Research and Design of Network RTK High-precision Positioning and Computer Vision Service Platform Based on Beidou

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Abstract: Beidou RTK (real-time kinematic) high-precision positioning is based on the Beidou Satellite Navigation System, utilizing differential processing techniques with ground-based augmentation systems, reference stations, and other means to achieve high-precision positioning. It has a wide range of application prospects. Integrating Beidou RTK high-precision positioning with computer vision, a service platform based on Beidou RTK high-precision positioning and computer vision is constructed. This will further expand the application areas of the Beidou Satellite Navigation System. This article, based on the principles of high-precision positioning in satellite navigation systems, analyzes the working principles of Network RTK and computer vision. It proposes the structure and main functional modules of a service platform based on Beidou RTK high-precision positioning and computer vision, providing a reference for the development of Beidou RTK high-precision positioning service and application platforms.

Keywords: Beidou RTK; High-Precision Positioning; Computer Vision; Service Platform

1. Introduction

Satellite navigation system is the most widely used space technology in the world, playing an important role in the economy, national defense, aerospace, high technology and many other fields. At present, the global satellite navigation services providers include the Global Positioning System (GPS) from the United States, the Galileo satellite navigation system (Galileo) from the European Union, the GLONASS from Russia and the Beidou satellite navigation system (DBS) from China [1]. RTK technology, with the assistance of observation data and standard coordinates from satellite ground reference stations, utilizes differential correction methods to address errors in satellite navigation systems caused by ionospheric, tropospheric, multipath effects, as well as satellite ephemeris and satellite clock inaccuracies. Computer vision and image processing constitute a crucial branch of computer applications and serve as a foundational element for artificial intelligence. Building a platform based on Beidou RTK high-precision positioning and computer vision is an extension of the application of the Beidou Satellite Navigation System. It also forms the basis for higher-precision positioning and more intelligent applications, including autonomous driving, autonomous agricultural machinery operations, autonomous drone flights, terrain measurement, construction layout, road construction, smart cities, and other applications requiring higher precision positioning and increased intelligence.

2. Methods

2.1. Working Principle of Network RTK

RTK technology is an important application field of satellite navigation system. Its basic principle is that the satellite ground reference station receives the navigation information sent by the navigation satellite system, and obtains the navigation coordinate of the reference station through coordinate calculation. Because the navigation coordinate is affected by the navigation precision of the satellite navigation system, the error between it and the known standard coordinate of the reference station can be several meters or even tens of meters. The reference station calculates the difference between the navigation coordinate and the known standard coordinate in x, y and z axes to get $\triangle x$, $\triangle y$, $\triangle z$ values,

which are the difference between the navigation coordinate and the standard coordinate of the reference station [2-5]. Bringing together ground-based augmentation systems and reference stations within a specific region forms a Network RTK. This significantly extends the effective baseline of RTK, enabling the coverage area of Network RTK to reach over 100 kilometers, while simultaneously enhancing positioning accuracy further.

2.2. Computer Vision and Image Processing based on Beidou Terminals

We can install a camera on the Beidou terminal, utilize the camera to capture images or pictures, and transmit the information of these images or pictures to the server. The image processing module of the service platform performs real-time recognition and processing on the returned images or pictures, and then delivers the processed results to the user or relevant devices.

2.3. Working Principle of the Service Platform

After receiving navigation signals from the Beidou Navigation Satellite System, the Beidou terminal device utilizes the Network RTK system for coordinate computation, obtaining high-precision positioning. Simultaneously, the images captured by the camera installed on the Beidou terminal device are transmitted to the service platform. The service platform processes and recognizes the images, then sends the results of image processing and recognition back to the Beidou terminal device's intelligent machinery. This achieves autonomous operation for the intelligent machinery based on the processed and recognized images, as is shown in Figure 1.

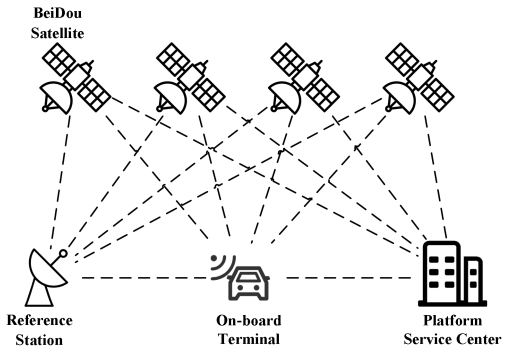

Figure 1. Working Principle of Service Platform

3. Overall Structure of the Service Platform

3.1 Overall Structure of the System

The overall structure of the system is shown in Figure 2.

