The Journal of GIS Association of Korea, Vol. 13, No. 4, pp. 373-380, December 2005

Accuracy Analysis of Image Orientation Technique and Direct Georeferencing Technique

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ABSTRACT

Mobile Mapping Systems are effective systems to acquire the position and image data using vehicle equipped with the GPS (Global Positioning System), IMU (Inertial Measurement Unit), and CCD camera. They are used in various fields of road facility management, map update, and etc. In the general photogrammetry such as aerial photogrammetry, GCP (Ground Control Point)s are needed to compute the image exterior orientation elements (the position and attitude of camera). These points are measured by field survey at the time of data acquisition. But it costs much time and money. Moreover, it is not possible to make sufficient GCP as much as we want. However Mobile Mapping Systems are more efficient both in time and money because they can obtain the position and attitude of camera at the time of photographing. That is, Image Orientation Technique must use GCP to compute the image exterior orientation elements, but on the other hand Direct Georeferencing can directly compute the image exterior orientation elements by GPS/INS. In this paper, we analyze about the positional accuracy comparison of ground point using the Image Orientation Technique and Direct Georeferencing Technique.

Keywords : Mobile Mapping System, Image Orientation, Direct Georeferencing Technique

요 약

모바일매핑시스템은 차량에 GPS(Global Positioning System), IMU(Inertial Measurement Unit), CCD 등을 탑재하고 대상에 관한 위치 및 영상 정보를 취득하는 효율적인 시스템이다. 모바일매핑시스템은 현재 도로 시설물 관리, 지도 갱신 등 다양한 분야에 활용되고 있으며 앞으로 그 활용도가 더욱 증가할 것으로 보인다. 항공사진측량과 같은

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기존의 일반적인 사진측량의 경우, 영상 외부표정요소를 구하기 위해서는 지상기준점이 필요하다. 이러한 기준점들은 자료취득 전후에 현장측량을 통해 좌표가 결정되는데 일반적으로 많은 비용과 시간이 소요되고, 사실 영상을 취득할 도로를 따라 필요한 만큼 충분히 많은 기준점을 설치한다는 것도 거의 불가능하다. 하지만 모바일매핑시스템의 경우 GPS/INS를 이용해 영상촬영당시의 카메라의 위치 및 자세, 즉 외부표정요소를 직접적으로 구할 수 있어 시간과 비용 면에서 훨씬 효율적이다. 즉 외부표정요소를 결정하기 위해 영상표정기법은 지상기준점이 필요한 반면, 직접위치참조기법은 GPS/INS를 이용해 직접 외부표정요소를 구할 수 있다. 본 논문에서는 영상표정기법과 직접위치참조기법에서 산출되는 영상외부표정요소를 이용해 지상점의 위치정확도에 대해 비교 · 분석해 보았다.

주요어 : 모바일매핑시스템, 영상표정기법, 직접위치참조기법

1. INTRODUCTION

For efficient management of the road and traffic control, the construction of the Road Facility Database is very important and necessary. One of the ways to acquire the data for the database is to take images along the target road, and extract necessary features and objects. Obviously, if this data acquisition and processing is fully automatic, the construction, management and update of the database could be easy and efficient.

Mobile Mapping Systems(MMS) are integrated by the Global Positioning System(GPS), Inertial Measurement Unit(IMU) and CCD camera for the automatic data acquisition and processing. The exterior orientations of the CCD camera are provided by GPS and IMU so that the obtained images can be processed in near-real time. Therefore, the accuracy of the product from a MMS highly depends on the accuracy of positions and attitudes from the GPS/INS integration system. But in the traditional photogrammetry such as aerial photogrammetry, the exterior orientations of the CCD camera can be only computed using the Ground Control Points (GCP). This is called Image Orientation Technique. It costs much time and money to measure the GCP. Moreover, if we take images along the road to make a map, it is not possible to install the sufficient GCP as much as we want.

In this paper, the positional accuracy comparison of objects on the road using the Direct Georeferencing and Image Orientation Technique is presented. The exterior orientations of the CCD camera were calculated both digital photogrammetry systems and GPS/INS loaded on a MMS to measure the position of the targets. And then these results were compared with the value measured by GPS survey.

2. Equipments

2.1 GPS

A GPS was used NovAtel DL-4 in this study. This is used L1/L2 to acquire the precise position data and 1pps signal can be gotten from the receiver. Also pps signal can be controlled 0.1 ~ 10 sec interval.

