Mobile Data Acquisition and Management System Design Based on GIS and GPRS

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Abstract
Aiming at the problem of low accuracy and low efficiency in the traditional way of mobile data collection, as well as the existing problem that the mobile data acquisition systems being specific to spatial position measurement and lacking of the universality characters, this paper proposes and develops a data acquisition system based on GPRS and mobile GIS technology, and applies the GIS, GPS and GPRS technologies to the mobile data collection operations. Combined with AicGISMobile9.3, the paper realizes the analysis of the system requirements and the functions proposed in the system design. Besides, this paper introduces the system applied in wetland planning survey.
Key words: GIS, GPRS, MOBILE DATA COLLECTION, FOREST RESOURCES INVESTIGATION

1. Introduction

Nowadays, the service based on the location (LBS, Location Based Service) becomes increasingly important and attracts the whole world's attention. The global Internet companies are in active deployment of this potential value-added business. LBS has been very common in emergency rescue, and smart traffic, and interest points query, work flow management and property monitoring. [1] While the basis of these LBS application service is the location-related data. Therefore, how to efficiently and accurately capture the location-related data is very important to the development of LBS [2]. Traditional data collection method that associated with the position is designing the collection information in the paper map, and then record the relevant property information in the paper forms. Afterwards, they can put these graphics data into digitalization manually in the office and then put the associated attribute data into database. Those traditional data collection methods exist mainly in the data collection of high-cost, low-efficiency, inaccurate-timeliness [3-4].

Therefore, in order to adapt to the rapid development of LBS, it is very necessary to study new methods of data collection. The rapid development of the mobile GIS, GPS and GPRS technology provides new solutions to these problems. On the one hand, mobile GIS will combine mobile computing, GPS and GPRS technology, and ensure the location-related data not limited by space constraints. In this way, we can realize the real-time data collection and uploading; on the other hand, the mobile GIS map reduces the use of paper maps, which can not only reduces the cost of data collection, but also can improve the quality and availability of data [5]. The current available mobile data acquisition systems mostly have the following two questions:

1. More emphasis on spatial position measurement.

Most of these systems focus on the collection of location information, and overlook other property information, such as collection time, photos information and are lacking of holistic description of the collection content.

2. Lacking of versatility

These systems aim mostly at the independent of design development with the single application requirement, like the forestry information monitoring system network of United States Virginia forestry sector [6], pet census system of United States Auckland animal protection organization [7], Liaoning province forestation verification system that Beijing forest information technology limited company developed for Liaoning province forestry sector[8], and the line patrol system designed by Yu Cao, who is in the North China electric power University[9]. If there is a new application needs which needs redesign the development software, and after the completion, it will lose its value, this kind of development will obviously add the cost of software development. If we can design a versatile mobile data collection system, which can meets the different application needs and only requires a simple custom activity to complete the task; it will apparently reduce software development costs greatly, and improve the software utilization ratio.

Based on the above analysis, we expect to be able to combine the GIS, GPs and GPRS technologies and apply them into the mobile data collection operations, then develop a set of mobile data collection system, overcoming the problems existing in the traditional methods, that is, the data collection being high-cost, low-efficiency, inaccurate-timeliness and lacking of the universality characters.

Mobile GIS and its key technologies

(1) Characteristics of mobile GIS

Mobile GIS is the extension and expansion of the GIS technology in the embedded platform, it has the following features:

Mobility: mobile GIS systems can run on various mobile devices, its main purpose is to make it easier for users to use the GIS-related functions on the move, such as mobile data collection, transmission line inspection, navigation and location, etc. Consequently, mobility is the most notable feature of mobile GIS.

Real time: mobile GIS serves for users. It should be able to respond to users' requests in a timely manner, and reflect changes in the environment around the users in a timely manner, for example, the navigation system must be able to obtain the current location information.

Reliance on location data: spatial data is the core of mobile GIS. The mobile GIS should solve the problems, such as "where am I?", "what is around me?", "how to reach your destination?" Such issues are inseparable from the location data. There is no doubt that there will be no mobile GIS without location data.

Diversity of mobile terminals: mobile GIS system will eventually run on a variety of mobile devices, including GPS Smartphone, mobile terminals, laptop, etc. The manufacturers of these devices, the technology applied and the operating system varies. So we should take the diversity into account while the system is designed.

