GPS Vehicle Positioning Monitoring System Integrated with CORS and Mobile GIS

Zechun Huang*1,a, Dingfa Huang1, Zhu Xu1, Zhigen Xu2 *a*

1Faculty of Geosciences and Environmental Engineering, Southwest Jiaotong University, Chengdu 610031, China
2School of Information Science & Technology, Southwest Jiaotong University, Chengdu 610031, China
a zenghuangli@126.com

Abstract. With the promotion of the continuous operational reference station system (CORS) and the development of the Mobile GIS technology, high-precision, fast and accurate GPS vehicle positioning monitoring is important in the construction of the intelligent transportation system. In order to seek for a solution to fast and high-precision moving target spatial location, and improve the application value of GPS location information in vehicle mobile positioning, this article has studied the design and implementation method of the vehicle orientation, monitoring & control system combined with CORS service network and Mobile GIS. It has designed the vehicle positioning monitoring system architecture integrated with CORS and Mobile GIS. It has also analyzed the characteristics of spatial and attribute data related to vehicle positioning control, studied the data classification organization and the integrated model which uses Oracle for object-relational storage of spatial and attribute data, and focused on the space-time cube model of vehicle track data. Besides, this article has made an elaboration on functional design and implementation of the monitor service center, mobile terminal and data communication server in the vehicle positioning monitoring system. Practice shows that the application of CORS service network and Mobile GIS in vehicle positioning monitoring system has improved the accuracy of spatial location of moving vehicles, and has helped visual display of located objects, which has also verified the feasibility to integrate CORS and Mobile GIS for mobile location services. It has important theoretical and practical value to further study the algorithm, model and technology of path analysis and map-matching in mobile location integrated with CORS and GIS.

© 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of Conference ESIAT2011 Organization Committee. Open access under CC BY-NC-ND license.

Keywords: vehicle positioning monitoring system, CORS, Mobile GIS, GPS, space-time cube model

*author for correspondence.
E-mail address: * zenghuangli@126.com
1. Introduction

With technological progress and social development, people have great demand for mobile positioning information. In recent years, it is particularly prominent to perform effective monitoring and emergency rescue on highly mobile and numerous moving targets, and provide various information services in passenger traffic, public security, banking, logistics and other industries. The location information all sectors of the community concern can generally be divided into mobile location information and fixed location information. Mobile location information mainly refers to the real-time locations of vehicles and people; fixed location information mainly refers to all ground objects and their attributes. Fixed location information is generally displayed by the Geographic Information System (GIS) technology; mobile location information is generally obtained by the Global Positioning System (GPS) technology. In order to facilitate the real-time mobile location geographic information services, we need support from the wireless communication technology of a mobile intelligent terminal (such as a smart phone) [1]. The development of intelligent transportation requires to improve the accuracy and reliability in vehicle positioning and navigation[2]. The GPS technology is widely used in tracking of ground moving targets. In particular, the positioning accuracy and reliability of the continuous operational reference station system (CORS) has been greatly improved. CORS is a real-time positioning network service system integrated with GNSS navigation and positioning technology, modern communication technology, computer technology, mapping technology and other technologies, which is formed by multiple GPS base stations, and provides sophisticated real-time positioning or behindhand location service for users within the service area covered by the system through the Internet and wireless communication network[2,3]. Network communication technology has become an effective means of information transmission for GPS tracking & positioning and remote monitoring, and wireless communication technology is the key to mobile location[2]. Vehicle positioning monitoring system takes satellite positioning as the main positioning means, supplemented with inertial navigation, terrain-aided navigation and other technologies to obtain real-time vehicle location information, which is then integrated into the mobile geographic information system technology that can provide vehicle location, path planning, information query and other functions whenever and wherever possible. The vehicle navigation system which is integrated with dynamic road traffic information can guide vehicles according to dynamic traffic information, so as to avoid the road with congestion and relieve urban traffic jams. In addition, the rise and rapid development of Mobile Geographic Information System (Mobile GIS) offers convenient, practical and reliable software technical support for the implementation and application of vehicle positioning monitoring system [4]. The networked vehicle positioning monitoring system based on the integration of CORS network and GIS technology has broad market prospects and application value, and is an important part of the current emerging intelligent transportation system. To start from the integrated system framework of vehicle positioning monitoring, this article will explore the vehicle location data model based on the database of relationship objects, and functional structure design and implementation of GPS vehicle monitoring system which is integrated with wireless network and mobile GIS technology.

