Application and Analysis of Mobile Phone Sensors of Mobile Phone Sensors in Indoor Navigation

Junxi Peng[1], Mingyang Xu[2], Hailin Zhu[3,*]

[1]Electrical and Computer Engineering, Shenzhen MSU-BIT University, Shenzhen, China
[2]Rosedale, Toronto, Ontario, Canada
[3]School of Information Science and Technology, NorthwestUniversity, Xi'an,710000 ,China
* hz22170@essex.ac.uk

Abstract. s smartphones become increasingly versatile, positioning services are present in all aspects of our lives. However, the positioning services of most mobile phones are limited to outdoor environments, and the positioning in indoor environments is often not accurate enough. This article mainly explores the main types of mobile phone sensors and the principles of indoor navigation technology based on mobile phone sensors. At the same time, this paper analyzes the processing flow of different signal interference and noise and common positioning accuracy calibration methods. Based on summarizing the existing research results of indoor positioning technology, its important significance to the development of the industry is clarified. Existing mobile phone sensors mainly rely on accelerometers and gyroscopes in indoor navigation, which have been relatively maturely developed and applied. However, there are still many areas for improvement in precision calibration and filtering algorithms, and relevant research is still needed in the industry. In summary, this paper looks forward to the possibility of further improving the application of mobile phone sensors in indoor navigation through the use of new technologies and new algorithms in the future.

Keywords: Mobile Phone Sensors, Dynamic Analysis, Indoor Navigation Technology, Filtering Algorithms, Calibration

1 Introduction

Recently, the internal structures of large buildings in cities have become increasingly complex, and people's demand for navigation in indoor environments has increased dramatically. In the field of navigation, although the Global Positioning System (GPS) plays a great role in outdoor navigation, the GPS signal will be attenuated or blocked in indoor environments, and traditional outdoor navigation technology is difficult to provide an effective indoor positioning solution. Therefore, in order to meet the high-precision requirements of indoor navigation, the application of mobile phone sensors in indoor navigation has become crucial.

The principle of indoor navigation technology based on mobile phone sensors is to use multiple sensors in the mobile phone to sense the movement state, direction and

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changes in the surrounding magnetic field of the mobile phone, and then use positioning algorithms to infer the user's position and movement trajectory [1]. Mobile phone sensors have the significant advantage of being highly portable. Users do not need to carry additional navigation equipment and can achieve indoor navigation with just their daily mobile phones, which greatly improves the convenience of use. In addition, there are many types of mobile phone sensors, such as accelerometers and gyroscopes, which can work together to sense the user's movement state and direction changes in real time, providing more accurate data support for indoor navigation.

Although mobile phone sensors have many advantages in indoor navigation, there are still research difficulties such as sensor error accumulation, geomagnetic anomaly interference, signal blocking and multipath effect. In the future, positioning accuracy and stability can be improved by improving algorithms, fusing multi-sensor data, optimizing indoor map construction and updating technology, and using artificial intelligence.

Research in this field has achieved certain results at home and abroad. For example, in 2013, research on geomagnetic indoor positioning and navigation was carried out [2]. In addition, the UNLOCK system (multi-sensor fusion positioning system) was developed by researchers from Duke University and others [3]. In 2023, Iranian researchers conducted research on sensor fusion algorithms and related research on indoor map construction and matching [4,5].

Therefore, this paper aims to explore the types of mobile phone sensors, dynamic analysis of mobile phone sensors, key issues and optimization strategies, principles of indoor navigation technology based on mobile phone sensors, experimental design and application case analysis, to advance the application and research of mobile phone sensors in indoor navigation.

2 Characteristics and Working Principles of Mobile Phone Sensors

2.1 Types of Mobile Phone Sensors

Firstly, mobile phone sensors are primarily categorized into motion sensors, environmental sensors, position sensors, biometric sensors, and other types of sensors. An indoor navigation system based on mobile phone sensors utilizes the accelerometer and gyroscope from motion sensors; the ambient light sensor and barometer from environmental sensors; the magnetometer and GPS from position sensors; as well as Bluetooth and Wi-Fi sensors from other types of sensors.