Resource limitation: Compared with the wired network, the bandwidth resources wireless mobile network are limited and the cost of communication is higher, and the mobile device screens and storage space is smaller than ordinary PC. Besides, the computing capacity of the mobile processor is limited.

(2) Mobile location technology

The global positioning system (GPS) is short for "time service, navigation system/global positioning system". The system is space satellite navigation and positioning system designed by the United States armed forces jointly, whose main purpose is to offer real-time and global navigation service for the three major areas of land, sea and air in the 1970s. GPS positioning system is mainly composed of three major parts, including the space segment (GPS satellite constellation), the ground control segment (ground surveillance system), and user equipment (GPS receiver).

The basic principle of GPS positioning is to regard the instantaneous location of the high-speed satellite as known data, and the space distance intersection method is used to calculate the location of the point to be tested, which requires the GPS receiver to receive 4 or more GPS satellite signals at some point. As Figure 1 shows, suppose the distance from the observation Site p to the four satellites measured by the GPS receiver respectively is p1, p2, p3, and p4. We can use the three dimensional coordinates (x_j, y_j, z_j), $j = 1, 2, 3, 40$ to figure out the three dimensional coordinates (X, Y, z) of point P and the deviation between the receiver clock t_1 and satellite clock t_0 ΔT through GPs signal with space distance rear rendezvous method. The observation equation $(\Delta T = t_1 - t_0)$ is as formula (1) shows (c represents for speed)

$$\begin{cases} \rho_1 = \sqrt{(X-x_1)^2 + (Y-y_1)^2 + (Z-z_1)^2} + \Delta T \cdot c \\ \rho_2 = \sqrt{(X-x_2)^2 + (Y-y_2)^2 + (Z-z_2)^2} + \Delta T \cdot c \\ \rho_3 = \sqrt{(X-x_3)^2 + (Y-y_3)^2 + (Z-z_3)^2} + \Delta T \cdot c \\ \rho_4 = \sqrt{(X-x_4)^2 + (Y-y_4)^2 + (Z-z_4)^2} + \Delta T \cdot c \end{cases} \quad (1)$$

Mobile data acquisition system design

The system adopts a four-tier structure--the mobile presentation layer, business logic layer, and data access and data tiers. The system applies a uniform data management system, which supports for simultaneous access for multiple clients to a database. Design of the overall system is as shown in Figure 1.

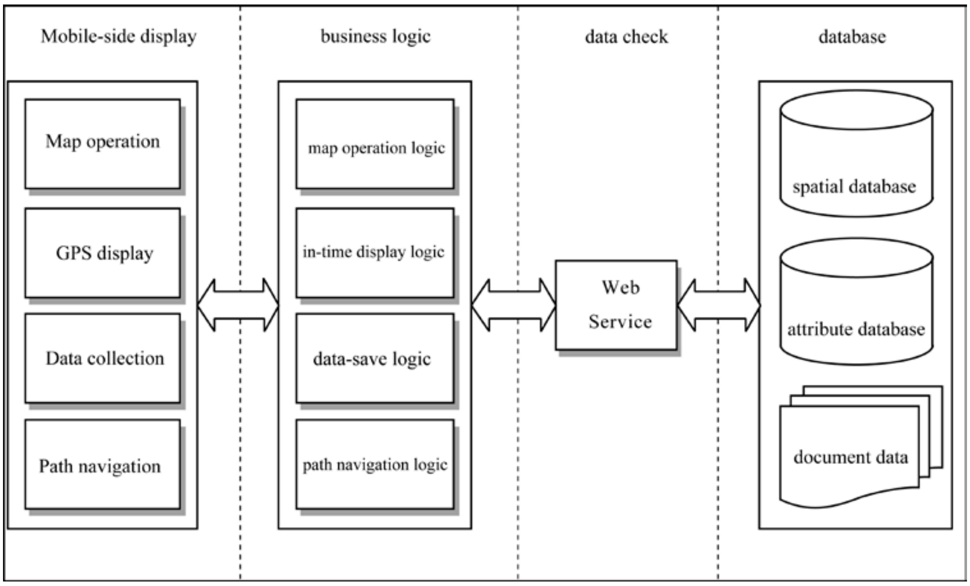

Figure 1. Design of the overall system

(1) The system function module

According to the content of the system requirements analysis, the features of the data collection system can be summarized as the following functional modules: job preparation module, map management module, data acquisition module, GPS navigation module, data transfer modules and systems assistant module. The diagram of the system function is shown in Figure 2.

