DGPS Based Nationwide Highway Surveying in China

Pengfei CHENG, Xiyin LI, Li ZHANG
Yanhui CAI, Xiujuan WU and Jingbin LIU, China

Key words: DGPS, Highway Network

SUMMARY

The highway networks at national and provincial levels in China (about 300,000km length) had been successfully surveyed based on the vehicle borne DGPS method proposed by this paper. In this paper the authors present detailed working flow chart in rapidly collecting geometric data and attributes of highway features, algorithms used for processing DGPS data, and a software package developed for this application. Through large scale highway data collection it proves the developed system can dramatically improve the efficiency and accuracy in field data collection.

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1. INTRODUCTION

The highway mileage in China had reached about 1.7 million kilometers by the end of 2001. For such large scale surveying work, two methods are considered, i.e. satellite image surveying and vehicle carried DGPS surveying. The relative advantage of the DGPS method exists as

- Higher Accuracy
  The accuracy of DGPS is better than 5 meters[1] while the resolution of SPOT-4 image is only 10 meters.
- Further Information
  Much more terrestrial objects such as gas stations, bridges and their attributes can be collected under vehicle carried DGPS condition.
- Lower Cost
  The expense on the satellite image purchase and image processing is much more than DGPS way. For instance, a 60km×60km SPOT-4 image costs about CN¥10,000 while the expense of vehicle carried DGPS for 60km×60km is less than CN¥2,000.
  Considering those factors, the State Bureau of Surveying and Mapping of China adopts the DGPS method for the development of transport layer in the 1:50,000 scale national fundamental geographic database.

The flow chart of the vehicle carried DGPS highway surveying is given as Fig. 1.

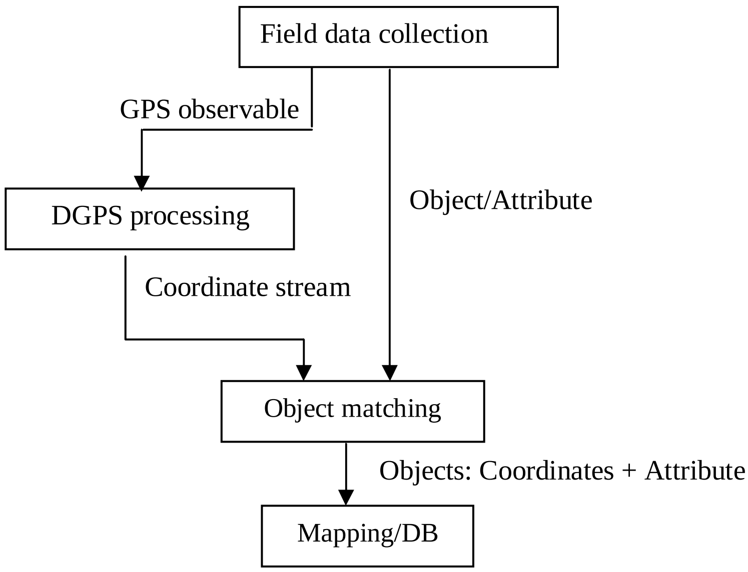

Fig. 1: Flow chart of the vehicle carried DGPS highway surveying

[1] With SA policy turning off

2. FIELD DATA COLLECTION

Many teams joined the field work. Each field team is configured with one base station and one or more rover(s). Surveying receivers are equipped on both base stations and rovers. Laptops with special designed recording software are also needed for the rovers.

The main purposes of the recording software are 1) to record the terrestrial objects and their attribute, and 2) to record the precise epochs of the objects. This leads to two key problems, the organization of different kinds of objects and the synchronization of recording time with GPS time.

2.1 Object Data Structure

An object/attribute table file is used in the software with the following basic structure

```
Bridge          43020     MPA      7
     Name       CHR       30
     Material CHR   20
     Width      FLT       10.2
     Length    FLT    10.2
     …
```

Using C++ object oriented programming, different kinds of objects can be accessed in the similar way.

2.2 Time synchronization

The time on the laptop is synchronized to the GPS receiver with the NMEA interface. The diagram is shown as blow

