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Integrated GPS/INS/GIS for Vehicle Navigation System (2/3)

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Introduction

In recent years, Global Positioning System (GPS) plays an important role on navigation depends on the high credibility features.

Inertial Navigation System (INS) is an autonomous system. The angular velocity and acceleration information can be measured by using gyros and accelerometers. However, the inertial measurement units (IMU) still have drift problems in navigation system. These errors might increase with time by the integral procedure. Therefore, INS always combined with the GPS to calibrate the errors.

Besides, we can develop the car navigation system with the help of Geographic Information System (GIS). The integrated GPS/INS/GIS system block diagram is shown in figure 1.

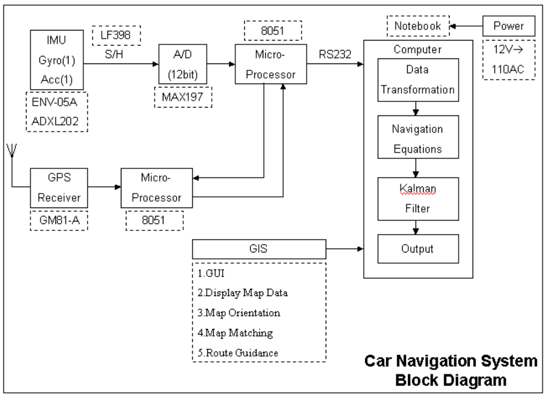


Fig.1. Car Navigation System Block Diagram

In the last year, we have developed the integration of GPS with INS. Therefore, we focus on the development of GIS and the integration of GPS with GIS this year.

GPS depends on the concepts of "positions" and "absolute coordinates." On the other hand, GIS depends on the concepts of "locations" and "relative coordinates." With GPS, users can get to know the positions (i.e., the coordinates that specify where the users are); combined with map and GIS data users can know the locations (i.e., where the users are with respect to objects around the users). Besides, the digital map data is more accurate than the positioning data provided by GPS. Therefore, we can integrate GPS with GIS to get the more accurate location in the vehicle navigation system.

In the developed vehicle navigation system, the GPS receiver module copes with the received GPS data. The map orientation module and the map data displaying system facilitate the map reading of the drivers. The map matching module use the fact that " A vehicle moves always on a road network", to integrate the GPS absolute position with a digital road map to get the more accurate location. The Graphic User Interface (GUI) for vehicle navigation system will display driver's location on the map and provide drivers with the basic map functions.

GPS Receiver Module

The Visual Basic software is utilized to develop the GPS receiver module. The useful information is picked up from the separated sentences and put into the Access files.

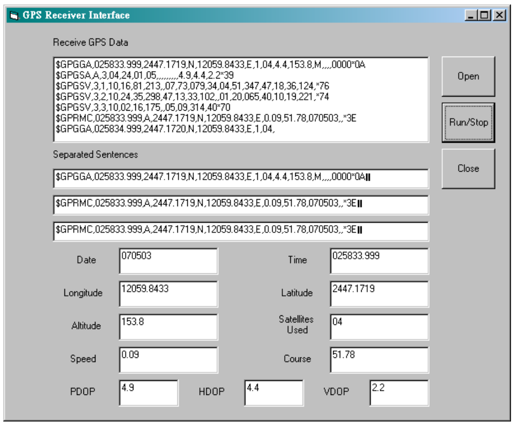
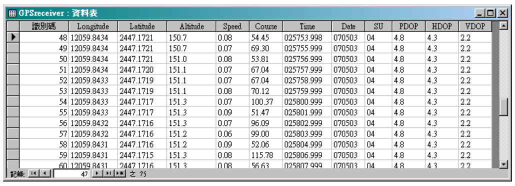


Fig.2 GPS Receiver Interface


GPSreceiver : 資料表

識別碼	Longitude	Latitude	Altitude	Speed	Course	Time	Date	SU	PDOP	HDOP	VDOP
48	12059.8434	2447.1721	150.7	0.08	54.45	025753.998	070503	04	4.8	4.3	2.2
49	12059.8434	2447.1721	150.7	0.07	69.30	025755.999	070503	04	4.8	4.3	2.2
50	12059.8434	2447.1721	151.0	0.08	53.81	025756.999	070503	04	4.8	4.3	2.2
51	12059.8434	2447.1720	151.1	0.07	67.04	025757.999	070503	04	4.8	4.3	2.2
52	12059.8433	2447.1719	151.1	0.07	67.04	025758.999	070503	04	4.8	4.3	2.2
53	12059.8433	2447.1719	151.1	0.08	70.12	025759.999	070503	04	4.8	4.3	2.2
54	12059.8433	2447.1717	151.3	0.07	100.37	025800.999	070503	04	4.8	4.3	2.2
55	12059.8433	2447.1717	151.3	0.09	51.47	025801.999	070503	04	4.8	4.3	2.2
56	12059.8432	2447.1716	151.3	0.07	96.09	025802.999	070503	04	4.8	4.3	2.2
57	12059.8432	2447.1716	151.2	0.06	99.00	025803.999	070503	04	4.8	4.3	2.2
58	12059.8431	2447.1716	151.2	0.09	52.06	025804.999	070503	04	4.8	4.3	2.2
59	12059.8431	2447.1715	151.3	0.08	115.78	025806.999	070503	04	4.8	4.3	2.2
60	12059.8431	2447.1716	151.3	0.08	56.63	025807.999	070503	04	4.8	4.3	2.2

