Research progress of smart phone positioning and navigation sensors

DanQi Wen*

1 School of Geomatics and Urban Spatial Information, Beijing University of Civil Engineering and Architecture, Beijing, 100044, China

*Corresponding author’s e-mail: 2108160319004@stu.bucea.edu.cn

Abstract. Smart phone has gradually become an indispensable mobile device in people's life, and its built-in sensors develop rapidly with the popularity of smart phones. A variety of sensors built in smart phones can provide different positioning sources for indoor positioning, so as to provide convenience for people's activities in large public places. Nowadays, multi-sensor indoor positioning technology based on smart phones has become a research hot spot, such as indoor visual positioning technology developed by Google and ibeacon indoor positioning technology based on low-power Bluetooth launched by apple. This paper summarizes the development status of smart phone built-in sensors for indoor positioning, sorts out the new smart phone built-in sensors of several popular mobile phone brands in the current market, expounds the sensors for indoor positioning in smart phone sensors and related positioning technologies, and finally looks forward to the future development of smart phone positioning and navigation sensors in the field of positioning.

1. Introduction
Before the popularization of smart phones, people had very narrow views on the application fields of sensors in daily life. With the progress of science and technology, smart phones, tablet computers and other intelligent devices occupy many areas of life. More and more sensors are implanted in mobile phones. The sensor usually resides alone in a certain device and is designed for a single purpose. The emergence of smart phones brings together different sensors in the same mobile device, and the types of sensors inside smart phones of different brands and models are not exactly the same. It also allows users and developers to simultaneously access sensors that support various functions. Multiple sensors are embedded in a smart phone. Different sensors have different environmental perception and computing capabilities[1]. For example, the portable smart devices that people use every day integrate WiFi[2], Bluetooth[3], cameras, gyroscopes, accelerometer, distance sensors, light sensors[4], barometers[5]. The variety of built-in sensors in smartphones has gradually increased, and the performance has also been continuously improved, creating the possibility for smartphones to provide high-performance location and navigation services anytime and anywhere.

Mobile phone sensors are those devices and devices that can be measured and converted into output signals in accordance with certain rules. With the popularization of smart devices in life, indoor positioning technology suitable for consumption has become a research hot spot, making indoor positioning moved from the laboratory in the 1990s to people's daily life. At this stage, smart phones continue to be implanted with new sensors. ToF sensors have been embedded in new phones from major brands such as Samsung, Xiaomi, Huawei, and vivo, while UWB are currently only implanted...
in iPhone 11 series phones. I believe soon, mobile phones of major brands will also be implanted with the sensor. The indoor positioning technology has been greatly developed in the 1990s. However, due to the fact that portable smart devices such as smart phones were not popular at that time, indoor positioning technology was not applied on the mobile terminal[6]. In the 21st century, with the arrival of smart phone era, portable devices can integrate various types of sensors and accelerated the development of indoor positioning technology. At present, the Android system and iOS system smartphones have become essential communication devices in people’s lives, making major communication companies conduct research on indoor location services based on the built-in sensors of mobile phones. For example, domestic Baidu, AutoNavi, Huawei and foreign Google, Apple, Qualcomm. In the process of technological development, the size of the built-in sensor elements of smart phones has been continuously reduced, and the power consumption has also been continuously reduced, thus providing a guarantee for the realization of positioning and navigation technology based on smart mobile devices, and meeting the needs of indoor positioning based on the built-in sensors of mobile phones[7]. Wi-Fi, Bluetooth, gyroscope and accelerometer have become the standard sensors in smart phones. Among them, Bluetooth developed from 4.0 to 5.1[8], and the transmission distance became longer and the speed became faster. At present, Bluetooth 5.1 has been installed in all major brands of new smart phones. Samsung Galaxy S8 is the world's first smartphone supporting bluetooth 5.1. In addition, ToF sensors and ultra-wideband sensors are also installed on smart phones one after another.

At present, the mainstream application scenarios of indoor positioning include shopping guides in shopping malls, car searching in parking lots, and autonomous tour guides. With the improvement of positioning technology, in order to expand the breadth and depth of the application of positioning technology, smart phones will load more sensors suitable for indoor positioning and navigation[2]. The "Smart Beacon Flying Project" of the "Da Yue Cheng" in Xidan, Beijing, China is an interactive marketing and WeChat smart operation platform built by Tencent WeChat Pay, Tencent Maps, and indoor positioning technology service provider Wisdom Map, which can achieve rapid positioning Functions such as payment, virtual shopping, and entertainment interaction have created a new type of shopping experience.