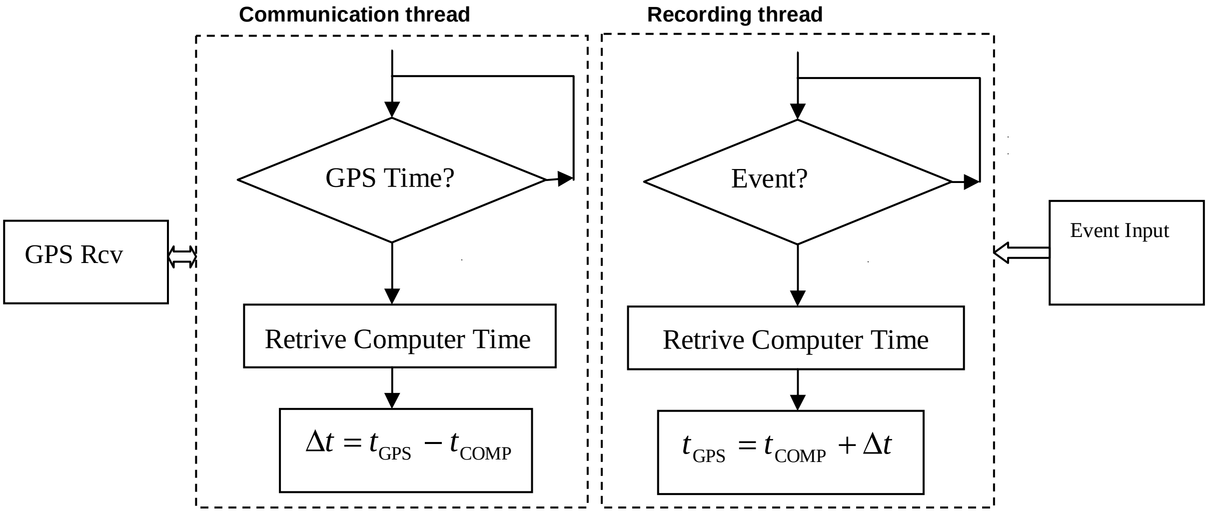

Fig. 2: Time synchronization between Computer and GPS

3. DGPS PROCESSING

Local Area Differential GPS (LADGPS) post processing model is used in this project.

3.1 Algorithm

According to the LADGPS model, the base station *B* is set up on a site with known coordinates, and the observation equation for satellite *j* is given as

$$R_B^j(t_0) = \rho_B^j(t_0) + \Delta\rho_B^j(t_0) + c\delta^j(t_0) - c\delta_B(t_0) \quad (1)$$

where $R_B^j(t_0)$ is the pseudorange observable for satellite *j*, $\rho_B^j(t_0)$ is the geometry distance from satellite *j* to site *B*, $\Delta\rho_B^j(t_0)$ is the bias of observable caused by the propagation route, $c\delta^j(t_0)$ is the bias of observable caused by the satellite and $c\delta_B(t_0)$ is the bias of observable caused by the receiver and its ground environment.

As $\rho_B^j(t_0)$ can be calculated from the known coordinate of satellite and site *B*, the correction for the pseudorange, namely PRC, can be calculated by

$$\begin{aligned} \mathrm{PRC}^j(t_0) &= -R_B^j(t_0) + \rho_B^j(t_0) \\ &= -\Delta\rho_B^j(t_0) - c\delta^j(t_0) + c\delta_B(t_0) \end{aligned} \quad (2)$$

Its derivative with respect to time is called RRC,

$$\mathrm{RRC}^j(t_0) = \left.\frac{d\,\mathrm{PRC}(t)}{dt}\right|_{t_0} \quad (3)$$

So PRC at time *t* can be calculated as formula

$$\mathrm{PRC}^j(t) = \mathrm{PRC}^j(t_0) + \mathrm{RRC}^j(t_0)(t - t_0) \quad (4)$$

Observe equation on the rover is given as

$$R_r^j(t) = \rho_r^j(t) + \Delta\rho_r^j(t) + c\delta^j(t) - c\delta_r(t) \quad (5)$$

After applying the correction derived from PRC and RRC

$$\begin{aligned} R_r^j(t)_{\mathrm{corr}} &= R_r^j(t) + \mathrm{PRC}^j(t) \\ &= \rho_r^j(t) + \Delta\rho_r^j(t) + c\delta^j(t) - c\delta_r(t) \\ &\quad - \Delta\rho_B^j(t_0) - c\delta^j(t_0) + c\delta_B(t_0) - \mathrm{RRC}^j(t_0)(t - t_0) \end{aligned} \quad (6)$$

During a limited term, PRC can be considered as time-invariant, so

$$\begin{aligned} R_r^j(t)_{\mathrm{corr}} &\doteq \rho_r^j(t) + \Delta\rho_r^j(t) + c\delta^j(t) - c\delta_r(t) - \Delta\rho_B^j(t) - c\delta^j(t) + c\delta_B(t) \\ &= \rho_r^j(t) + \Delta\rho_r^j(t) - c\delta_r(t) - \Delta\rho_B^j(t) + c\delta_B(t) \end{aligned} \quad (7)$$

Within a limited area, due to the strong correlation between $\Delta\rho_r^j(t_0)$ and $\Delta\rho_B^j(t_0)$,

$$R_r^j(t)_{\text{corr}} \doteq \rho_r^j(t) + c\delta_B(t) - c\delta_r(t) \qquad (8)$$

It shows that the biases caused by satellite and propagation are mainly removed. Carrier-phase aided code smoothing is also adopted to improve the accuracy.

