Direct Geo-referencing for Laser Mapping System

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ABSTRACT

Contrary to the traditional text-based information, 4S(GIS,GNSS,SIIS,ITS) information can contribute to the citizen's welfare in upcoming era. Recently, GSIS(Geo-Spatial Information System) has been applied and stressed out in various fields. As analyzed the data from GSIS arena, the position information of objects and targets is crucial and critical. Therefore, several methods of getting and knowing position are proposed and developed. From this perspective, Position collection and processing are the heart of 4S technology. We develop 4S-Van that enables real-time acquisition of position and attribute information and accurate image data in remote site. In this study, the configuration of 4S-Van equipped with GPS, INS, CCD and eye-safe laser scanner is shown and the merits of DGPS/INS integration approach for geo-referencing is briefly discussed. The algorithm of DGPS/INS integration for determination of six parameters of motion is eccential in the 4S-Van to avoid or simplify the complicated computation such as photogrammetric triangulation. 4S-Van has the application of Laser-Mobile Mapping System for three-dimensional data acquisition that merges the texture information from CCD camera. The technique is also applied in the fields of virtual reality, car navigation, computer games, planning and management, city transportation, mobile communication, etc.

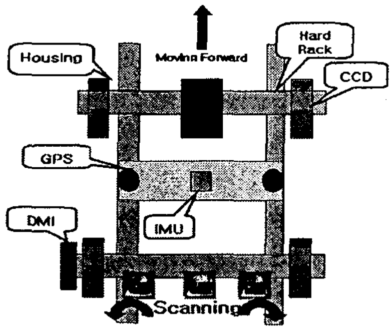
Keywords : 4S, DGPS/INS, CCD, Laser - Scanner

1. INTRODUCTION

Recently, the expanding application of GIS data has resulted in the demanding of new systems for 3D data acquisition, processing and visualization. Traditionally, GIS data acquisition process is huge time-consuming process and costs a lot of expense because of inverse photogrammetry. The inverse photogrammetry requires a lot of ground control points and block adjustment process and the data should be handled and processed by only skilled operators. Using the emerging technology of satellite, inertial devices with digital photogrammetry, we suggest 4S-Van equipped with eye-safe laser scanner, GPS, IMU and CCD camera. 4S-Van is the state-of-the-art solution to quickly, accurately, economically and effectively acquire and update geo-referenced information, related field and image data. 4S-Van utilizes the laser scanner to acquire depth information between sensor and surface of objects and to build 3D data. The obtained 3D information can be integrated in global reference system by applying (D)GPS/INS solution. However, in terms of conventional survey,. With emerging technology, vehicle-borne-laser mapping system named 4S-Van can construct 3D city data modeling by collecting urban data such as building, streets, trees, pedestrians, traffic signs. A couple of laser scanner devices can acquire more accurate data than single laser device and texture image from CCD camera can be used to intensify 3D-visualization. In this paper, We designed 4S-Van equipped with (D)GPS/CCD/INS/Laser scanner for laser mapping and direct geo-referencing procedure is introduced.

2. 4S-Van Configuration

4S-Van is designed to collect 3D road and surface data. The system comprises of IMU, (D)GPS, CCD camera and Laser scanner. The major H/W configuration is illustrated in Figure 1.



[Fig. 1] . 4S-Van Configuration

2.1 (D)GPS/INS system

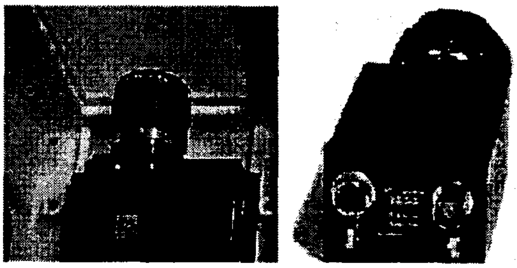
GPS provides accurate position data. However, GPS has disadvantages such as low data rates and poor DOP. In contrast, INS provides high data rate, but its sensor errors tend to grow with time. Therefore by integrating GPS and INS, we are able to heighten the advantages of both systems while reduce the drawbacks. In the calibration process called "initial alignment, the kalman filter can detect and remove position, velocity, alignment errors, bias and drift from the low grade inertial instruments. After the alignments, GPS/INS system plays the key role to provide position information of moving object and attitude information of image sensors. For details on (D)GPS/INS integration and test results are discussed in next chapter.

2.2 CCD Camera

Two CCD cameras are used with parabolic reflecting mirrors. Each unit of CCD camera is housed in a single frame in case of weather condition. Figure 2 and table 1 shows the configuration and specification of CCD camera.