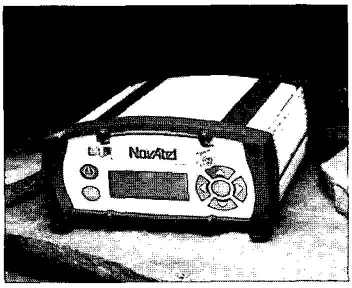


Figure 27. NovAtel DL-4

2.2 IMU

A IMU used in this study is VG600CA-200, the Dynamic Measurement Unit-Fiber Optic Gyro(DMU-FOG), manufactured by Crossbow. <Figure 2>. It has 3-axis accelerometers and gyros measuring the accelerations and rotations with respect to an inertial frame. It should be noted that the biases and scale factor errors of accelerometers and gyros are hundreds to thousand times poorer than high-performance IMU such as LN 100 from Litton. For example, the accelerometer bias of LN100 is within 25 mGal while that of VG600CA-200 is 8.5 mg which corresponds to 8,330 mGal.

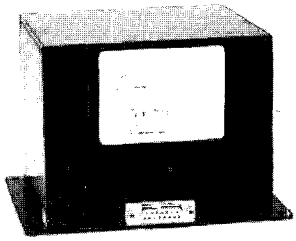


Figure 28. DMU-FOG

2.3 CCD Camera

CCD Camera was used SVS085 color CCD. This is a progressive sensor with 1280×1024 pixels and pixel size is $6.7 \times 6.7 \mu m$. The progressive-Sacn-Technology provides an image with full resolution even in asynchronous or flash mode. The camera's output is a 10-bit signal and it has 12 or 25 full frames/sec.

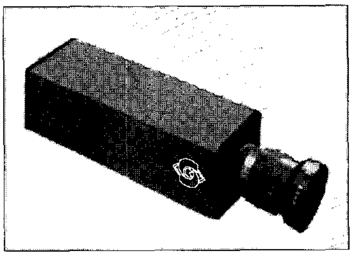


Figure 29. SVS085

3. Direct Georeferencing

MMS Integrate navigation sensors and algorithms together with sensors that can be used to determine the positions of points remotely. All the sensors determine the position and orientation of the platform, and the latter sensors determine the position of points external to the platform. The sensors that are used for the remote position determination are predominantly photographic sensors and thus they are typically referred to as imaging sensors. However, additional sensors such as laser rangefinders or laser- scanners are also used in MMS and therefore the more general terms of mapping sensors or relative sensors may also be used when referring to the remote sensors.

The strength of MMS lays in their ability to directly georeference their mapping sensors. A mapping sensor is georeferenced when its position and orientation relative to a mapping coordinate frame is known. Once georeferenced, the mapping sensor can be used to determine the positions of points external to the platform in the same mapping coordinate frame. In the direct georeferencing done by MMS the navigation sensors on the platform are used to determine its position and orientation. This is fundamentally different from traditional Image Orientation Technique where the position and orientation of the platform are determined using measurements made to control points. These control points are established through a field survey prior to or after data acquisition, and their establishment is typically expensive and time-consuming. Therefore, eliminating this step results in obvious decreases in both the cost and time-requirements for data collection. The task of establishing GCP is additionally complicated since its cost and time requirements are frequently difficult to estimate. Also, for many terrestrial surveys the establishment of sufficient GCP is virtually impossible. Fore example, consider the control requirements to map an entire city using close-range photogrammetry.

For some mapping sensors, such as laser-scanners or push-broom CCD camera, it is difficult or even impossible to establish the GCP. The use of these sensors is not practical unless Direct Georeferencing is performed.

The basis for all Direct Georeferencing formulas is a 3D-conformal transformation where the coordinates of a point in the MMS imaging sensor's coordinate frame (r_p^s) are related to their coordinates in a mapping coordinate frame (r_p^m).

$$r_p^m = r_s^m + \mu_s^m R_s^m r_p^s \tag{1}$$

In the above equation, r_s^m is the position of the mapping sensor in the mapping coordinate frame, and μ_s^m and R_s^m are respectively the scale factor and rotation matrix between the mapping sensor coordinate frame and the mapping coordinate frame. In a MMS, all parameters are measured by direct or indirect methods. The position of the GPS antenna and the orientation of IMU or other attitude sensing devices are measured when they are loaded on a MMS. The scale factor can be determined directly using the laser rangefinder, or indirectly using the space intersection with the stereo images. The following equation is the Direct Georeferencing formula for system integrating a mapping sensor with merging the GPS and the IMU.

$$r_p^m = r(t)_{GPS}^m + R(t)_{IMU}^m (r_{IMU/s}^{IMU} - r_{IMU/GPS}^{IMU} + \mu_s^m R_s^{IMU} r_p^s) \tag{2}$$

Figure 4 shows the principle of the Direct Georeferencing and table 1 describes the meaning and determination of the various parameters. By examing this table, it can be seen that there are many quantities dependant upon either calibration or synchronization, and thus total system accuracy critically depends on both of these tasks being correctly performed.

