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A Brief Discussion on Understanding GNSS and Navigation Engineering

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Abstract: Navigation and positioning technology is used to determine the location of objects and guide their movement, and it is widely applied in fields such as transportation, logistics, mobile applications, and the military. The main technologies include Global Navigation Satellite Systems (GNSS), such as the United States' GPS, Russia's GLONASS, Europe's Galileo, and China's BeiDou system. These systems provide global positioning services. Satellite-Based Augmentation Systems (SBAS) enhance positioning accuracy and reliability through ground stations. Additionally, Inertial Navigation Systems (INS) calculate position by measuring acceleration and angular velocity, often in combination with GNSS. Radio positioning technology utilizes cellular base stations and Wi-Fi signals for positioning, suitable for urban and indoor environments. Bluetooth positioning and Ultra-Wideband (UWB) positioning use short-range beacons and high-frequency signals to provide high-precision indoor positioning. Visible Light Positioning (VLP) and acoustic positioning use light signals and sound waves, respectively, for positioning in specific environments. These technologies are used in transportation for vehicle navigation and intelligent transportation systems, in logistics management for tracking the location of goods, in Geographic Information Systems (GIS) to provide geographic data support, in mobile applications to support location-based services (LBS), and in the military for target positioning and missile guidance. In the future, navigation and positioning technology will advance towards higher precision, wider coverage, and greater reliability, supporting emerging applications such as autonomous driving, smart buildings, and the Internet of Things (IoT).

Keywords: Navigation; Positioning Technology; Satellites.

1. Daily Applications and Key Issues of Navigation and Positioning Technology

Nowadays, navigation and positioning technology has been widely applied in our daily lives, such as in the positioning chips embedded in smartphones, various map software, and autonomous driving technology. Thanks to the existence of positioning technology, we can solve many issues in our current environment, where it plays a crucial role. Moreover, it holds a significant position in technological progress. For example, in people's daily lives, delivery personnel rely on provided location information to plan the shortest route and find the delivery destination. Tourists visiting a new place find in-car navigation indispensable. The basic idea of satellite positioning involves precise time synchronization and determining one's own position. Satellite signals propagate at the speed of light. When a receiver picks up the signal, it can measure the time it takes for the signal to travel from the satellite to the receiver. Since the speed of light is known, the receiver can calculate the distance to the satellite based on the travel time, which is known as the pseudorange. However, to determine a three-dimensional position, the receiver needs to receive signals from at least four satellites: three satellites provide the basic data for three-dimensional positioning, and the fourth satellite is used to correct the receiver's clock error. By solving these satellites' pseudoranges, the receiver can determine its position.

While the basic principle is straightforward, the process of signal propagation is subject to several factors that limit positioning accuracy. These include the influence of water vapor, atmospheric dust, electron density in the ionosphere [1], satellite clock errors, multipath effects, and satellite orbit errors. Therefore, exploring ways to achieve higher positioning accuracy has always been a challenging issue and a topic of ongoing research for many scholars.

2. Accuracy and Error Handling in Navigation and Positioning Technology

Navigation and positioning technology has rapidly evolved from manual measurements to using satellites to transmit electromagnetic waves to ground stations. Systems like the United States' GPS, Europe's Galileo, and China's BeiDou have collected extensive global point data. In this process, accuracy is paramount. Most people spend a significant amount of time indoors, where buildings block electromagnetic signals, necessitating precise data processing methods to address this challenge. Absolute positioning and relative positioning are the two main methods, with the latter being more widely used. Various errors, such as clock errors, ionospheric delays, and measurement errors [2], must be considered during positioning. The precise positioning process includes data reading, preprocessing, error model correction, accuracy evaluation, and result output. PPP (Precise Point Positioning) and RTK (Real-Time Kinematic) are the two main technologies, each with its advantages and disadvantages. PPP-RTK, which combines the strengths of both, is considered the preferred technology for future autonomous driving.

3. Integrated Navigation with GNSS and INS

Although GNSS systems provide long-term high accuracy, they suffer from issues like high-frequency noise, low sampling frequency, and susceptibility to electromagnetic interference. INS systems, while highly accurate in the short term, accumulate errors over time. Integrated navigation using GNSS and INS combines the advantages of both systems, enhancing overall system accuracy and reliability. Further combining this with visual positioning technology, which captures environmental features through cameras and uses intelligent algorithms to analyze the three-dimensional spatial position of targets, achieves multimodal integration, further improving the accuracy and reliability of navigation systems.

4. Indoor Navigation and Positioning Technology

While satellite navigation systems have met outdoor navigation needs, there is still a huge demand for indoor navigation. In complex indoor environments, such as large basements, malls, and workshops, higher positioning accuracy is required. Infrared positioning, due to its weak penetration capability, results in insufficient positioning ability. Inertial navigation technology can calculate positions but suffers from error accumulation over time, which can potentially be mitigated using artificial intelligence (deep learning). Wi-Fi and ultra-wideband (UWB) positioning have their applications but face issues like instability, high cost, and high-power consumption. Combining modern technologies (such as 5G) with surveying and mapping can collaboratively address these challenges.

5. The Role of Navigation and Positioning in Deep Space Exploration

Navigation and positioning play an irreplaceable role in deep space exploration. As the aerospace industry develops, the number of satellites launched into space increases, making satellite positioning and tracking more important, ensuring economic and security benefits. In deep space exploration, such as the positioning of the Zhurong Mars rover and future explorations into deeper space, navigation and positioning technology will continue to play a crucial role [3]. Considering the future, if an asteroid were to collide with Earth, whether humanity could accurately locate it using navigation and positioning technology and alter its trajectory is a thought-provoking question.

6. Conclusion

With the development of the digital age, the surveying and mapping industry has entered a new phase in information collection and data acquisition. The service areas and application scope of surveying will continue to expand, further developing and playing a greater role supported by "3S" technologies (Remote Sensing, GIS, GPS).

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