The accelerometer in a mobile phone is a miniature electromechanical vibration system known as Micro-Electro-Mechanical Systems (MEMS). It is a vibrating structure whose vibration characteristics are influenced by external acceleration, thereby allowing it to measure acceleration. Essentially, the accelerometer measures acceleration by quantifying force [6].

The gyroscope sensor is capable of detecting the real-time angular velocity of a phone's rotation. The microelectromechanical gyroscope, abbreviated as MEMS gyroscope, consists fundamentally of an application-specific integrated circuit and a micromechanical silicon sensor. The MEMS gyroscope relies on the alternating Coriolis force generated by mutually orthogonal vibrations and rotations. The vibrating object is suspended above the substrate by a flexible elastic structure. The overall dynamic system is a two-dimensional elastic damping system, within which the Coriolis force induced by vibration and rotation transfers energy proportional to the angular velocity to the sensing mode [7,8].

Magnetic field sensors utilize magnetoresistance to measure planar magnetic fields, thereby enabling the detection of magnetic field strength and the determination of a device's orientation and position. The most common application is the compass in smartphones, which assists individuals who are disoriented in easily obtaining directional information. Nowadays, they are also used in map navigation to help smartphone users achieve precise positioning [9,10].

2.2 Sensor Data Analysis

2.2.1 Timeliness of Data Changes.

Mobile phone sensors are capable of capturing changes in the external environment or device status in real-time. The accelerometer can instantly sense alterations in the phone's motion, such as when a user picks up, moves, or shakes the phone, causing the acceleration data to change rapidly. The gyroscope operates similarly; it can quickly detect changes in angular acceleration when the phone is rotated. For instance, during motion-sensing games, when a player turns the phone, the gyroscope promptly transmits the angle change information to the game software, enabling the virtual perspective in the game to adjust in real time according to the player's movements.

2.2.2 The continuity of data.

Sensor data is a continuous stream of information. Take the light sensor as an example. As the ambient light intensity gradually changes, such as when moving from indoors to outdoors or when moving between rooms with different light intensities, the light sensor will output continuously changing data. It doesn't exhibit sudden jumps, but smoothly changes its values according to the gradual change of light, providing a continuous and stable basis for functions like automatic screen brightness adjustment. For motion sensors, during the continuous movement of users, such as running or walking, the accelerometer and gyroscope will continuously output a series of relevant data. These data can be used to analyze multiple dynamic parameters such as the movement trajectory, speed, and direction. Moreover, the changes in these parameters are also continuous, enabling a complete description of the movement process.

3 Principle of Indoor Navigation Technology Based on Mobile Phone Sensors

3.1 Basic sensor positioning principle

The sensor positioning principle is drawn from the inertial navigation principle. As the research of this paper knows from the inertial navigation principle, the main sensors used in inertial navigation are accelerometers and gyroscopes. When the initial state (speed, direction, and initial position) is known, the position and motion state are continuously updated by integrating the acceleration and superimposing the monitored direction. Therefore, accelerometers and gyroscopes are also called Inertial Measurement Units (IMUs). According to different needs, IMUs are divided into different types, namely piezoresistive sensors, piezoelectric sensors, capacitive sensors, and resonant element sensors. An accelerometer is a measuring instrument that measures the magnitude of the acceleration of an object in a certain direction. In today's smart devices, it is often used in combination with magnetic sensors to detect the motion posture of the device, which is convenient for game development. The accelerometer usually includes the gravitational acceleration g (9.8m/s^2), so the value of the accelerometer is not zero even in a stationary state. According to different applications, it is also divided into single-axis, dual-axis, and three-axis accelerometers. Fig. 1 is a schematic diagram of the structure of a capacitive accelerometer:

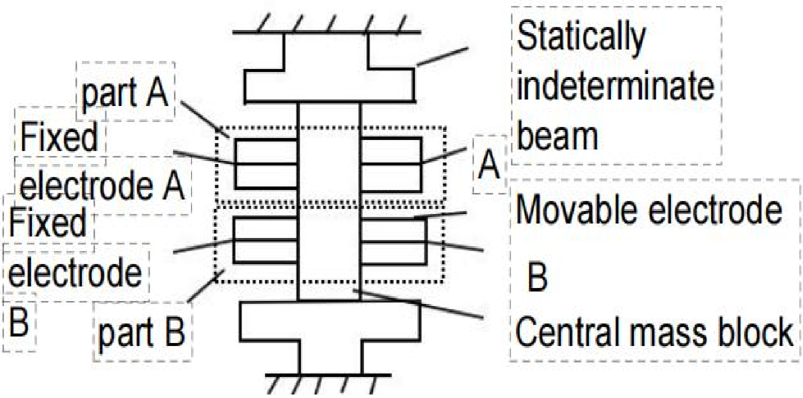

Fig. 1. Schematic diagram of capacitive accelerometer structure(Picture credit : Original)

A gyroscope is a device used to sense and maintain direction, designed based on the theory of conservation of angular momentum. It mainly consists of a rotatable rotor located on the axis. Once the gyroscope starts to rotate, due to the angular momentum of the rotor, it has a tendency to resist changes in direction. Moreover, it measures angular velocity by utilizing the Coriolis acceleration.

During the PDR (Pedestrian Dead Reckoning) process, magnetic sensors are often used to determine the north direction to reduce the accumulation of heading errors and determine the initial heading. In terms of distance determination, the number of steps is used instead of integrating velocity and time through the accelerometer. The accelerometer can be used to monitor changes in walking acceleration to determine the number of steps, and in special cases, the gyroscope can also be used for detection. Regarding heading determination, magnetic sensors can be used to monitor the heading, or after determining the initial heading, the gyroscope can be used to monitor the change in heading. Additionally, Kalman filtering can be applied to fuse the directions obtained from both sensors.

The calculation and implementation of pedestrian trajectories generally involve three elements: position coordinates, step length, and direction angle.

Position Coordinates: Usually, they include the abscissa (such as in the x-direction) and ordinate (such as in the y-direction) of the pedestrian in a certain reference coordinate system, which are used to determine the specific position of the pedestrian in space.

Step Length: It refers to the length of each step taken by the pedestrian. This is an important parameter as it affects the update of the pedestrian's position. The step length may vary depending on factors such as the pedestrian's walking speed and physical characteristics.

Direction Angle: It represents the direction in which the pedestrian is walking, usually expressed as an angle, for example, the angle relative to a reference direction (such as the true north direction). This angle determines the horizontal and vertical components of the pedestrian's movement in the next step. As can be seen from the above, it is first necessary to determine the initial position and initial heading. Then, during the subsequent position estimation process, direction and distance are crucial. However, obtaining distance and direction is the difficulty of the entire technology. Although MEMS (Micro-Electro-Mechanical Systems) sensor technology has made great progress and is being applied more and more widely, most of them are at the consumer-grade level with low accuracy. They cannot calculate the motion state and position information through integration like inertial navigation. As can be seen from the above, pedestrian dead-reckoning (PDR) does not require strict initial platform calibration as in traditional inertial navigation, nor does it need to integrate acceleration in real-time. However, in PDR, it is difficult to ensure that the body's center of gravity strictly coincides with the walking motion, so zero-velocity determination is necessary. As a result, when a person is not walking, the acceleration integration still occurs, leading to the accumulation of errors. The PDR technology directly determines the gait and distance through the periodicity of the waveform. Compared with traditional inertial navigation algorithms, it is simpler, but it requires a pre-prepared step-length training model. Therefore, as can be known from many conclusions [11], given the low-precision sensors, the cost-performance ratio of the PDR navigation technology is much higher than that of traditional inertial navigation technology. It can also achieve satisfactory navigation and positioning accuracy using low-cost and low-precision sensors [12].

