lambda, \delta h$ are position errors, $\delta K_{gx}, \delta K_{gy}, \delta K_{gz}$ $\delta K_{ax}, \delta K_{ay}, \delta K_{az}$ are three axis gyro and three axis accelerometer factor errors respectively.

The observation values of Kalman filter are listed as follows:

$$Z_k = [\delta\gamma, \delta\theta, \delta\psi, \delta v_E, \delta v_N, \delta v_U]$$

Where $\delta v_E, \delta v_N, \delta v_U$ are the observations of velocity error, since the velocity should be zero when the person is in a stance phase, the velocity calculated by the foot-mounted IMU is input to KF as the observation value of velocity errors. $\delta\gamma, \delta\theta$ are the roll, pitch angle observation errors, the difference between the roll, pitch angle recalculated by accelerometer output at zero speed stage and the roll, pitch angle calculated by inertial navigation algorithm are used as the observation values of Kalman filter. $\delta\psi$ is the yaw observation error measured from the difference between the foot-mounted IMU and mobile IMU.

C. Indoor and outdoor seamless integration strategy

Seamless positioning technology using a variety of navigation technologies to navigate carriers in different areas, and meet the demand of seamless connection when carrier moves between different environments. Positioning mode is divided into GPS signal mode and no GPS signal mode [10]–[12].

As shown in Figure 2, the algorithm will determine the availability of GPS signals to select the system's working mode at the initial time. In the process of navigation, the system can also automatically make the indoor and outdoor mode switching through the real-time judgment of the GPS signal. It's remarkable that current GPS reference position only accepts set once, which is also used as the reference point for the integrated navigation of inertial navigation and GPS position, subsequently integrated navigation position used relative position with the relative position of the first GPS valid time position.

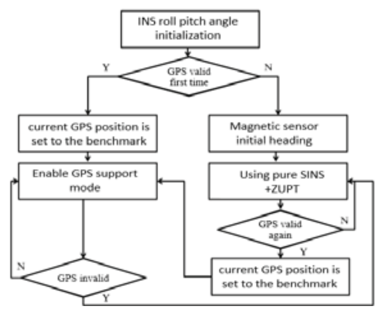

Figure 2. Sketch map of seamless positioning algorithm

III. DESIGN OF PEDESTRIAN NAVIGATION SYSTEM

A. Hardware system

As shown in Fig.3, the wearable mobile seamless navigation and positioning system includes: lithium battery and a voltage stabilizing module, micro inertial data acquisition module, a Bluetooth serial module, and smart phone terminals; considering the processor of volume, cost, power consumption, convenient use and the like in many situations, the foot-mounted IMU chooses ST companies' latest STM32f4 series. Compared to ARM7, ARM9 processor, has the advantages of small volume, low power, embedded independent DSP core, and has a large internal capacity of ram and flash capacity, without the need for external memory expansion, to ensure that the volume of the system.

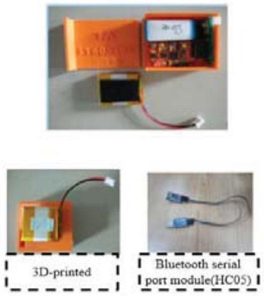

Figure 3. Hardware physical map

As shown in Fig.4, Intelligent mobile terminal chooses Samsung Galaxy S6, and its equipped sensors include: light intensity sensor, proximity sensor, gesture sensor, a three-axis accelerometer, gyroscope and magnetometer, fingerprint recognition, heart rate sensor and barometric altimeter. Its ability to locate in the outdoor GPS include: A-GPS, GPS, GLONASS and Beidou satellite positioning.