記錄: 47 之 75

Fig.3 Access File

Geographic Information System

In 1988 the Federal Interagency Coordinating Committee defined the term *Geographic Information System* in the following manner: " A system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems." In essence, such a system is an electronic spreadsheet coupled with powerful graphic-manipulation and display capabilities. The three most important elements of a typical GIS can be summarized as follows: [8] [12]

A. Cartographic capability

B. Data management capability

C. Analytical capability

A geographic information system is best suited for the analysis of geographic data. A GIS adopts the relational database. In addition to graphic data (spatial data), a GIS also stores attribute data. These are associated with the spatial data and provide further descriptive information about them. This attribute data is placed in a database separate from the graphics data. Most importantly, the spatial relationships among all data elements are defined. Accordingly, we can get not only the information of the data element itself, but also the information nearby.

Universal Transverse Mercator (UTM) Projection

The UTM coordinate system is a worldwide system originally adopted by the U.S. military in 1947, and since has been widely used by civilian mapping in many countries. Its popularity can be attributed to its nearly worldwide coverage (it excludes only small regions around the poles) and its ease of use. Because the UTM projection is very accurate in narrow zones, it has become the basis for a global coordinate system.

Combining GPS with GIS

There are six steps for combining GPS with GIS.

A. Create a Record set. (Access Files or Excel Files)

B. Receive GPS data.

C. Perform the unit transformation.

D. Perform the UTM projection.

E. Display the coordinates (*x, y*) on map.

F. Store the GPS receiver information and the processed coordinates (*x, y*).

Display Map Data

Although there are seven layers (region, railway, river, road, bridge, landmark and node) in the map structure, the display of each layer must depend on the map extent.

Table 1 List of Display Map Data

Scale / **Layers**	Width of Map Extent >= 1/2 Width of Full Extent	Width of Map Extent < 1/2 Width of Full Extent	Width of Map Extent < 1/4 Width of Full Extent
Region	○	○	○
Railway	○	○	○
River	○	○	○
Road	∗	○	○
Bridge	∗	○	○
Landmark	∗	∗	○
Node	∗	∗	∗

○ : Visible ∗ : Invisible

Basic Map Functions

The basic map functions for vehicle navigation system must have special features, which are far different from the ordinary maps. The specified basic map functions are developed to assist the users in manipulating the vehicle navigation system. They are (1) Zoom, Zoomin, Zoomout, (2) Pan, (3) Fullextent, (4) Event, (5) Measure, (6) Locator, (7) Label, (8) Find, (9) Trajectory, (10) Located Road, (11) Speeding Warning, (12) Demonstration, and (13) Export.

Map Matching Function

The purpose of the map matching module of a vehicle navigation system is to locate the position of the vehicle relative to the map data that is referenced by the system. In other words, the map matching problem can be defined as the identification problem of the road through which the car is moving.

Map Matching Algorithm

There are three measures according to three issues to be used in the map matching algorithm. The first measure is the projected error. Projected error is defined as the distance between the vehicle position obtained from the GPS receiver and its projected position on the road. The first issue of the map matching algorithm is that the projected error must be small.

The second measure is the dot-product value. The dot-product implies the similarity between the shape of the road and the trajectory of the vehicle positions. However, the second issue of the map matching algorithm is that the dot-product value should be big.

The third measure is the moving distance. The definition of the moving distance is the distance between the present vehicle position and the previous vehicle position. The issue of the third measurement is that the difference between the moving distance and the projected moving distance should be small.

Map Matching Structure

In the map matching structure, three modes are used. They are the initial mode, the searching mode and the tracking mode.

The complete map matching flow chart is shown in Fig. 4. Notice that, there are some searching ranges used in the map matching algorithm. These searching ranges are chosen based on the errors of combining GPS with GIS.

