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The Use of a GPS in Geographic Information System Construction

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Abstract: The traditional method to construct Geographic Information System (GIS) is to scan the published maps, then the important and difficult step is to digitize the maps data. It costs a lot of time and human resource. Because a Global Positioning System (GPS) can offer high accurate digital signal directly, we developed a new method that uses the GPS to construct the GIS.

1. Introduction

Geographic information systems (GIS) is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations.[1, 2] GIS technology can be used for scientific investigations, resource management, and development planning. The key point of GIS is to input the map data. If the data to be used are not already in digital form, that is, in a form the computer can recognize, Maps should be digitized, or hand-traced with a computer mouse, to collect the coordinates of features. Electronic scanning devices will also convert map lines and points to digits.[3] But this is the time-consuming component of GIS work. Identities of the objects on the map must be specified. Editing of information that is automatically captured can also be difficult. Electronic scanners record blemishes on a map just as faithfully as they record the map features. [1]

Recently advanced GPS methods allow latitude, longitude and elevations to be determined in a comparatively short time with accuracy to within a meter. The GPS refers to a satellite based navigational system allowing the determination of any point on the earth's surface with a high degree of accuracy given a suitable GPS receiver. Using GPS to capture data for GIS, we can get lower cost but highly accurate, digital and mobile GIS data in a comparatively short time. The data can then be stored, displayed, manipulated, overlaid, integrated and analyzed in a GIS platform. [4]

2. GPS measurement principle

GPS is funded and controlled by the U.S. Department of Defense (DOD). While there are many thousands of civil users of GPS worldwide, the system was designed for and is operated by the U.S. military. GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.

The Space Segment of the system consists of the GPS satellites. We often call the GPS satellites as space vehicles (SVs). These space vehicles (SVs) send radio signals from space. The nominal GPS operational constellation consists of 24 SVs. There are six orbital planes with nominally four SVs in each. This constellation provides the user with between five and eight SVs visible from any point on the earth.

GPS receivers are used for navigation, positioning, time dissemination, and other research. Navigation in three dimensions is the primary function of GPS. Navigation receivers are made for aircraft, ships, ground vehicles, and for hand carrying by individuals.

The positioning accuracy offered by GPS varies depending upon the type of service and equipment to which a user has access. For reasons of the United States National Security, GPS exist in two distinct forms, the Standard Positioning Service (SPS), and the Precise Positioning Service (PPS). The US Department of Defense (DOD) reserves the PPS for use by its personnel authorized federal agencies, and NATO partners. The United States Government provides the SPS free of charge worldwide, to all civilian users. For many positioning and navigation applications, an accuracy of 100 meters or more is insufficient, and differential positioning techniques must be employed.

The purpose of differential GPS (DGPS) is to eliminate or dramatically reduce the effects of atmospheric, and satellite errors. To accomplish this, a reference GPS receiver is established at a point of known coordinates. This receiver makes pseudo range measurements to each of the GPS satellites, and computes a non-differentially corrected. The receiver also calculates true ranges using its known position, and the location of each tracked satellite. The amount by which the true range to one satellite and the observed range differ, is the differential correction. These corrections are transmitted to a remote receiver in real-time by broadcasting (Beacon Signal). The remote receiver corrects its range measurements using these differential corrections, providing a much more accurate position. The principle of a DGPS is shown in Fig 1.[5] The Beacon Signal we used is coming from Gesashi site.

