Accuracy Analysis for a Mobile Mapping System

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Abstract: Constructing a geo-spatial database of Graphic Information Systems(GIS) in various applications is suffering from the difficulty of data acquisition, which is labor-intensive and time consuming. In order to provide the spatial data rapidly and accurately, 4S-Van, a prototype mobile mapping system, has been developed. This paper presents a novel approach for an analysis for Mobile Mapping Systems. Furthermore, we discuss the accuracy of measurements using images acquired from the 4S-Van. The first part of this paper introduces accuracies of other mobile mapping systems. Then, we describe main features of the 4S-Van and our proposed method for an analysis accuracies, which can be applicable to other mobile mapping systems. The last part of paper concludes with a summary and our suggestions for implementation of mobile mapping system.

1. Introduction

Mobile mapping system has become popular in recent days due to its capability of providing highly accurate 3D position. Mobile mapping system technology has been developed since late 1980'. It consists of CCD cameras for data acquisition and GPS and INS for navigation[5].

We have developed a prototype mobile mapping system, called 4S-Van, for spatial data acquisition. It enables acquisition of the position information and accurate image data of objects by post processing. 4S-Van consists of hardware integration part and post-processing part. The hardware integration parts are GPS, INS, CCD camera, IR camera, External Synchronization Device(ESD), IPC, and laser scanner. The post-processing parts are self-calibration, GPS/INS integration, geo-referencing, and 3-D positioning. The remainder of this paper is organized as follows. In section2, we provides the system configuration of 4S-Van. In section 3, we show the result of performance analysis for 4S-Van. In section 4, a summary and our suggestions are presented.

2. 4S-Van Configuration

4S-Van is shown in figure 1. The GPS combined with INS generates data to produce accurate position and orientation information by Carrier Differential GPS(CDGPS) and loosely coupled methods. CCD cameras acquire stereo images of objects. Three-dimensional(3-D) coordinates of various objects included in the stereo images are calculated by using GPS/INS data and internal and external parameters of CCD camera. The IPC stores images from CCD camera and the ESD generates a pulse to synchronize GPS, INS, and image data.

Fig.1 The outside of 4S-Van

Finally, we calculate 3-D position of the object using GPS/INS integration, self-calibration, and geo-referencing process. Fig. 2 shows the flow diagram of data processing in our suggested system.

2.1 Self-calibration

A self-calibration is a process that adds lens distortion parameter of CCD camera in fundamental space intersection algorithm. That is, self-calibration calculates exterior orientation as well as focal length, principal point, lens distortion parameter. This method has advantage that it can get exterior orientation as well as focal length, principal point, and lens distortion.

2.2 GPS/INS Integration

While GPS provides position and velocity data with long-term stability, INS provides high-rate position and velocity data with short-term stability. By integrating the GPS with INS, an enhanced navigation system can be achieved to provide highly accurate navigation data. The GPS/INS Integration system is usually configured in a tightly-coupled method or a loosely-coupled method. Specially, the loosely-coupled method has an advantage of simple structure and easy implementation.

There are two error calibration techniques for implementation of GPS/INS integration system: the feed-forward method and feedback method. In this paper, loosely-coupled method is applied for the integration design, and feedback update technique is applied for the calibration of system

2.3 Geo-referencing

To get the 3-D position of an object, we must calculate position and orientation of CCD camera of the moving 4S-Van. The position and orientation can be estimated through a process that calculates position and attitude of each CCD by combining position and attitude of CCD with GPS/INS data.

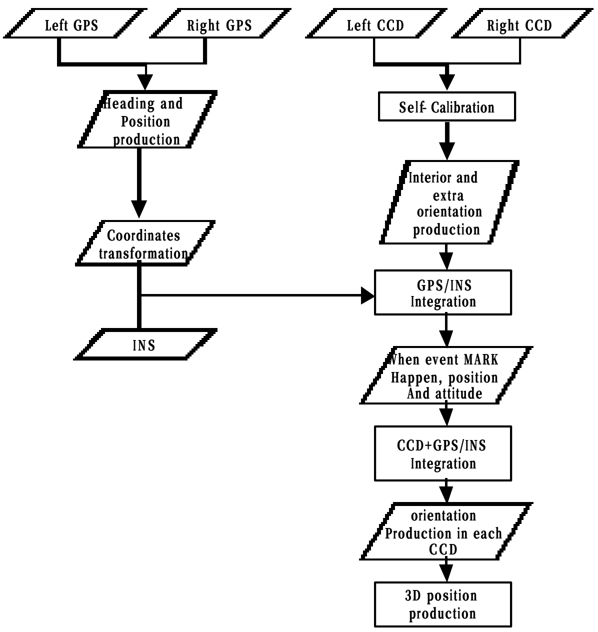

Fig.2 data processing of 4S-Van

3. Performance analysis

To estimate the accuracy of mobile mapping system, we can measure camera calibration error, sensor synchronization error, GPS/INS integration error, and ground coordinates error obtained by the photogrammetric methods. For the tests presented here, we established calibration target to ETRI parking lot for self-calibration test. The imagery was collected along the GPS surveyed road.