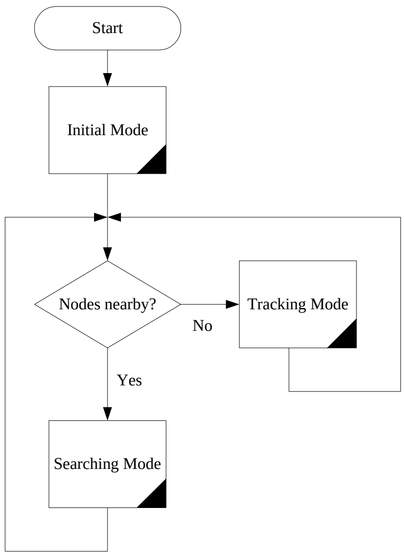


Fig.4 Map Matching Flow Chart

Searching Mode

The three introduced measures are used in the searching mode. In addition, they are applied according to priority. The complete flow chart of the searching mode is shown in Fig. 5.

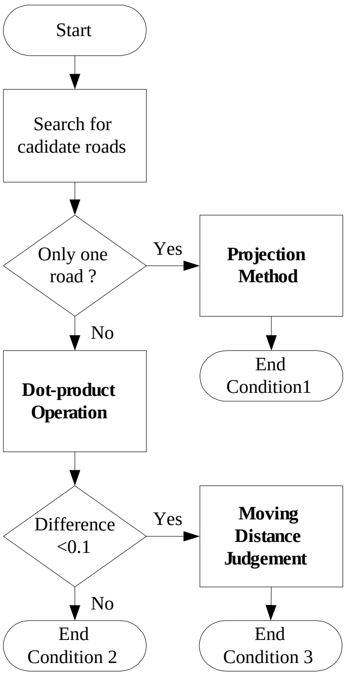


Fig.5 Searching Mode Flow Chart

Map Orientation Function

Map orientation function is also an important module in the vehicle navigation system. Map orientation function utilizes a rotation angle, which is called bearing to rotate the map. When the map is reoriented along the direction of driving, driver can read map easily since it can be mapped into what he or she sees on the road. Driver may feel uneasy if the map rotates too frequently. The measurement noise of the GPS satellite signal can rotate map abruptly and too frequently. Therefore, it is important to make the map rotation unnoticed. Its performance depends on how to determine the bearing for map and when to rotate map according to the bearing.

The complete map orientation flow chart is shown in Figure 6.

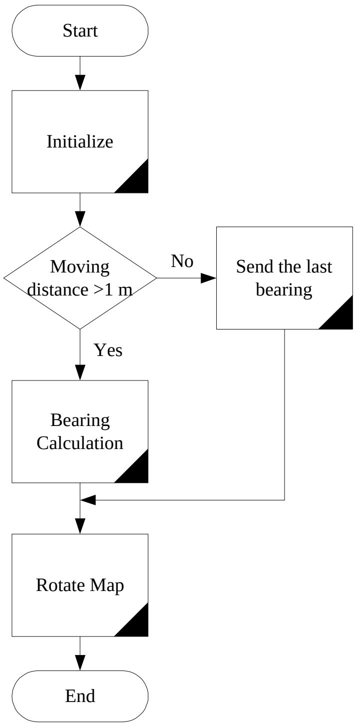


Fig.6 Map Orientation Flow Chart

Hardware Description

The vehicle navigation system hardware consists of a GPS receiver, a battery, a voltage transforming circuit, RS232 interface, and a notebook computer. The notebook computer is regarded as a main navigation processor. All modules and algorithms are performed in the notebook computer. The navigation results are also displayed on the notebook monitor.

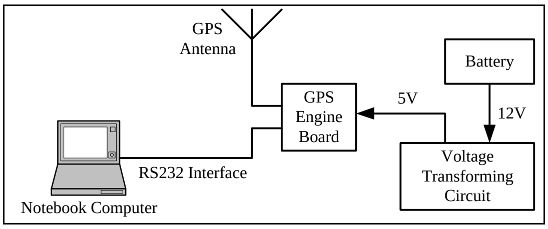


Fig.7 Hardware Structure

Vehicle Navigation System Interface

The Visual Basic software and the GIS component, MapObjects, are utilized to develop the vehicle navigation system. The vehicle navigation system consists of the GPS receiver module, the combination of GPS with GIS, the digital map data, the display map data, the basic map functions, the map matching module, and the map orientation module. The complete vehicle navigation system interface is shown in Figure 8.