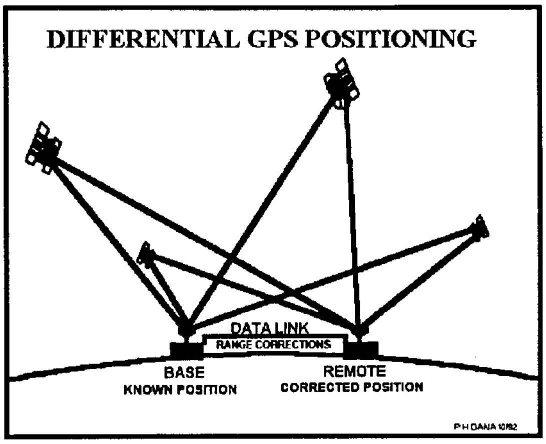

Fig 1: Differential GPS Positioning

3. Measurement accuracy of GPS

We have a GPS instrument (GBX-PRO model) made by Communication System International Inc. Canada. This GPS uses an Ashtech G-12 high accuracy, 12 channel GPS board. It utilizes free GPS satellite and 300kHz beacon signals to calculate differential corrected 3D positions with a horizontal accuracy of less than one meter with 95% confidence. It also has a data port (RS-232C) on the back to provide access to the internal GPS and DGPS device through the same serial cable.

3.1 Position measurement error

It is important for us to know the measurement accuracy of the position and the distance. For checking the measuring accuracy and the steadiness of our GPS, we measured a fixed point for several times. The Fig 2 and table 1 display the results of our measurements.

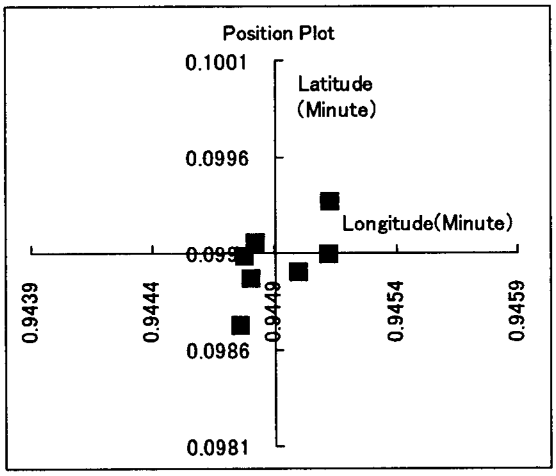

Fig 2 Point measured data

Table 1: The result of point measurement

	Latitude (D°M.M)	Longitude (D°M.M)
Average(μ)	26°15.09906	127°45.94491
Std(σ)	0°0.00018	0°0.00016

Let the ϕ, λ and h be the geodetic latitude, longitude and height. Then the earth centered earth fixed Cartesian coordinates (X, Y, Z) can be calculated as:

$$X = (N + h)\cos\phi\cos\lambda \quad (1)$$

$$Y = (N + h)\cos\phi\sin\lambda \quad (2)$$

$$Z = [N(1 - e^2) + h]\sin\phi \quad (3)$$

$$N(\phi) = a / \sqrt{1 - e^2 \sin^2\phi} \quad (4)$$

$$f = \frac{a - b}{a} \quad (5)$$

$$e^2 = 2f - f^2 \quad (6)$$

where N is the radius of curvature in prime vertical; a is the semi-major earth axis (ellipsoid equatorial radius); b is the semi-minor earth axis (ellipsoid polar radius); f is the flattening and e^2 is the eccentricity squared.

By using the Equations (1)-(6), the Fig 2 can be redrawn as Fig 3. It can be seen that the position measurement error is less than 1 meter.

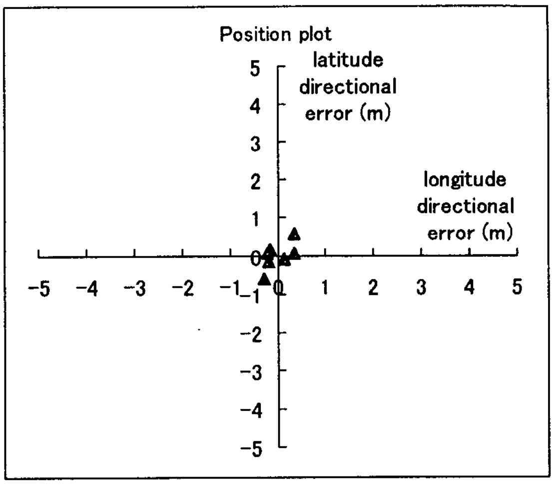

Fig 3: Point measured error

3.2 Distance measurement error

The distance is calculated from two measured points as:

$$d = \sqrt{(X1 - X2)^2 + (Y1 - Y2)^2 + (Z1 - Z2)^2} \quad (7)$$

The measured distance data are shown in Fig 4. The measuring error (Δd) and relative error ($\Delta d/d$) are shown in Fig 5 and Fig 6, respectively. It can be seen that the relative error of the distance measurement is less than 20% for the distance larger than 5m.