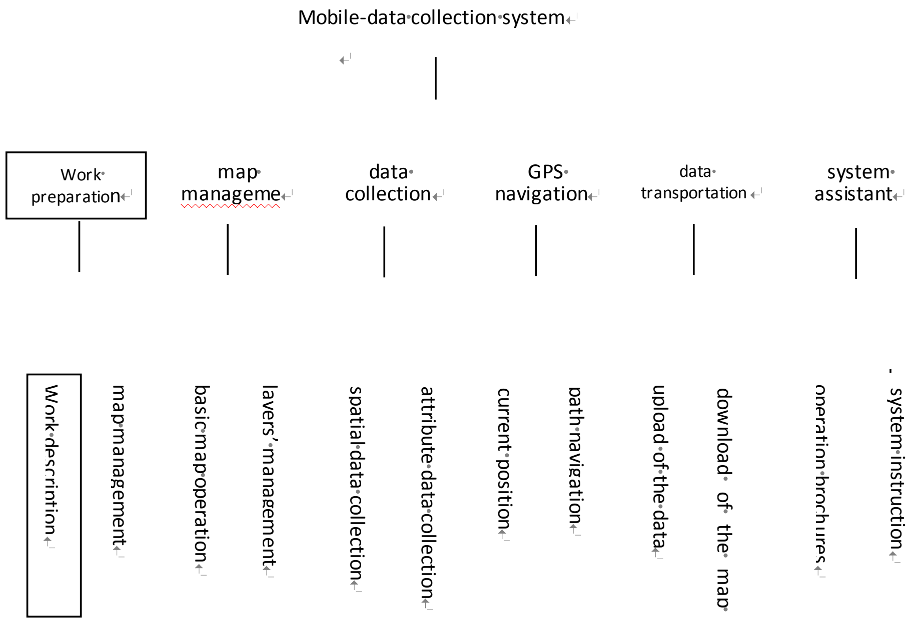

Figure 2. System function diagram

(2) Database design

This system uses the ARCSDE spatial database technology to manage the spatial data and attribute data simultaneously. As for the spatial data, we should manage them by layers. According to the type of the collected object, it can be classified into point, line and surface layer, as it is shown in table 1. The position data of the collectors and their walking-track data are shown in table 2.

Table 1. The information table of the collection points

Field name	data type	length	null or not	instruction
OBJECTID	ObjectID	4	Not	the ID number of the collection spot (Automatic generation)
Lon	Numeric	15	Yes	the longitude of the collection spot
Lat	Numeric	15	Yes	the latitude of the collection spot
Alt	Numeric	15	Yes	the height of the collection spot
Time	Date time	8	Yes	the collection time of the collection spot
Addr	Var char	50	Yes	the collection spot
……	……	……	……	the collection information for the customers
Shape	Point	4	Yes	the type of the collection spot (Automatic generation)
GlobaIID	Unique identifier	16	not	the unique mark of the collection spot (Automatic generation)

Table 2. The information table of the collection surface

Field name	data type	length	null or not	instruction
OBJECTID	Int	4	not	The ID number of the collection layer (Automatic generation)
Time	Date time	8	Yes	The collection time of the
Addr	Var char	50	Yes	The collection site
……	……	……	……	The information of the customers
Shape	Polygon	4	Yes	The geometric types of the collection layer'

				(Automatic generation)
GlobaIID	Unique identifier	16	not	The unique mark of the collection layer' (Automatic generation)

(3) Improvement of GPS positioning algorithm

Hybrid positioning is based on the idea of introducing more measurements and enhancing the location estimation conditions, so as to obtain a more accurate position. So, through combining with time measurements and angle measurements in the location estimation, we can limit and narrow the range of positioning and get a more accurate location result. CHAN's algorithm actually makes twice weighted least squares. So, it is much better than a one-weighted least squares (WLS) positioning performance. Suppose the undetermined coordinates in a cellular network is (x, y), the Bsi coordinates is (x_i, y_i), then we can get the following equations based on the measured TOA value:

$$r_i^2 = (c\tau_i)^2 = (x_i - x)^2 + (y_i - y)^2 = K_i - 2x_i x - 2y_i y + R \quad i = 1, 2, \cdots, M$$