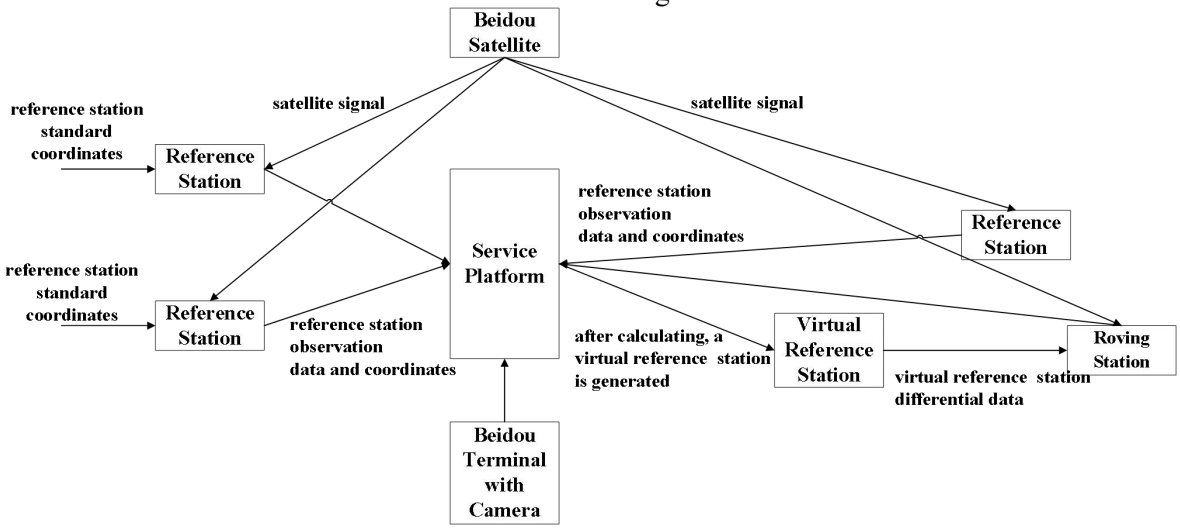

Figure 2. Overall Structure of the System

3.2 Basic Composition of the Service Platform

The RTK high-precision positioning service platform based on Beidou is mainly composed of a network communication module, a reference station management module, a positioning calculation module, a data processing module, a platform management module, a user management module, an image processing module, a data service module, a database management module, a view display module, etc[6]. The basic structure of the service platform is shown in Figure 3.