3.2 Overview of Positioning Technologies Based on Different Platforms

3.2.1 Wi-Fi-based positioning technology and RFID-based indoor positioning technology

Wi-Fi-based positioning technology has developed along with the growth and popularization of Wi-Fi technology. Currently, there are mainly two types. The first type is achieved based on triangulation. First, the signal strengths of the user device relative to three Wi-Fi networks are obtained. After that, precise positioning is realized through a calculation using the differential algorithm. The second type involves recording the Wi-Fi signal strengths at a large number of determined locations in advance. Then, whenever a new device joins the network by connecting to Wi-Fi, its location can be determined by querying and comparing the closest "fingerprint" in the database according to its signal strength. RFID is a positioning method through card-swiping. It is an interval-positioning method, which can locate the person or device that swipes the card based on the location of the card reader. Its main application scenarios are warehouses and factories where card-swiping is required to enter the corresponding spaces. Its drawback is that it cannot achieve real-time positioning of people or devices, and can only perform positioning based on card -swiping records. Therefore, its positioning accuracy is relatively low, and its application scenarios are limited [13].

3.2.2 Based on GPS positioning (mostly used outdoors).

GPS stands for Global Positioning System, which is currently the most widely used positioning technology worldwide. Its main principle is to determine the position by receiving position coordinate information from satellites. Under normal circumstances, the positioning accuracy can be within 5 meters, so it can meet numerous outdoor positioning scenarios. It only needs to receive signals from at least 4 satellites to locate the position of the GPS-using a terminal on the Earth's surface. Moreover, the more satellite signals it receives, the higher the positioning accuracy will be. The positioning service it provides has covered 98% of the global area, but it is limited to positioning on the Earth's surface. However, in some cases, such as in tunnels where the GPS signal is extremely weak, the positioning error will be very large. On complex overpasses, where the roads are very dense and criss-cross both vertically and horizontally, the positioning error of GPS will also increase.

3.2.3 Base station positioning.

Base station positioning is a location-based service that realizes the positioning of mobile terminal users based on the GSM network. A mobile device joins the GSM network by inserting a SIM card. After joining the network, it will actively search for information about the base stations within its signal range. Due to the large number of currently deployed base stations, their distances from the mobile terminal vary depending on the signal strength. After finding the nearby base stations, the mobile terminal will establish a connection with them. Since the farther the distance from the base station, the weaker the received signal, the approximate distance between the mobile terminal and the base station can be inferred according to the strength of the signal received by the mobile terminal. The trilateration method is used to locate the approximate position where the mobile terminal is located. Table 1 shows the advantages and disadvantages of positioning technologies based on various platforms.

Table 1. Inductive Diagram of the Advantages and Disadvantages of Positioning Technologies for Each Platform

	WIFI Indoor Positioning	RFID Indoor Positioning	GPS positioning	Base station positioning
Advantages	Strong applicability Low cost High accuracy (fingerprint method)	Easy to use Low cost Suitable for specific scenarios	Wide global coverage Convenient to use	No additional hardware is required. The approximate location can be obtained quickly.
Disadvantages	Vulnerable to interference Reliant on database updates	Poor real-time performance Low accuracy Limited application scenarios	Weak performance indoors Greatly affected by the environment	Rely on the density and distribution of base stations Affected by signal interference

4 Methods of signal interference and noise handling

Compared to outdoor environments, indoor environments have more complex and variable layouts, and there are multiple sources of interference that can affect indoor navigation performance, including walls, electronic devices, metal fixtures, and crowded areas. When the signals from the sensors encounter these interference sources and are reflected and refracted, resulting in multiple paths with different signal strengths and phases, they may interfere with each other, leading to attenuation or distortion of the signals received by the sensors. The basic principle is shown in Fig. 2.