$K_i = x_i^2 + y_i^2, R = x^2 + y^2$, C is the wave propagation speed; M is the OTA measurement values. Assuming the service BS (BSI) can always provide AOA measurements of MS, we can establish equations based on AOA measurement value Q:

$$\tan\alpha = \frac{y - y_1}{x - x_1} \quad (2)$$

Set $z_a = \left[z_p^T, R\right]^T$ as the unknown data and $z_p = [x, y]^T$. we can have the next equation based on the variable z_a:

$$h = G_a z_a \quad (3)$$

The error is as the following:

$$\Psi = h - G_a a_a \quad (4)$$

In this equation,

$$h = \begin{bmatrix} r_1^2 - K_1 \\ r_2^2 - K_2 \\ \vdots \\ r_m^1 - K_m \\ x_1 \tan\alpha - y_1 \end{bmatrix}, \quad G_a = \begin{bmatrix} -2x_1 & -2y_1 & 1 \\ -2x_2 & -2y_2 & 1 \\ \vdots & \vdots & \vdots \\ -2x_m & -2y_m & 1 \\ \tan\alpha & -1 & 0 \end{bmatrix}$$

With the calculation, we can get:

$$z_a = \arg\min\left\{\left(h - G_a z_a\right)^T Q^{-1}\left(h - G_a z_a\right)\right\} = \left(G_a^T Q^{-1} G_a\right) - 1G_a^T Q^{-1} h$$

(5)

With the help of the above equations, we can calculate the positions accurately.

Mobile data acquisition system and its application

The mobile terminal adopts a Trimble Juno GPS handheld device and the HTC XV695O Smartphone to test the data acquisition system. The map management module provides the manipulating function, including the map zoom in, zoom out, pan, full image display, attribute query, layers control and map measurement and so on. As for the map manipulation, such as the map's zooming in, zooming out as well as translation, we can directly adopt the packaged Map to complete it. We just need to set the property of current MapAetion as corresponding MapAetion. As for the full-map display, property query, layers control and map measurement, we just need to edit a few codes. So, using ArcGIS Mobile SDK for the development of the map functions can greatly reduce the difficulty of system development and improve the development efficiency.

(1) Data acquisition module

Data acquisition modules mainly realize the function of spatial data collection, spatial data editing, property data acquisition, and other functions. Spatial data collection users can manually collect the spatial data such as points, lines, surfaces, or you can use GPS location information to realize the automatic collection. When adding the point, line and facial elements, users can directly use sketch Graphic Layer and the MapAetions that ARCGIS Mobile SDK has already packaged to finish the task, such as adding a point on the map

(1) Spatial data editing

Spatial data editing mainly includes inserting node, moving the nodes, deleting the nodes, and so on. For these operations, we can directly use the sketch Graphic Layer and the MapAetions to finish them, for example, the main codes on lines are as follows:

(2) Property data acquisition

Property data acquisition page is generated by the program according to the collection layer's information and the content of the data dictionary dynamically. After the acquisition of the space data, the program will input the information of the collection layers, and then generate the data collection page according to the properties of this layer in the dictionary.

In the process of the data collection, we should minimize the trouble of text input and determine the collection data type from several types in advance, and we can also list all these types for the collectors to choose conveniently. In this way, we can not only reduced the trouble of inputting word by word, but also reduce the risk of inputting errors. General property acquisition system can not only make usual data collection, but it can also collect pictures, videos, audios, and other data. Due to the collected images, videos, audios, and other data is not suit for saving in the property field of the acquisition layer. So, we should save all these information separately. In the appropriate fields of the layers, we should only record the names of the collected pictures, videos, audio files. In this way, we can connect the pictures, videos, audios with the spatial data and attribute data we have collected through the file names.