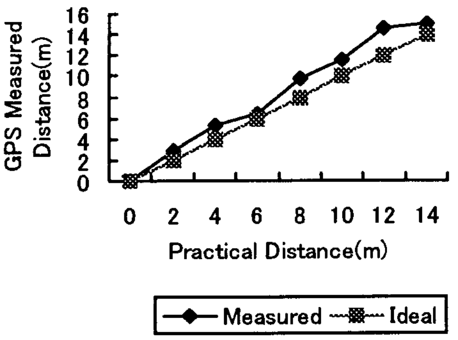

Fig 4: Distance measurement

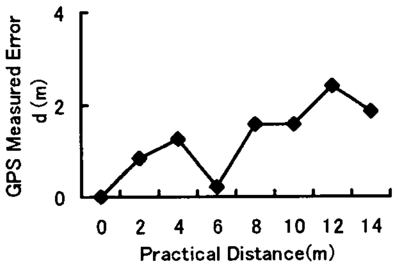

Fig 5: Distance measuring error

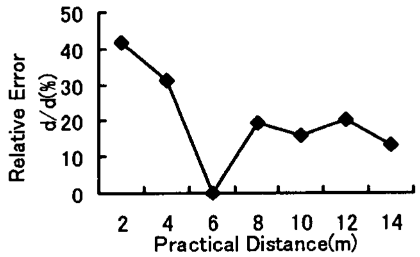

Fig 6: Relative error of distance

4. Road measuring experiment for GIS

To accomplish our idea, we did an experiment that used the GPS to measure the loop road of University of the Ryukyus' campus.

The experimental equipment is shown in Fig 7. The GPS is connected to a note computer. The GPS has a RS-232C data access port, which can receive the control command and output the NMEA 0183 standard data messages. NMEA 0183 is a communications standard established by the marine industry. The computer is connected with the GPS through the RS-232C serial port and receives the GPS data in the form of NMEA 0183. The data is then converted to and stored in ASCII form. The

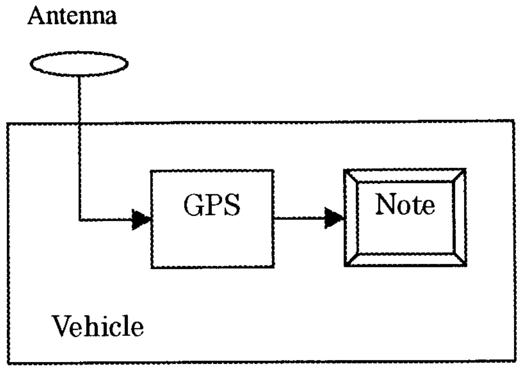

Fig 7: Experimental equipment for road measurement

GPS and the note computer are arranged into a vehicle. Put the antenna of the GPS on the roof of the vehicle where unobstructed view of the sky, and was as far as possible from all other equipment like motors, radios and other electronic devices.

The parameters used for experiments are shown in Table 2. The sampling rate of the GPS is 2.5Hz (the maximum sampling rate is 5Hz). The speed of the vehicle is about 40 km/hr, which is reasonable speed for driving on the road. So the sampling distance (the distance between two neighbor points) is estimated as 4m. Increasing the sampling rate of the GPS or decreasing the vehicle speed can reduce the sampling distance.

Table 2: Experiment parameter

	Practical parameter
Sample rate	2.5 Hz
Vehicle speed	0~40 km/hr.
Neighbor point distance	3.54 m(aver) 4.26 m(max)

The measured result is shown in Fig 8. In order to make a comparison, we also show the campus map[6] of the University of the Ryukyus, which is including the loop road in same scale, in Fig 9. It can be seen that the measured loop road is almost same with the true map and it can be used as digitized map data for GIS construction.