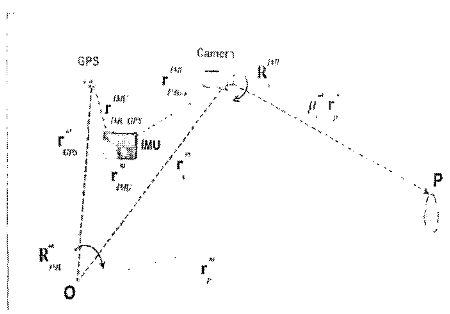


Figure 4. The principle of Direct Georeferencing

Because the position and orientation are typically determined using a previously integrated GPS and IMU. In this case, equation (2) is diminished like equation (3).

$$r_p^m = r_{IMU}^m + R_{IMU}^m (r_{IMU/s}^{IMU} + \mu_s^m R_s^m r_p^s) \quad (3)$$

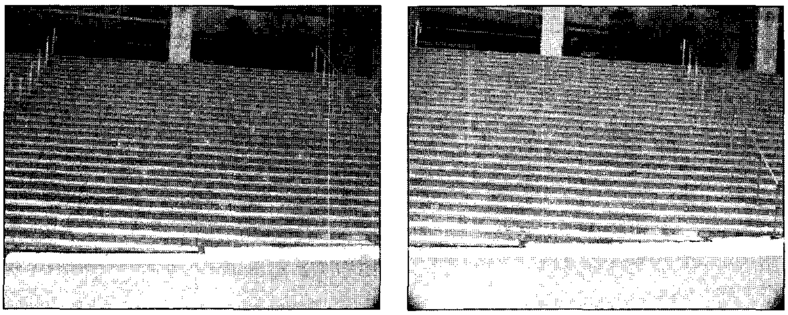
The missing calibration terms from equation (2) have not disappeared. They are merely "hidden" in the r_{IMU}^m term, which is the position of the IMU determined from the integrated GPS/IMU navigation system.

4. Real Test

A test was experienced using a car equipped with GPS, IMU, and CCD camera for the GCP in Inha University. The test was executed

Table 1 Terms in Expanded Georeferencing Formula (by Cameron Ellum, Naser El-Sheimy)

Variable	Description
r_p^m	Position vector of the point of interest in the mapping frame. Unknown.
r_p^s	Position vector of the point in image. Measured.
$r(t)_{GPS}^m$	Position vector of the GPS antenna. Determined using kinematic GPS, and measured in the mapping coordinate frame.
$R(t)_{IMU}^m$	Rotation matrix between IMU and mapping coordinate frames. Determined using integrated IMU measurements.
$r_{IMU/s}^{IMU}$	Vector of position differences between IMU and camera. Determined through calibration, and measured in the IMU coordinate frame.
$r_{IMU/GPS}^{IMU}$	Vector or position differences between IMU and the GPS antenna. Determined through calibration, and measured in the IMU coordinate frame.
μ_s^m	Scale factor from camera-space to object-space. Determined using stereo techniques.
R_s^{IMU}	Rotation matrix between IMU and camera coordinate frames. Determined through calibration.



Left Image Right Image

Figure 5. Targets in front of a library

about P.M 12:00~15:30 to decrease the effect of sunlight. The altitude of Sun is the highest about noon for a day. First of all, the eleven targets were set up on the stairs in front of the library in Inha University. The coordinates of targets were measured by Total Station, and the images of targets were taken using the CCD cameras loaded on a vehicle. The ImageStation, in the Digital photogrammetry system was used to compute the exterior orientation elements of the CCD cameras. And then, the information of the formation between IMU and CCD camera and the rotation was gained through the obtain images by Boresight transformation. The following figure 5 are the images of the target in front of a library in INHA University.