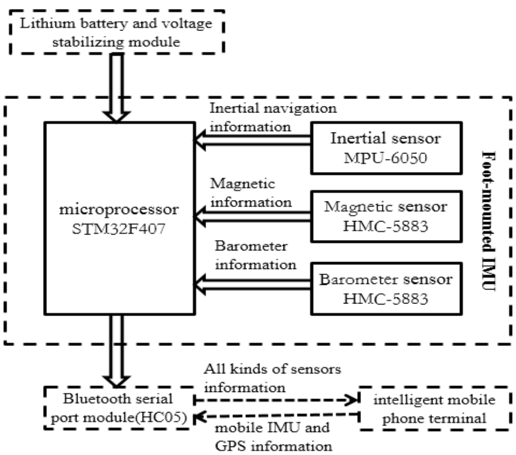

Figure 4. hardware design of system

B. *Software system*

The goal of the system software platform is to develop a real-time solution and display integrated platform which can read data from the sensors and can also save real-time sensor data and navigation data for later analysis. In addition, the software platform needs to realize the online calibration of inertial sensors and navigation two functions. According to this requirement, the software platform framework is set up as shown in Fig.5.

The entire software procedure can be divided into three main modules according to the function: data receiving and unpacking module, navigation module of data calculation, data storage, and display module. The original IMU data and navigation data are both save in files for the convenience of users to call and check etc. Software platform receives the foot-mounted IMU data though Bluetooth APIs, and conducts real-time navigation calculation, as shown in Fig.6.

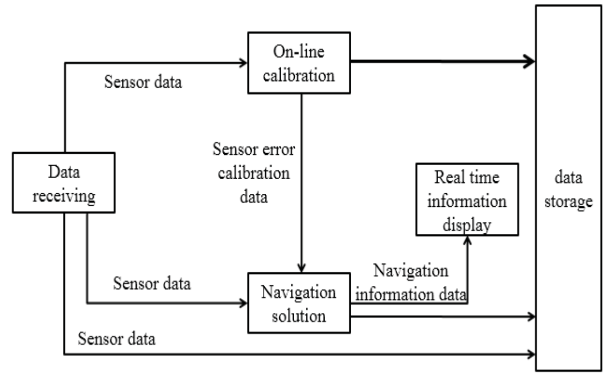

Figure 5. Schematic diagram of software system structure

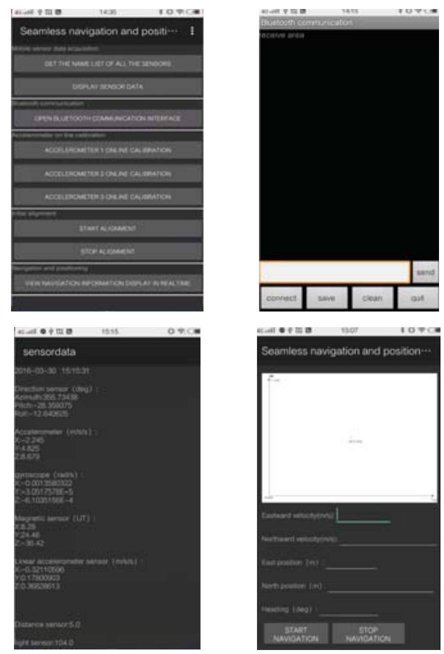

Figure 6. Intelligent terminal software interface diagram

IV. EXPERIMENTAL VERIFICATION

In order to validate the effectiveness of indoor and outdoor seamless positioning navigation system hardware and software platform, the author carries out a lengthy walking experiment in Nanjing University of Aeronautics and Astronautics. The experimental routes include indoor and outdoor environments, and total travel route length is more than 1000m. GPS signals are lost in indoor environments. In addition outdoor sections due to occlusion of the buildings and trees, GPS signal also exist partial failure. During the experiment, the MEMS sensor is fixed on the human foot, sending data to the intelligent mobile phone.

Seamless positioning software provides the navigation results, as shown in Table 1, the unit of the horizontal coordinate is the meter. After navigation two dimensional position error of starting point is 4.69 meters. The whole navigation results can reflect the walking track very well.

TABLE I. COMPARISON OF POSITIONING RESULTSC

Navigation mode	position error	Distance percentage	Heading drift
Seamless positioning mode	4.69m	0.47%	no
Inertial positioning mode	56.88m	5.6%	yes

V. CONCLUSION

This paper has designed the corresponding hardware and software platform, and has realized the individual indoor and outdoor seamless personal positioning system based on multi information fusion. This system has the advantage of low power consumption, convenient installation, small size, light weight, high stability, wide applicability, normal activities without restriction and portability. Multiple experimental results show that the system can effectively complete the pedestrian navigation.

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