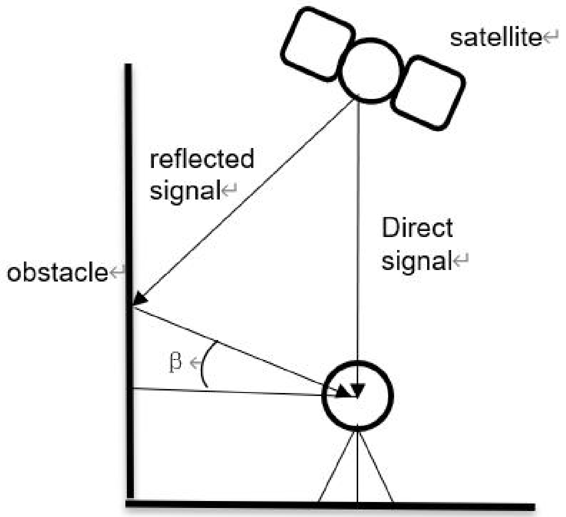

Fig. 2. Schematic diagram of multipath effect(Picture credit : Original)

To filter these disturbances as much as possible, various filtering algorithms are widely used

4.1 Kalman filtering

Unlike traditional filtering methods that can only be realized under the condition that the useful signal and the noise have different frequency bands, Kalman filtering makes use of the linear system state equation to optimally estimate the state of the system through the system's input and output observations, without requiring the assumption that both the signal and the noise are smooth processes. Kalman filtering can predict the coordinate positions and velocities of objects from a finite set of observation sequences that contain noise with respect to the object's position. At the same time, Kalman filtering can combine information from multiple sources, including sensor data, to optimize the estimation of the system state under different noise conditions.

4.2 Low-pass filtering

Low-pass filtering is a type of filtering where the rule is that low-frequency signals pass through normally, while high-frequency signals above a set threshold are blocked and attenuated. Low-pass filter is often used to process the raw data obtained from accelerometer sensors. In practice, the signal output from an accelerometer may be affected by high-frequency noise. For example, small vibrations from handheld devices, circuit noise within the sensor, etc. These noises can affect the accuracy and stability of the acceleration signal. Processing the output signal of the accelerometer through a low-pass filter can effectively remove the high-frequency noise and retain the useful low-frequency signal, thereby improving the accuracy and reliability of the acceleration measurement.

4.3 Complementary filtering

The principle of complementary filtering utilizes the characteristics of accelerometers that are more accurate over a long period and gyroscopes that are more accurate over a short time, doing low-pass filtering on the accelerometers to filter out high-frequency noise and high-pass filtering on the gyroscopes to filter out low-frequency noise, and by combining these two types of signals, utilizing their respective advantages to compensate for the other's shortcomings, thus providing a stable and accurate estimate of the attitude. Complementary filtering can also effectively reduce the error of a single sensor by fusing multiple sensor data. Compared to other algorithms, complementary filtering does not require complex mathematical calculations and model building, and is easy to implement and debug. This enables it to operate efficiently even in resource-constrained embedded systems.

5 Challenges and Prospects

5.1 Discussion of Common Positioning Accuracy Calibration Methods and Deficiencies

In the application of cell phone sensors for indoor positioning, there exist multiple positioning calibration methods, and this section discusses common positioning accuracy calibration methods and their shortcomings from the perspective of data received from five different sensors.

5.1.1 Zero Calibration.

Determine the output value of the sensor in the absence of an input signal, i.e. the zero offset.

Power on the sensor and allow it to reach a stable operating condition. Ensure that the sensor is measuring without an input signal. Record the output value of the sensor in this no-input state, this value is the zero offset value. Adjust the zero offset to zero by adjusting the sensor's calibration parameters (e.g., zero knob, software calibration options, etc.). Record the final calibrated zero output value.