2. Sensor classification
Driven by smart phones, sensors represented by gyroscopes, accelerometer, and pressure sensors have developed rapidly. There are many kinds of sensors in smart phones, and each sensor plays a different role in smart phones. Some sensors can coordinate indoor positioning and navigation, such as Wi-Fi sensor, Bluetooth sensor, gyroscope, accelerometer, image sensor and geomagnetic sensor. The sensors built into the smartphone are shown in Figure 1:

![Figure 1. Embedded sensors in smartphones](image-url)
2.1. WiFi
Every Wi-Fi router has a unique identifier in the world, which can find out the user's location by looking up the database, and the accuracy is within tens of meters. Wireless local area network (WLAN) composed of wireless access points can realize the tasks of location, monitoring and tracking in complex environment, and its function is to receive and send Wi-Fi signals and measure their strength.

2.2. Bluetooth
Bluetooth is a radio technology that supports short-distance communication between devices, enabling short-distance data exchange between fixed devices, mobile devices, and personal area networks. As a small-range wireless connection technology, it can realize convenient, fast, flexible, safe, low-cost, and low-power data communication between devices. Therefore, Bluetooth is one of the mainstream technologies for realizing unlimited personal area network communication. The Bluetooth device inside the smartphone has been updated to version 5.1.

2.3. Inertial sensor
Inertial sensors implement attitude detection and motion detection in various smart mobile devices or terminals. Inertial sensors include acceleration sensors, gyroscopes, direction sensors, and magnetometers.

2.3.1. Accelerometer
Accelerometer sensors are also called motion sensors. It can capture several typical mobile phone motion modes, such as shaking and flipping. So as to achieve the purpose of controlling the mobile phone by motion.

2.3.2. Gyroscope
The three-axis gyroscope was first adopted by Apple's product iPhone4, and later gradually adopted by major brands of smart phones. It's a device that measures and maintains the direction of motion of the phone so that the phone responds correctly. Through the corresponding position of the mobile phone, you can achieve the purpose of changing the direction, and the operation is more convenient.

2.3.3. Magnetometer
Magnetometer is used to test the magnetic field strength and direction, its strength lies in the positioning of the device, can measure the current intelligent equipment and the southeast, northwest of the four directions on the Angle.

2.4. Camera
The Camera sensor uses the TOF measurement principle to determine the distance between the camera and the object or the surrounding environment, and generates a depth image or 3D image from the measured points.

2.5. Barometer
Barometers are usually used to determine the height of floors in complex buildings in indoor positioning applications. However, barometers are affected by ambient temperature and the absolute pressure of each floor changes greatly with time, but the pressure difference between different floor pairs remains stable.

2.6. UWB
UWB, ultra wide band technology, is very different from traditional communication technology. It does not need to use the carrier in the traditional communication system, but transmits and receives extremely narrow pulses with nanoseconds or less to transmit data, thus having a bandwidth of GHz.
order. According to the current mobile phone market statistics, only the iPhone11 series of smartphones are equipped with U1 chips with UWB technology.

2.7. NFC
NFC is a two-way short-range wireless communication technology. In the indoor positioning process, the accuracy of the built-in sensor of the smartphone is limited. As time goes by, the user's moving distance increases, and the accumulated positioning error becomes larger and larger. Therefore, it is necessary to place NFC tags on key nodes on the walking path, such as turns, corners, and doorways of large rooms, according to the characteristics of the indoor environment, and correct the current position by touching the NFC tags.

2.8. Sound Sensor
The built-in audio sensor of the smartphone is set up for receiving and playing music, and its working frequency band is around 0~21kHz. Generally, the frequency of music or people's voice is less than 16kHz, so the frequency band of 16~21kHz can be used for indoor positioning.

3. Technologies Used for Indoor Positioning
The rapid development of various sensors in smartphones has the potential to become an indoor accurate positioning and navigation platform, and it also promotes the development of indoor positioning technology. Based on the built-in positioning and navigation sensors in the smartphone, combined with some indoor positioning methods, a variety of indoor positioning technologies are derived. The following will give a brief overview of the indoor positioning technology for smartphone positioning.

3.1. Bluetooth
The Bluetooth indoor positioning technology mainly lays out a certain amount of Bluetooth LAN access points in the indoor environment, measures the Bluetooth signal strength of the transmitter and receiver, calculates the geometric relationship, and obtains the real-time position. In theory, for portable terminal devices that have integrated Bluetooth, ensure that the Bluetooth service is turned on, and the Bluetooth positioning system can locate the specific position and coordinates of the target.