(2) GPS navigation module

GPS navigation module implements the following functions: connect the GPS, disconnect the GPS, display the satellite information and signal strength that the GPS received, display the current location information on a map, route navigation. For the GPS connection, GPS disconnection, GPS signal acquisition and other related information, we can make use of the serial port connection provided by the ARCGIS Mobile SDK to finish these tasks. For the display of current location information on the map, we can use the GPSDisplay control. Firstly, we can use the Satellites of the Connection property Serial Port GPS to obtain the current satellite information that we have received. Then use the Id, Elevation, and Azimuth attributes of the Satellite to gain the accesses to the satellite ID number, height angle, azimuth angle, noise ratio and other information. And finally, we can draw out all these information in a visually graphic way.

(3) Navigation

Given that the mobile Wi-Fi is not as stable as the cable network, if we rely entirely on the backend server at the time of navigation, we cannot realize the navigation without the mobile network. Consequently, our system adopts the combined method supported by the server-side, that is, combine the path analysis services with the autonomous client-side navigation. If the mobile network is unobstructed, we can use the path analysis service released by the server ARCGIS Server for the collectors to carry out the navigation. In the case of unable to connect to the mobile networks, we can directly make path calculation on the mobile side so as to carry out the navigation.

When we adopt the server-side path analysis, we should firstly release a service on the server side with the help of the ARCGIS Server, and then we can adopt the service in the program through the Web service method, and set the relevant parameters information of the path analysis. The system will firstly transmit the relative parameter information that has been set to the server. After the server has received these parameters information, it can go ahead with the path computation. After the finish of the calculation, the server will send the calculated path information to the mobile terminals, which just need to show the path information on the map. When we carry out the path calculation on the mobile end, we will need the help of the Dijkstra algorithm. The basic idea of the Dijkstra algorithm is as the following shows: set $G=(V,A)$ is an assigned right figure, that means, for each side in the figure $e=(v_i,v_j)$, they are given a right value w_{ij}. In Figure G, there are two specific points, which can be defines as the beginning point and the end point. We may set v_1 as the beginning point, while the v_k is the end point. Then the process of the algorithm is as follows: Firstly, let's start from the starting point v_1, and label each vertex. There are two kinds of labels, label T and label P. Label T stands for the upper bound of the shortest path's weight value from the starting point v_1 to this point, which is known as the provisional label; while label P stands for the weight value of the shortest path from the starting point v_1 to this point, which is known as the fixed label. Those vertexes that have been labeled as P will not change any more, while those unlabeled vertexes will be marked as label T. Each calculation step we make, we will change the label T into label P. When v_k was labeled as P, it suggests that the shortest path from v_1 to v_k has been obtained and the calculation is finished. The detailed calculating steps are as follows:

(1)Label the v_1 as $P(v_1)=0$, the other point labeled as T, $T=(v_1)=+\infty(j\neq1)$

(2)If the label of P that we have just obtained is v_i, then for all these point $\{v_j \mid (v_i, v_j) \in E$, and the label of v_j is label T}, we can change the label T as: $\min\left[T(v_j), P(v_i) + w_{ij}\right]$.

(3)If the point v_k is labeled as P, and then we should stop the calculating. Otherwise, the label of v_{j0} should be changed as label P. Then we can go back with the step (2). The v_{j0} should meet the condition: $T(v_{j0}) = \min T(v_j)$.

The main code of the calculation can be seen in the appendix.

(3) System application

Click the "Task description", you can check the related information about the task. Click the "Data dictionary editing", you can set the data information in the data dictionary.

With the help of the GPS navigation menus, we can make the following operations: connect the GPS, disconnect the GPS, display the collectors' current location on the map, real-time display of the satellite information that the GPS received, display the current latitude and longitude coordinates as well as the information of the GPS accuracy.

The data that the mobile-end has collected can be uploaded to the back-end server via GPRS wireless network in real time. So, we can check those data that the collectors have collected in real time on the server side.

Conclusions

Aiming at the problem of low accuracy and low efficiency in the traditional way of mobile data collection, as well as the existing problem that the mobile data acquisition systems being specific to spatial position measurement and lacking of the universality characters, this paper proposes and develops a data acquisition system based on GPRS and mobile GIS technology, and applies the GIS, GPS and GPRS technologies to the mobile data collection operations.

Our system is quite different from the currently available mobile data acquisition system, because our system is a versatile mobile data acquisition system. Users can customize the collection content according to their own application requirements, so as to make it available to the survey of land use, census, market research, forest resource investigation, etc.

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