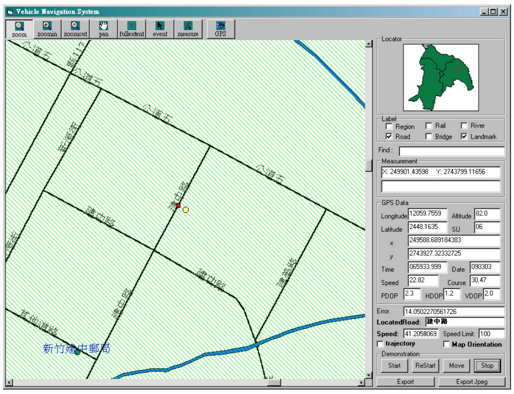


Fig.8 Vehicle Navigation System Interface

Experimental Results

The experiment is performed in the NCTU campus. The shape of the road is complicate. Furthermore, there are many tall trees beside the road. The trees will obstruct the GPS satellites signal. The fig. 9 shows the experimental results. The circles represent the received GPS positions from the GPS receiver and the rectangles represent the map-matched vehicle positions. We could see that the map-matched vehicle position locates the proper road whenever the vehicle is moving. The fig. 10, fig. 11,and fig. 12 are the zoom-in figures of the fig. 9.

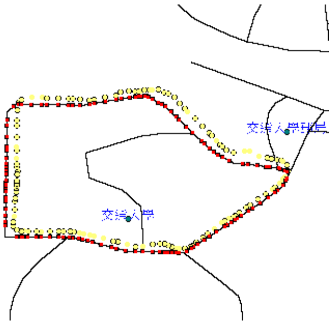


Fig.9 Experimental Results (1)

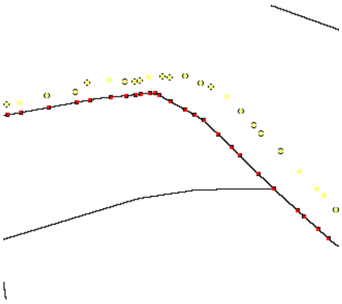


Fig.10 Experimental Results (2)

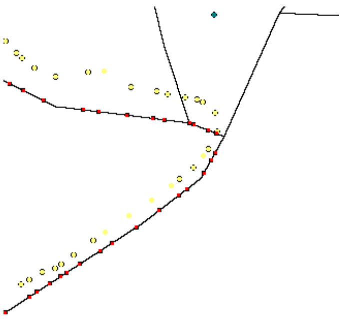


Fig.11 Experimental Results (3)

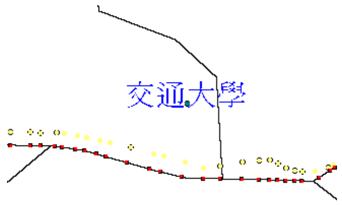


Fig.12 Experimental Results (4)

Furthermore, the map orientation results are shown below. Four figures are chosen to present the map orientation about the experimental route.

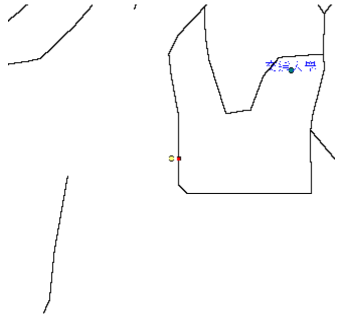


Fig.13 Map Orientation (1)

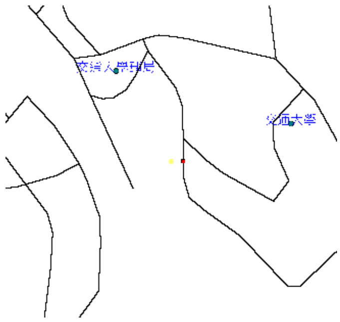


Fig.14 Map Orientation (2)

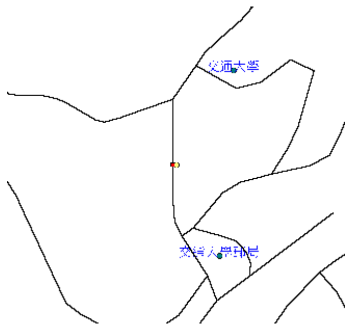


Fig.15 Map Orientation (3)

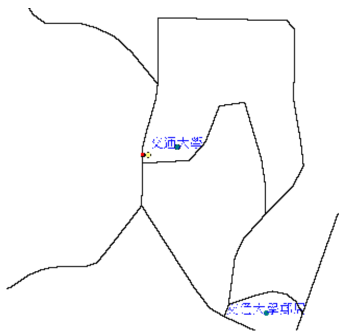


Fig.16 Map Orientation (4)

Conclusions and Future Works

In this year, we integrate GPS with GIS to develop a real-time vehicle navigation system. The developed vehicle navigation system consists of many modules to assist drivers or users to manipulate the navigation system. A map matching algorithm and a map orientation algorithm are proposed in this project. The two algorithms work well in the outdoor experiments. Moreover, the proposed algorithms need little computation time. Therefore, the integrated GPS with GIS is a real-time system.

In the next year, we will focus on the integration of GPS, INS, and GIS. We will utilize the fruitful results of these two years to develop an integrated GPS/INS/GIS vehicle navigation system.

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