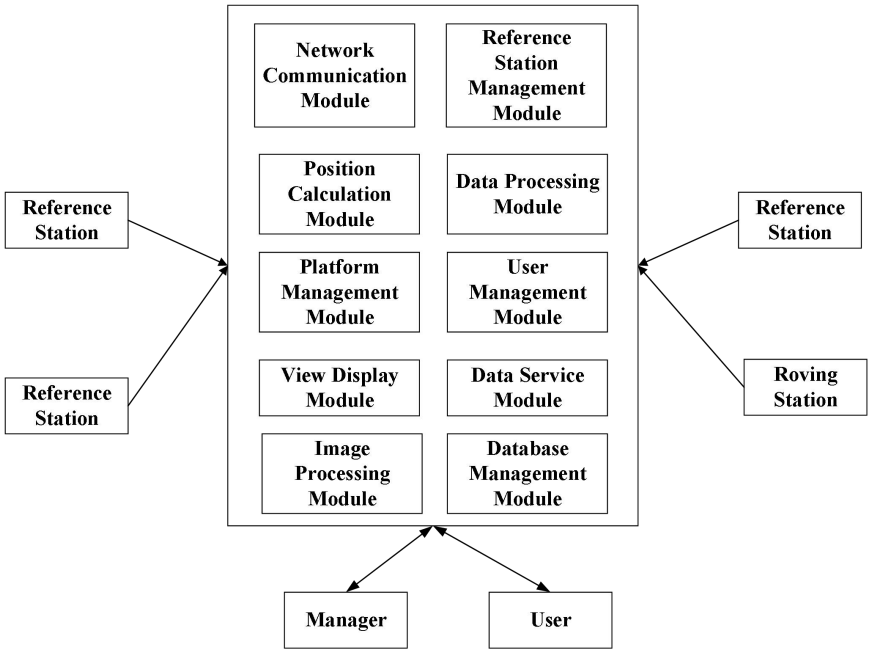

Figure 3. Basic Structure of the Service Platform

3.3 Three-layer Structure of the Service Platform

The service platform is built in a three-layer structure, in which the presentation layer is mainly used to display data, and the distribution of the reference stations can be in the form of a view, where the position and coordinates of the reference station would be displayed, and the dynamic position of users would be displayed on the map according to their requests. The operational layer is mainly used to process various data, including the procession of user information, observation data, positioning solution, error values, image processing and data broadcasting. The data layer is mainly used to communicate with the database, including relevant data sources of the reference stations, observation data, satellite ephemeris, user information, etc. [7] . The three-layer structure of the service platform is shown in Figure 4.

4. Introduction to the Platform Function Module

4.1 Network Communication Module

The network communication module is mainly used for the data communication between the reference stations, mobile user and the server of the service platform. Its function is to receive the requests, information and observation data from users. The service platform responds to users' requests through the procession of these data. Data communication can be achieved through an independent communication link, or with the aid of the current 5G reference station and the Internet line.

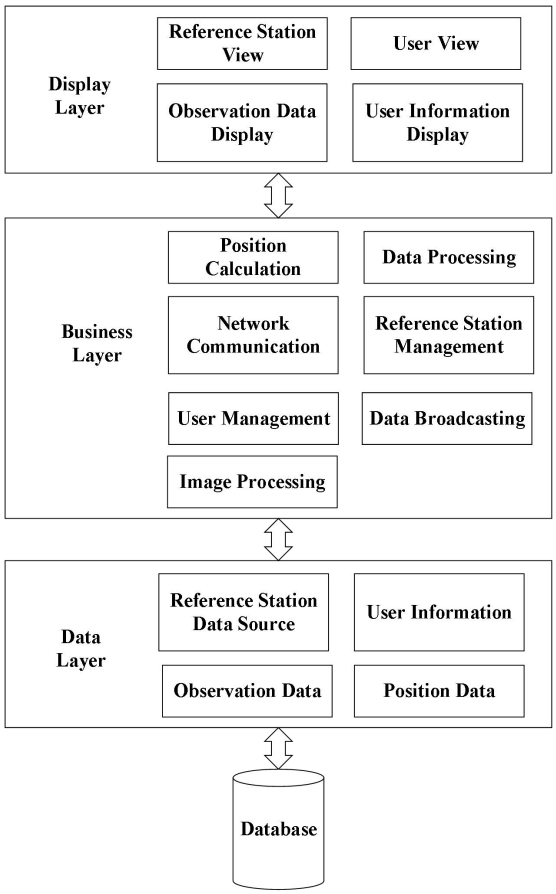

Figure 4. Three-layer structure of the Service Platform

4.2 Reference Station Management Module

The reference station is the basis of the service platform to carry out the service. The reference station management module manages the reference stations distributed all over the place in a unified manner. When a user sends a request and provides the rough navigation coordinates, the system can screen the reference stations near the user's point from the library, and acquire their observation data, which would be provided to the related module for data processing.

4.3 Positioning Calculation Module

The positioning calculation module is an important function of the service platform. In order to ensure that the system can fix position quickly, the service platform shall automatically download the satellite ultra-fast precise ephemeris in real time, and solve the real-time coordinates of the points required by users through the satellite real-time observation data sent by the user.

4.4 Data Processing Module

The service platform involves many types of data, including navigation satellite observation data, positioning information, ephemeris files, distribution information of surrounding reference stations, observation data of receiving reference stations, information for user management, backup of user measurement data, etc. The data processing module mainly carries out background processing, decodes, classifies, stores and manages the received navigation satellite signals and the related data sent from the reference stations, performs error calculation on the navigation position obtained from the navigation satellite, processes the received observation data and positioning information sent by multiple reference stations or operational reference stations, generates a virtual reference station and differential information to provide high-precision RTK service; carries out subsequent correction and error processing for accurate measurement of the users using the service platform, and makes data query for different demands of different types of users.