3.2. WLAN
Wi-Fi hot spots have a unique Mac address (BSSID). After turning on WiFi, the smart phone automatically scans nearby hot spots and uploads their location information, thereby building a huge hot spot location database for matching and positioning. The WiFi based positioning method will not cause interference due to geographical factors, and can accurately locate in an environment full of obstacles.

3.3. Visible light positioning
Visible light communication technology uses high-speed on-off LED light for information transmission. The blinking frequency of LED is much higher than the resolution ability of human eyes, so the transmission signal is encoded, the LED is controlled on and off, so that it can be broadcast in the space, and finally decoded at the receiving end to obtain the transmission information. Huaceguang Communication Technology Co., Ltd. is a domestic company engaged in indoor positioning and navigation. They used LED lights for indoor positioning and developed an indoor positioning and navigation system called Ubeacon.

3.4. Visual positioning technology
There are two main types of visual positioning technology. One is the positioning based on landmarks, which uses the information contained in the landmarks to solve the camera matrix for positioning. The other is database-based positioning, which quickly and accurately extracts the movement parameters
of people from the indoor environment sequence images collected by the visual sensor, and matches them with the indoor digital map. At the same time, it is used in the database to store the location information of the camera, and use image fingerprint matching to achieve positioning. Since monocular cameras are usually used on smartphones, the visual positioning based on smartphones is dominated by monocular visual positioning.

3.5. **Inertial sensor technology**

The positioning technology of inertial sensors relies on accelerometer to measure physical quantities of acceleration and gyroscopes to measure physical quantities of angular acceleration. Then analyse these physical quantities combined with pedestrian movement to obtain pedestrian position information.

3.6. **Sound technology**

The sound source localization technology often requires the deployment of anchor nodes that can send and receive sound signals in the area to be located, and the anchor nodes send beacon signals in a synchronous or asynchronous manner. The indoor positioning technology based on sound signals uses a smartphone with a microphone for the target user. Through the demodulation of the beacon signal, with the cooperation of the server, the time information contained in the beacon signal is calculated to obtain the location information.

3.7. **NFC technology**

NFC technology is a short-distance high-frequency wireless communication technology that allows non-contact point-to-point data transmission (within ten centimeters) between electronic devices to exchange data. It was first successfully developed by Sony and Philips, mainly to provide M2M communication for smart mobile handheld devices such as mobile phones.

In summary, the advantages and disadvantages of each positioning technology are shown in Table 1:

| Positioning Technology | Advantages                                      | Disadvantages                                           |
|------------------------|------------------------------------------------|---------------------------------------------------------|
| Bluetooth              | Small size and easy integration                | Short propagation distance and poor stability            |
| WiFi                   | Extensive network and strong communication     | Vulnerable to environmental interference                |
| Visible light          | High communication speed, strong anti-interference ability | Small coverage                                        |
| Vision                 | Low cost                                       | Large amount of calculation and difficult calculation    |
| Inertia                | Independent of external environment            | There is accumulated error and it is not suitable for long-term use |
| Sound source           | High precision and strong penetration          | Additional hardware deployment                          |
| NFC                    | Simple operation and low energy consumption    | Short propagation distance                              |
4. Conclusion
So far, there is still no positioning technology that can achieve large-scale promotion and application. The reason is that each of these technologies has certain limitations. Although the accuracy of indoor positioning technology continues to improve, it has not yet been widely used in various industries. There are mainly difficulties such as complex and changeable indoor environments, high construction costs, and immature indoor and outdoor positioning technology. Improving the accuracy level of the mobile phone's built-in sensor hardware is a key issue to further optimize the indoor positioning effect. People will continue to explore new technologies based on vision, audio signals and radio frequency signals to study the direction to achieve higher precision positioning. There is a great demand for indoor positioning, but there are few technologies and applications that can meet the demand for positioning accuracy. If the sensor information inside the mobile phone can be used to use the Android smart terminal as the carrier of indoor positioning and meet the positioning accuracy requirements, it will be convenient for people's lives to a large extent.

In the future development, smart phone positioning and navigation sensors will occupy a major position in the field of indoor positioning. Integrating smart phone positioning sensors with mobile terminal development to realize positioning and navigation in a three-dimensional scene map will make our lives more intelligent and make our lives more convenient.

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