A common problem is that environmental factors such as temperature, humidity, electromagnetic interference, etc. can affect the zero output of the sensor, and mechanical stresses during installation and use can cause the zero offset.

5.1.2 Sensitivity Calibration.

Determine how well the sensor responds to changes in the input signal, i.e. the sensitivity factor.

Power on the sensor and allow it to reach a stable operating condition. Apply a standard input signal to the sensor and record the sensor output value. Based on the known standard input signal and the sensor output value, calculate the sensor's sensitivity factor, which is usually expressed as the ratio of the change in the sensor's output signal to the change in the physical quantity. Adjust the sensitivity factor of the sensor to the standard value using calibration equipment or software. Record the calibrated sensitivity factor and the corresponding output value.

A common problem is that the accuracy of the sensitivity calibration can be affected if the relationship between the sensor output and the input signal is not linear.

5.1.3 Linearity Calibration.

Determine the linear relationship between the sensor output and the input signal, calibrated with multiple known input signals.

Power on the sensor and allow it to reach a stable operating condition. Select several different input signal values within the operating range of the sensor, and for each known input signal, record the output value of the sensor. Plot the input signal against the output signal in a coordinate system. A calibration curve is obtained by fitting the measured data using linear regression or least squares. The equation of the calibration curve is: $y = kx + b$ where y is the output signal, x is the input signal, k is the sensitivity coefficient and b is the zero offset. Based on the fitted calibration curve equation, the calibration parameters of the sensor are adjusted so that the sensor output conforms to a linear relationship.

The common problem is that if the measuring range of the sensor changes (extreme high and low values), this may result in measurements outside the expected range.

5.1.4 Temperature Calibration.

Consider the effect of temperature changes on sensor performance and compensate for temperature errors by calibrating at different temperatures.

Select an environment where the temperature can be controlled and regulated, power on the sensor and allow it to reach a stable operating state. Select a number of different temperature points for calibration within the sensor's operating temperature range. Place the sensor at the set temperature, wait for it to stabilize, and record the sensor's output value. Repeat this process at each temperature point. The recorded temperature points and corresponding output values are plotted on a graph to analyze the effect of temperature changes on the sensor output and to establish a temperature compensation curve. Based on the fitted compensation curve, adjust the temperature compensation parameters of the sensor to stabilize its output at different temperatures. Record the data after calibration.

The common problem is that the sensor needs a certain amount of time to reach temperature equilibrium, if the waiting time is not enough, it may lead to inaccurate measurement.

5.1.5 Repeatability Calibration.

Evaluate the repeatability and stability of the sensor by taking multiple measurements of a known input signal.

Power on the sensor and allow it to reach a stable operating condition. Set a fixed input signal value within the measurement range of the sensor. Repeat the measurement of the fixed input signal several times under the same conditions and record the output value of each measurement. The mean and standard deviation are calculated for all measurements to assess the central tendency, dispersion and repeatability of the sensor. Based on the results of the analysis, the calibration parameters of the sensor are adjusted.

A common problem is that the sensor may drift over a short period of time, resulting in a change in the output signal.

5.2 Existing deep research on indoor positioning techniques

5.2.1 Adaptive Pedestrian Trajectory Extrapolation Algorithm.

The PDR technology based on inertial sensors can measure and count the number of steps, step length, and direction of the walker's walking, and extrapolate the information of the walker's walking trajectory, and position. It has the ability of accurate localization in short distances. However, when PDR technology is used for long time or long distance localization, its localization accuracy will gradually decrease because the error will be accumulated. And the adaptive pedestrian trajectory projection algorithm proposed by chen et al [8], which combines the over-zero detection method and the peak prediction technique based on dynamic time planning, can accurately recognize the gait, accurately estimate the stride length, and dynamically adjust the stride parameter, so as to reduce the cumulative error of the PDR technique.