After some images are taken around the Inha University by a vehicle, the coordinates of the GCP were obtained. The coordinates of the GCP were precisely measured by GPS survey for comparing the accuracy of between Direct Georeferencing and Image Orientation Technique. Also, the accuracy of the coordinates was compared using the ImageStation and the module of Direct Georeferencing which is developed in this study. The following figure 6 and figure 7 are the images of object

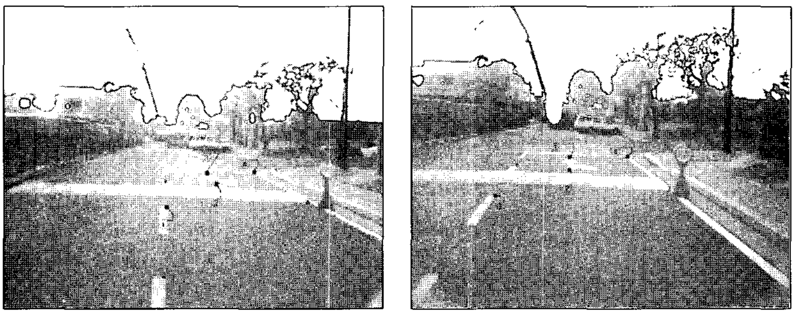


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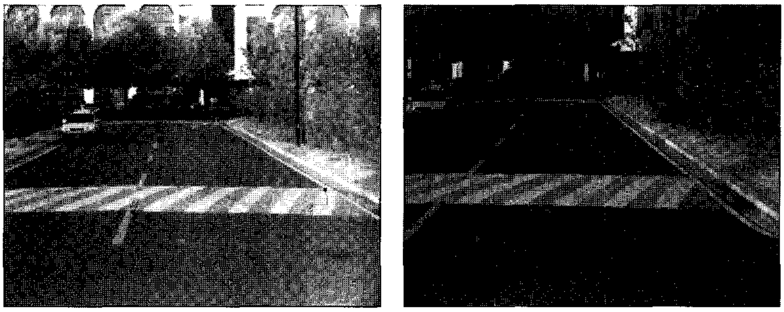
Figure 6. Images of the object area 1



Left Image Right Image

Figure 7. Images of the object area 2

area which is taken by CCD cameras loaded on the MMS. The table 2 shows the differences of coordinates between Direct Georeferencing and GPS survey. And table 3 are presented the differences of coordinates between Image Orientation Technique and GPS survey. 7 points are measured by GPS in each object area. In images, 3 red points are used as GCP and 4 blue points are used to compare coordinates.

Table 2. Error in Direct Georeferencing

Point	Direct Georeferencing			
	Ex	Ey	Ez	Exyz
1	-0.323	-0.532	-0.345	0.711
2	0.660	1.795	-0.856	2.095
3	-0.456	-1.564	-0.578	1.729
4	0.571	0.985	0.389	1.203
5	0.664	-1.684	-0.801	1.979
6	-0.402	1.326	-0.446	1.455
7	0.543	1.359	-0.591	1.578
8	-0.760	1.755	-0.808	2.076
RMSE	0.564	1.434	0.630	1.665

Table 3. Error in Image Orientation Technique

Point	Image Orientation Technique			
	Ex	Ey	Ez	Exyz
1	0.095	-0.203	0.076	0.237
2	-0.072	-0.158	-0.085	0.193
3	0.085	-0.238	-0.087	0.267
4	0.075	0.167	0.080	0.200
5	-0.089	-0.220	0.074	0.249
6	0.084	-0.178	0.074	0.210
7	0.061	0.162	-0.045	0.179
8	0.098	0.285	0.089	0.314
RMSE	0.083	0.206	0.077	0.235

In above tables, the error in Y-axis is larger than other axes. This reason is presented because MMS has the characteristics that the error of advancing direction is large. In table 2, the Direct Georeferencing has the very large RMSE about the 3-D distance(Exyz). It seems to be affected by the accuracy of IMU.

On the other hand, Image Orientation Technique is very accurate because the coordinates of points are computed using the GCP precisely measured by GPS.

5. Conclusion

This test shows that the Image Orientation Technique is more accurate than the Direct Georeferencing to determine the position. In the case of Direct Georeferencing, the accuracy of IMU is very important element to determine the position. But the IMU used this test has not high level accuracy. Generally, the acquisition of the road facility data should have the accuracy within 30cm~40cm by MMS. If more accurate IMU is used, the accuracy of position is satisfied with this accuracy. As mentioned above introduction, it costs much time and money to measure the GCP. A number of GCP are needed when the Image Orientation Technique is used for MMS. If the ability of equipment loaded a MMS satisfy the certain condition, the Direct Georeferencing is much efficient than Image Orientation Technique for terrestrial photogrammetry.

Acknowledgment

This Research was supported by the MIC (Ministry of information and Communication), Korea, under the ITRC(Information Technology Research Center) support program supervised by the IITA(Institute of Information Technology Assessment).

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