5. Convert GPS data to GIS shapefile

We have got the GPS data stored in NMEA format, but these data can not be used directly in the GIS directly. In our group, we use ESRI's GIS structure, which store data in the ESRI shapefile. A shapefile stores nontopological geometry and attribute information for the spatial feature in a data set. The geometry for a feature is stored as a shape comprising a set of vector coordinates. An ESRI shapefile consist of a main file, an index file, and a dBASE table. The main file is a direct access, variable-record-length file in which each record describes a shape with a list of its

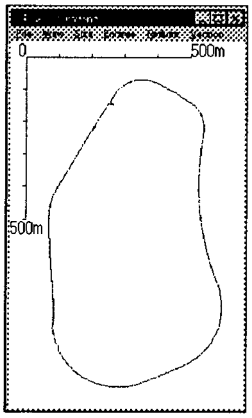

Fig 8: The loop road measured by the GPS

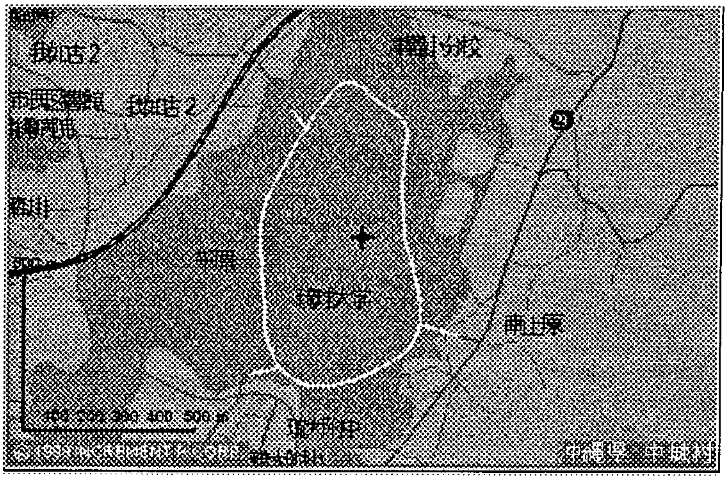

Fig 9: The Loop Road in the Map

vertices. In the index file, each record contains the offset of the corresponding main file record from the beginning of the main file. The dBASE table contains feature attributes with one record per feature.[7]

According to the ESRI Shapefile Technical Description, we convert GPS data to shapefile that include a main file, an index file and a dBASE table. Fig 10 shows the loop road displayed by ESRI ArcExplorer Version 1.1.488 – A GIS data explorer built with MapObject technology.

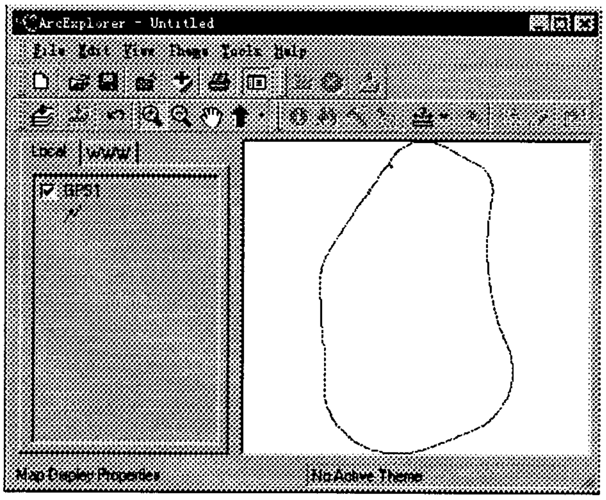

Fig 10: The loop road displayed by GIS

6. Conclusion

We have demonstrated the possibility of using a DGPS for GIS construction. The position measurement error of the DGPS is less than 1m and the relative error of distance measurement is less than 20% for the distance larger than 5m. The measured loop road is almost same with the true map and it can be used as a digitized map data for GIS construction. The GPS measuring data can be converted to the GIS shapefile that can be used in GIS.

Finally, we would like to thank Ms. Zeng Xiangyan and Mr. Takeshi Kuniyoshi for their help in experiments and data analysis.

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