5.2.2 Continuous indoor visual localization method combining perceptual hashing and spatial constraints.

Visual localization realizes position calculation by matching the visual information obtained from the camera with the visual features of the environment, which is difficult to support continuous localization when the amount of calculation is large indoors. And for environments with less visual data, continuous trajectory localization cannot be achieved by relying only on visual matching. Chao Wang et al [9] proposed a continuous indoor visual localization method by combining perceptual hashing and spatial constraints, which can achieve accurate visual localization by matching continuous video frames captured by a smartphone with indoor image datasets, and its localization accuracy can reach the nanometer level.

6 Conclusion

This paper mainly studies the application of mobile phone sensors in indoor navigation, and the results show that it can effectively make up for the shortcomings of GPS in indoor environment navigation. The research of this paper integrate multiple sensor data and different positioning technologies to accurately track the user's movement trajectory indoors. Sensor fusion algorithms can effectively improve data processing accuracy and anti-interference capabilities. This article mainly describes how to combine indoor positioning technologies such as inertial measurement unit (IMU), Wi-Fi positioning, FRID-based indoor positioning, GPS positioning, and base station positioning to achieve complementary advantages. These make the application of mobile phone sensors in indoor navigation more portable, real-time and cost-effective. At the same time, this paper discusses the shortcomings of common positioning accuracy calibration methods for sensors and proposes to use an adaptive pedestrian dead reckoning algorithm and indoor continuous visual positioning method combining perceptual hashing and spatial constraints to improve this problem. In the future, the research of this paper can try to use artificial intelligence methods to intelligently identify the characteristics of complex indoor environments and improve the adaptability and intelligence level of navigation systems. Through continuous in-depth research and technological progress, mobile phone sensors can provide people with more accurate, convenient, and efficient indoor navigation services in the field of indoor navigation. Therefore, mobile phone sensors have broad application prospects and research value in the field of indoor navigation.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

1. Ghahramani, M., Zhou, M., Wang, G.: 'Urban sensing based on mobile phone data: approaches, applications, and challenges', IEEE/CAA Journal of Automatica Sinica, 2020, 7, (3), pp. 627-637
2. Ashraf, I., Hur, S., Park, Y.: 'Smartphone sensor-based indoor positioning: Current status, opportunities, and future challenges', Electronics, 2020, 9, 891
3. Wen, D. Q.: 'Research progress of smartphone positioning and navigation sensors', Journal of Physics: Conference Series, 2021, 1930, (1), pp. 012013
4. Chen, R., Pei, L., Chen, Y.: 'A smartphone-based PDR solution for indoor navigation', Proceedings of the 24th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS 2011), Portland, OR, 2011, pp. 1404-1408
5. Atzori, L., Dessi, T., Popescu, V.: 'Indoor navigation system using image and sensor data processing on a smartphone', 13th International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), Brasov, Romania, 2012, pp. 1158-1163
6. Zou, L.: 'Research on physics experimental teaching based on cell phone sensors—Taking cell phone accelerometer measuring free fall acceleration as an example', Secondary School Physics, 2019, 37, (9), pp. 28-30
7. Huang, J., Shi, F., Zhao, C., et al.: 'Study on the measurement of rotational inertia by smartphone gyroscope sensor', Physics and Engineering, 2018, 28, (3), pp. 103-108
8. Wang, C.: 'Research on indoor navigation and positioning based on cell phone sensors', China University of Geosciences (Beijing), China, 2018

9. Li, S.: 'Research on positioning technology based on smartphone sensors', Nanjing University of Aeronautics and Astronautics, China, 2023
10. Ren, Y.: 'Research on indoor localization technology based on geomagnetic fingerprint map and PDR', North Central University, China, 2024
11. Zhang, X., Lin, J., Li, Q., et al.: 'An indoor continuous visual localization method combining perceptual hashing and spatial constraints', Journal of Surveying and Mapping, 2021, 50, (12), pp. 1639-1649
12. Lin, Y.: 'Research on indoor localization of smartphone based on Wi-Fi and PDR', China University of Mining and Technology, China, 2024