2. Vehicle positioning monitoring system architecture

Vehicle positioning monitoring system architecture is constituted by CORS network data center server, mobile positioning integrated terminal, Mobile GIS, CDMA/GPRS/3G mobile digital communication network, positioning and monitoring center server, application server, positioning and monitoring spatial database, Internet and so on, which is shown in Figure 1. It is a comprehensive integrated system based on GIS which uses Internet for information collection and integrates monitoring, positioning, alarming and scheduling. CORS network data center performs network transmission of RTCM positioning...
correction data by way of the Internet through the NTRIP protocol, which helps the mobile positioning integrated terminal to obtain accurate positioning data. Mobile positioning integrated terminal receives satellite positioning data with the NMEA format from its GPS receiver module, and then transmits it to CORS network data center server. After the operation, the server transmits positioning correction data to the mobile positioning integrated terminal in the way of the NTRIP/HTTP protocol through the Internet, so as to achieve the purpose of accurate positioning. The mobile positioning integrated terminal is composed of the GPS receiver, mobile communication module, mobile GIS, and operating terminal equipment. Mobile GIS is an integrated system with GIS, GPS, mobile communication, Internet services and multimedia technology, which also provides the electronic map information required by positioning. The mobile positioning integrated terminal and the positioning and monitoring center achieve real-time data transmission through the mobile communication technology. The mobile communication technology is the transmission medium of Mobile GIS. It connects the mobile GIS terminal with the spatial information server, uploads user requests and transmits service responses, which may facilitate users to obtain location-based services at all time and places [4]. After receiving positioning information from the mobile positioning integrated terminal, the monitoring center server displays the terminal’s real-time specific location on the electronic map according to the received location coordinates, and provides the basic GIS functions for operating the map, so as to achieve visual monitoring of moving targets. The positioning monitoring center server obtains the electronic map data needed by visual monitoring from the positioning monitoring spatial database through the application server. The application server exposes business logic in mobile positioning spatial data manipulation to the positioning monitoring center server through various protocols, and it provides a way to access business logic for the use of the application program of the positioning monitoring center server. The positioning monitoring spatial database is mainly to store and manage geospatial data and thematic attribute data related to mobile positioning and monitoring, which stores all data in the database in a form of the overall data model to facilitate data management and use.

Figure 1 The architecture of the vehicle positioning monitoring system integrated with CORS and Mobile GIS
3. Object-relational storage of vehicle positioning monitoring data and the space-time cube model

3.1. Data organization and object-relational storage

Data organization in the vehicle positioning monitoring system is always a difficult and hot issue, and is also a core problem concerning sound and stable system functions [6]. Relevant vehicle positioning monitoring data mainly includes the following four categories: first, base map data, including administrative divisions, residential areas, gas stations, toll stations, overpasses, residential areas, arterial streets, etc; second, road network data, including road centerline network diagrams, overpasses, scissors, crossing and other road network data; third, vehicle monitoring and navigation attribute data, including vehicle location, driving route, distance, direction, speed, length of stay in one position, history data in vehicle operation, etc; at last, business attribute data, including personnel information, vehicle information, driver job information, etc. Fundamental geographic data uses hierarchical management model for design, and can abstract the real world to levels with different characteristics, so as to simplify the system data model and data processing, and improve the flexibility of data organization and management. Road section elements and node elements form a topologically structured road network, which are also the foundation to find the optimal path and to use the road network and vehicle location for map matching [6]. Object-relational database system can better solve object-relational storage of vehicle positioning monitoring data. According to the characteristics of vehicle operation management and multi-source data analysis, a universal data storage model can be constructed, which is oriented to vehicle positioning monitoring management services, and meanwhile the Oracle database management system can be used for centralized management and maintenance. Oracle makes an object-oriented expansion in the traditional relational database, and increases the data type of SDO-GEOMETRY dedicated to the storage of geometric entities of geographic objects, which can facilitate the integration of fundamental geographic data, road data, control and navigation attribute data and business data which are all related to vehicle positioning monitoring for storage management, achieve the storage of the object-relational model, and help data sharing service.