First, To get position of an object using CCD image, camera calibration as well as lens distortion, focal length, principle point is essential. Table1 shows the position difference of acquired position by self-calibration and acquired position by GPS survey.

Table 1.The position of space intersection method

ID	X direction(m)	Y direction(m)	Z direction(m)
1	0.004053	0.004312	0.031481
2	5.42E-05	0.003528	0.004697
3	0.001119	0.00351	0.023237
4	0.001813	0.004768	0.013425
5	0.005952	0.006996	0.037186
6	0.004135	0.001589	0.005886
7	0.001084	0.000977	0.002902
8	0.000385	0.000376	0.008664
9	0.000524	0.001428	0.014051
10	0.00048	0.001388	0.003367

Second, According as the time difference of each CCD camera increases, the final accuracy of 4S-Van increases. Table2 shows the time difference between CCD1 and CCD2 when image is captured by each CCD camera. CCD1 is the left camera of 4S-Van and CCD2 is the right camera of 4S-Van.

Table 2.Time sync. between CCD1 and CCD2

TIME	CCD1	CCD2	TIME	CCD1	CCD2
0	0.000	0.000	11	10.992	10.991
1	0.992	0.991	12	11.992	11.991
2	1.992	1.992	13	12.992	12.991
3	2.992	2.991	14	13.992	13.991
4	3.992	3.991	15	14.992	14.991
5	4.992	4.991	16	15.992	15.991
6	5.992	5.991	17	16.992	16.991
7	6.992	6.992	18	17.992	17.991
8	7.992	7.991	19	18.992	18.991
9	8.992	8.991	20	19.992	19.991
10	9.992	9.991	21	20.992	20.991

Third, If GPS/INS integration is not handled properly, they will be a serious source of error because they directly affect the determination of exterior orientation of of CCD cameras. Fig3 and Fig4 show the performance of GPS/INS integration. Fig.4 is an enlarged version of part A in Fig.3. To analyze the 4S-Van's mapping performance, the GPS and INS data collected over the road were processed by loosely-coupled.

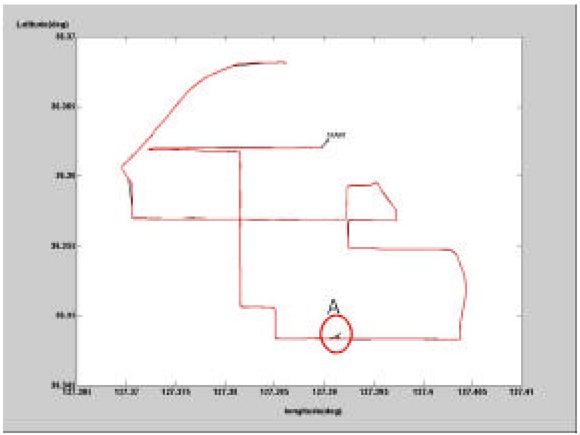

Fig3. Van trajectory over the road

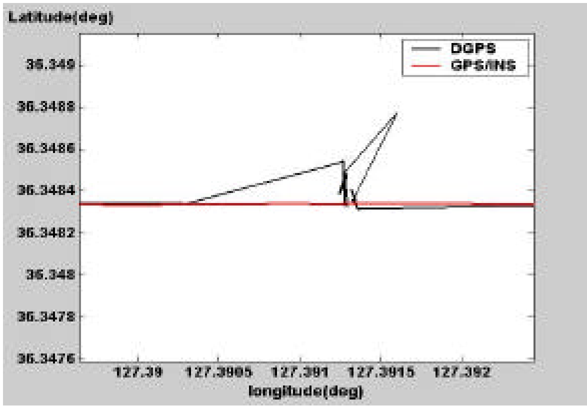

Fig4. Enlarged version of part A in Fig.3.

Final, Fig5 shows observing the objects for 4S-Van's accuracy test and Table3 shows the comparison of the ground coordinates obtained by the photogrammetric methods and ground coordinates of the GPS survey.

Fig5. The image of observing the objects

Table 3. The position difference between position by measured in imagery and GPS survey position

ID	Measurement by 4S-Van(A)			Measurement by GPS(B)		
	X	Y	Z	X	Y	Z
1	236296	326343	30.02	236296	326343	30.14
2	236297	326342	30.08	236297	326341	30.23
3	236290	326337	30.16	236290	326337	30.30
Relative error(A-B)(m)						
1	0.242568					
2	0.258034					
3	0.33461					

Results show that positioning error range from 20cm to 40cm. But error range will vary depending on distance from 4S-Van to observing objects and road environment.

To confirm the performance of our system, we will achieve performance tests under a various of dynamic environments

4. Conclusions

In this paper, we discuss the performance of 4S-Van's each parts, which is evaluated through the vehicle tests. Test results show that the performance of the integrated GPS/INS should be implemented and the performance of the time synchronization should be synchronized of each CCD. As a further study, a tightly-coupled method should be considered to achieve better accuracy under dynamic environments. Furthermore, the following aspects have to be investigated more: 1)time synchronization between GPS/INS and CCD camera, 2) error correction between GPS/INS and CCD camera, 3) minimizing vibration effects of vehicles, and 4)error correction methods due to multi-sensor integrations.

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