3.2 Accuracy Test

Comparison with static GPS point can give the DGPS pointing accuracy. Two experiments have been done, one in the Xi'an-Baoji express way, which is 170km's long in west-east direction and another on the Xi'an-Lintong highway, which is 102km's long in north-south direction. The result the those tests is give as blow

Bias[2]	0~2.5	2.5~5.0	5.0~7.5	7.5~10	>10	Maximum
Point Num.	16	14	8	5	1	12.2
Percent	36.4	31.8	18.2	11.4	2.2	

4. OBJECT-COORDINATE MATCHING

From one terrestrial object's start and end epoch recording in field, the corresponding coordinates of the object can be retrieved. The Diagram is shown as blow

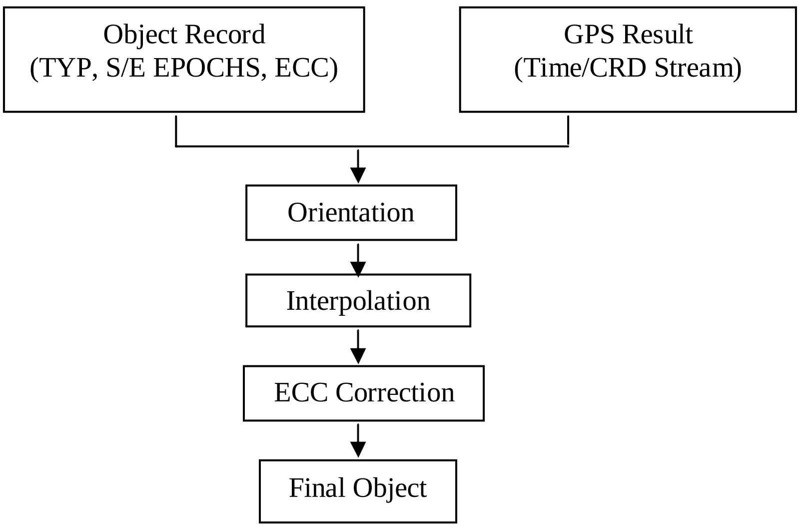

Fig. 3:Diagram of Object-Coordinate Matching

[2] The experiment is implemented before the SA turning off

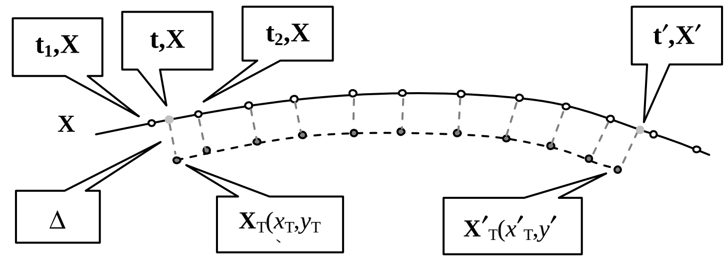

Fig. 4: Diagram of eccentricity correction

For those are not right on the trace of vehicle, as illustrated in Fig.4, an eccentricity correction should be implemented. The correction relies on direction of the vehicle's speed and the quantity of eccentricity. The formula of correction is given as

$$\begin{cases} x_T = x + \Delta\cos(\tan^{-1}(dy/dx) + \pi/2) \\ y_T = y + \Delta\sin(\tan^{-1}(dy/dx) + \pi/2) \end{cases} \qquad (9)$$

5. CONCLUSION

The highway networks at national and provincial levels in China (about 300,000km length) had been successfully surveyed based on the vehicle borne DGPS method. Now highways at the county and township level are being surveyed. The whole project was completed at the end of 2003.

REFERENCES

Junyong Chen, Real Time Positioning Technique of GPS: Development in Surveying Technologies, Vol.97, 1996.2

Jingnan Liu, Junyong Chen, et al., Principle and method of Wide Area Differential GPS, Press of Surveying and Mapping, 1998

Pengfei Cheng, Xiyin Li, et al., Key Technologies of DGPS in 1:50,000 Highway Surveying, Science of Surveying & Mapping, 2000, No.1, P34-36.

B.Hofmann-Wellenhof, et al., GPS Theory and Practice Fourth edition, Springer,1997

Pengfei Cheng, Investigations on the Establishment of DGPS Services in China, PhD Thesis, Technical University of Graz, 1998.

U. Hugentobler, et al., Bernese GPS Software Version 4.2, Astonomical Institute University Of Berne, 2001.

CONTACTS

Professor, Dr Pengfei Cheng
Chinese Academy of Surveying and Mapping
16 Beitaiping Road, 100039
Beijing
CHINA
Tel. + 86 10 8822 9385
Fax + 86 10 6821 8654
Email:pfcheng@public.bta.net.cn
Web site: http://www.casm.ac.cn/