3.2. Space-time cube model of vehicle track data.

In the vehicle positioning monitoring system, track data of a vehicle object has high change frequency, massive volumes of data and continuous dynamic changes, resulting in a huge amount of data storage and inefficient data manipulation. In order to improve the storage efficiency and effective management of vehicle track data, we need to establish an effective data management approach to reduce data redundancy and increase the efficiency of information query. It’s a better solution to use the spatial database to store the vehicle motion track data, store each historical position as a spatial point object, and mark time stamp, so as to establish a space-time storage model of vehicle track data. The space-time model takes the concept of space-time objects to organize spatial data and attribute data, making history query and analysis of vehicle motion track possible. In the space-time cube, x-axis and y-axis form a space region, and t-axis is the time dimension. The whole space-time cube region shows the spatial and temporal range in vehicle object research. Using the space-time cube to show the track data storage model of a moving vehicle object is to describe the mobile changes of a vehicle object in a spatial location. According to the characteristics of a moving vehicle object, the space-time cube model is mainly constituted by points, track, space division, events and unit elements of the space-time cube. A point (x, y, z) in the cube is an abstract expression of the spatial location of a moving vehicle object at a certain time. The continuous moving of a point forms a track, which is a set of points, and reflects the movement of a moving vehicle object during a period of time. A space division can be formed through the ground space
division, which is an important reference for the research on positioning of moving vehicle objects. Vehicle positioning monitoring events mainly include data sampling event and state event. The occurrence of data sampling event records the location information of the object in the computer. The occurrence of state event reflects the instantaneous state of a moving vehicle object, which records data at this position in the computer, and also takes the time interval of the sampling point when direction or state changes occur twice as the unit for moving track segmentation and storage. Then sampling time points when direction or state changes occur to each moving vehicle object can form an X-Y plane at a time. Meanwhile, segment the cube according to the timeline, which then can be divided into multiple space-time cube units from the perspective of the timeline. Each space-time cube unit includes at least one track segment, which is the most basic spatial and temporal range for moving vehicle object research, and various cube units constitute a spatio-temporal data model of the entire vehicle track data [7].

4. Functional design and implementation of GPS vehicle positioning monitoring system

4.1. Functional design and implementation of monitor service center.

From the software structure, the monitor service center can be divided into basic GIS operations, vehicle positioning monitoring, information query, data maintenance and management, data communication and other modules. The basic GIS functional module mainly includes map operations, layer control, spatial query and other functions. Map operations facilitate users to observe the details of the location where a moving target stands, including map display, zoom in, zoom out, roam, etc; layer control is to control a layer’s explicit/implicit, stacking sequence, field of view, etc; spatial query can help users inquire ground objects quickly. The vehicle positioning monitoring module can show the location of a vehicle in real time on the electronic map at the monitoring center based on the positioning data returned from the on-vehicle GPS device, and can also set time intervals and the number of return in vehicle monitoring. Vehicle track playback is a basic function of the data maintenance and management module in the monitor service center, which can play back the track of the given vehicle according to the given time interval, and show playback track and the corresponding coordinates in real time on the map. The main function of the communication control module is that the vehicle monitor service center can connect and communicate with the middleware of the GPS server through the TCP/IP protocol, so as to achieve monitoring and scheduling of the vehicle positioning terminal. The basic technology to achieve the function and data storage of the monitor service center: use Oracle and ArcSDE for storage management of spatial and attribute data related to vehicle positioning monitoring; use ArcEngine to develop and implement electronic map display and manipulation at monitor service center, spatial information query, vehicle positioning and monitoring, track playback and other functions; take Windows Server 2003 as the operating system, and Visual Studio.Net 2008 as the visual development tool to build the development and runtime environment.