4.5 Platform Management Module

The platform management module is mainly used by administrators to set up the service platform software interface, monitor the operation of the platform, review user information, approve user registration, and do online Q&A, etc.

4.6 User Management Module

The user management module classifies users into three categories: super administrators, platform administrators, and service users. Different roles correspond to different levels of permissions. User management typically includes user account management, user permission management, usage billing management, and user usage status, among other aspects.

4.7 View Display Module

Using JavaScript API of maps such as Baidu and Gaode, dynamic views of the surrounding reference stations and users' real-time positioning information can be visually generate, so as to facilitate online monitoring and management of the reference stations and users.

4.8 Data Service Module

The data service module is mainly for the classification of the data and the communication with the background database.

4.9 Image Processing Module

The image processing module primarily processes and recognizes the images captured by the Beidou terminal camera, then returns the recognized results to the mechanical equipment of the Beidou terminal.

5. Key Technology of the Service Platform

5.1 Error Treatment

Beidou navigation satellite uses electromagnetic waves to transmit navigation information to the ground in the form of carrier waves. As the Beidou navigation satellite is far away from the ground, including 5 geostationary satellites with an altitude of 36,000km and 30 non-geostationary satellites with an altitude of 21,500km, the electromagnetic waves need to pass through the earth atmosphere during the transmission, and the atmosphere contains ionosphere and troposphere, both of which have certain refraction effects on the electromagnetic waves,

just like the refraction effect of water on light, the actual distance from the navigation satellite to the ground receiver is directly affected. Also, the refraction effect on the electromagnetic waves causes a certain delay when the satellite signals arrive on the ground, also known as ionospheric and tropospheric delays. In addition, the navigation satellite and the ground receiver also have a certain angle, as the angles to receive the same satellite are different in Hainan Island and the northeast area, The refraction effect of the ionosphere and troposphere on the electromagnetic wave is also related to that certain angle between. The lower the altitude angle is, the larger the refraction effect is, and the lower the navigation accuracy is. What's more, the high buildings in the city will cause the electromagnetic wave reflection effect and multi-path phenomenon, resulting in receiver noise. All of these would have a certain effect on navigation accuracy. In addition, satellite ephemeris and satellite clock can also affect the navigation accuracy.

5.2 Generation of Virtual Reference Stations

The virtual reference station is a crucial aspect of data processing on the service platform. Virtual reference station technology has advantages such as wide coverage, high positioning accuracy, and high reliability, making it a widely used technique in the current Beidou Network RTK technology. When a user sends a request and provides approximate coordinates obtained from navigation satellites, the service platform selects coordinates and observation data from three or more reference stations located near the user's approximate coordinates in the reference station database. By constructing a mathematical model for the virtual reference station, the service platform generates virtual reference stations in the vicinity of the user's provided approximate coordinates.

5.3 Computer Vision and Image Processing

Computer vision and image processing involve using devices such as cameras and other imaging equipment to replace human visual organs as input devices. Through processes such as image enhancement, segmentation, smoothing, sharpening, feature extraction, image recognition [8,9], and encoding and analysis of image information, the images are compared with those in the database to achieve recognition and understanding. Subsequently, the results of image processing are returned to the Beidou terminal equipment, guiding the devices installed on the Beidou terminal to perform corresponding operations. For example, in the case of unmanned driving of agricultural machinery encountering obstacles, it automatically recognizes and performs obstacle avoidance processing[10].

6 Conclusion

This passage combines Beidou RTK high-precision positioning with computer vision. It analyzes the working principles of the Beidou Network RTK and the methods for image acquisition and processing based on Beidou terminals. Considering the characteristics of current devices based on the Beidou Satellite Navigation System, it designs the main functional modules of a service platform based on Beidou RTK high-precision positioning and computer vision. Following the three-tier framework design philosophy of software architecture, the service platform is organized into a three-tier structure, providing valuable reference. Due to the involvement of extensive satellite communication data in satellite navigation systems, the conversion and storage of various data types by the service platform are not deeply explored in this article. As the application scope of the Beidou Satellite Navigation System continues to expand, especially in the increasingly tight integration with artificial intelligence, big data, 5G, autonomous driving in vehicles, intelligent logistics, etc., developing a system that integrates Beidou RTK high-precision positioning with computer vision will be a future development direction.

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