4.2. Functional design and implementation of the mobile terminal.

The mobile terminal is a major component of the vehicle positioning monitoring system, which is made up of the GPS receiver, PDA and wireless network card. The mobile terminal receives satellite signals from the GPS receiver, and parses the received NMEA string information to extract positioning information; it sends the collected positioning information to the monitor service center, and converts latitude and longitude coordinates into map coordinates for navigation and positioning of the mobile terminal. The functional modules of the mobile terminal are designed to have GPS module, communication module, map matching module and navigation module. GPS module mainly
completes GPS signal receiving, processing and sending. Communication module implements information exchange between the mobile terminal and the monitor service center, which sends the mobile terminal’s location and alarm information to the monitor service center, and receives instructions sent from the monitor service center. Map matching module achieves correction of the positioning information parsed by GPS module, so that the positioning information can automatically find the most likely path. Navigation module achieves the optimal path from the current location to the destination, and then guides the user to arrive at the destination smoothly. Based on the WinCE environment, the mobile terminal takes ESRI’s ArcPad as the development platform for design and implementation, which integrates the mobile GIS technology with the CORS service network. ArcPad software is the main platform for the implementation of Mobile GIS, and it offers map display, positioning, query, GPS integration and other basic functions at the mobile terminal, so that various functions of the mobile terminal can be easily achieved.

4.3. Design and implementation of data communication server.

The main framework of the data communication server is constituted by the GPS server, the monitoring center and the mobile terminal, as shown in Figure 2. The GPS server is responsible for receiving and forwarding data, which receives GPS positioning information and other information sent from each mobile terminal, and then sends it to the monitoring center. Meanwhile, the GPS server also sends the instructions and other relevant information from the monitoring center to each monitored mobile terminal. Data receiving and sending at the mobile terminal is implemented by programming in the PDA. The real-time positioning information of the mobile terminal can be obtained and decoded from the GPS receiver which is connected to the PDA. After the decoded positioning information and the identification information of the mobile terminal is encoded, it is then sent to the GPS server through the wireless network. Data receiving and sending at the monitor service center is implemented on the Internet, which receives the positioning information and identification information from the GPS server which is originally sent from the mobile terminal.

![Figure 2 The framework of data communication server](image)

Conclusion

The vehicle location service system integrated with CORS service network and Mobile GIS can provide integrated information services based on geo-spatial location in real time for moving targets. This article has discussed how to design and develop a vehicle positioning monitoring system integrated with CORS, the wireless communication technology and Mobile GIS. According to the characteristics of spatial and attribute data which is relevant to vehicle positioning monitoring, this article has studied the space-time cube model and the object-relational storage model of vehicle positioning monitoring data, and has also explored an integrated model of data organization and object-relational storage. It has made a
practical study on the method that making comprehensive use of ArcPad, ArcEngine, Oracle and other software for the development and implementation of functions in the vehicle positioning monitoring system, which then has verified the technical feasibility of integrating CORS and Mobile GIS for the development of the GPS vehicle positioning monitoring system. Path analysis based on CORS service network and map matching are both very important functions in the vehicle positioning monitoring system, which however have not been discussed in that article owing to the limitation of space. In the future, we can further study the algorithms and models about how to combine CORS for path analysis and map matching and how to use the ArcPad software platform for the development and implementation of map matching and path analysis. With high positioning accuracy and fast computing speed, the GPS vehicle positioning monitoring system integrated with CORS and Mobile GIS has broad market prospects and application value, which can be applied in bus scheduling, taxi monitoring and navigation, vehicle anti-theft and other fields, and has a practical significance to relieve urban traffic congestion and improve road utilization efficiency.

Acknowledgement

The research is supported by the following foundation items: Fundamental Research Funds for the Central University (SWJTU11BR016, SWJTU09ZT01), Science and Technology Plan Projects in Sichuan Province (05GG007-012-02)

References