[Table 1] CCD Specification

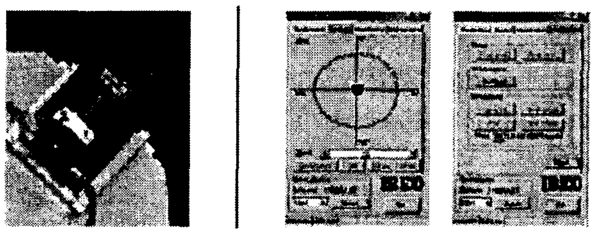
Resolution	1392 * 1040
Unit Cell Size(micrometer)	4.65 * 4.65
Shutter Speed(sec)	1/31,000 - 1/15



[Figure 2] CCD Camera

2.3 Laser Scanner

The laser scanner measures the distance to the points of objects and provides the intensities of the return signals. Three laser scanners are mounted on the 4S-Van and emit infrared beams at high frequency (~20Hz) because of the data from different viewing angle. The laser scanner configuration and S/W are given in Figure 2.



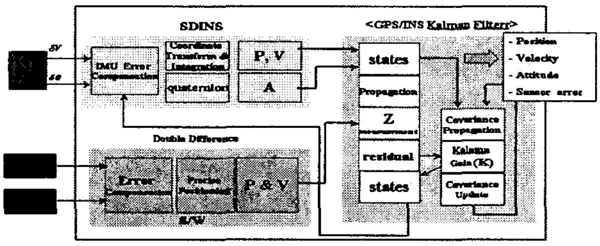
[Figure 2] Laser scanner and S/W

3. Sensor Integration

In 4S-Van system, we use laser scanners as the main data acquisition device and the data can be merged with CCD texture information. (D)GPS/INS can provide the orientation and position.

3.1 (D)GPS/INS integration

The Integration of GPS and INS is the only suitable technical solution. It also creates synergy effects that can provide accurate position information and precise attitude information. The Kalman filtering technique is used to optimally combine the redundant information, which the inertial state vector is regularly corrected by GPS measurement. We designed the decentralized kalman filter approach for advantages of data integrity and speed. In this scheme, different filters are run simultaneously between GPS and INS and interact when two data are synchronized. Figure3 shows the closed loop (D)GPS/INS integration for 4S-Van.



[Figure 3] (D)GPS/INS Integration

3.2 Direct Georeference

Using (D)GPS/INS, direct georeferencing is possible, which avoid or simplify the complicated computation such as photogrammetric triangulation. (D)GPS and inertial data are integrated to achieve the optimal performance. Once the position and orientation of image sensors are known at each epoch via coordinate transformation and offset determination between sensors, then the data are integrated with laser range data to provide 3-dimensional information on the surface of the target. Provided the orientation and position of Image sensors, the direct geo-reference takes the form as follows

$$r_i^m = r_{(D)GPS/INS}^m + C_b^m[\, s_m C_c^b r_i^c + r^b] \qquad (1)$$

where,

r_i^m is a vector to the mapping frame for a target

$r_{(D)GPS/ins}^m$ is a vector of INS frame to the mapping frame

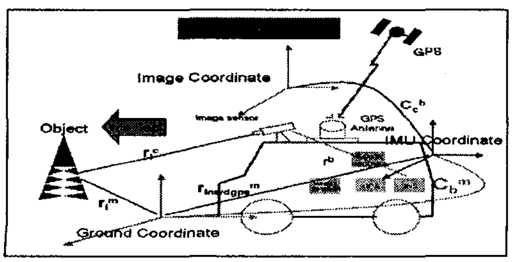
r_i^c is a vector of image frame to the target

r^b is the offset vector between INS and image sensor

C_b^m is the rotation matrix between INS and mapping frame

C_c^b is the rotation matrix between image sensor and INS frame

The direct georeferencing relation by (D)GPS /INS is depicted in Figure 4.



[Figure 4] Principles of georeferencing process

3.3 Laser mapping

The laser scanner is mounted on the 4S-Van and emits infrared laser beams at a high frequency. The scanner records the difference in time that laser signal emits and returns. The mirror that installed in front of scanner rotates and causes the laser pulses to sweep at an angle, back and forth along a line. As vectors from the 4S-Van to the objects are combined with orientation parameters determined by (D)GPS/INS, the 3-dimensional points of object surface and feature are computed. For laser mapping system, We should perform laser calibration process. But it is too difficult to find perfect targets like CCD calibration process because of cloud laser range data. So using physically measured offset data between CCD and Laser scanner, Laser scanning orientation parameters can be referred from CCD parameters.

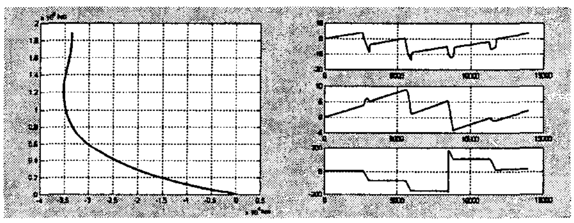
4. Tests and Results

This section presents the analysis of (D)GPS/INS integration and self-calibration for image sensors.

4.1 (D)GPS/INS test

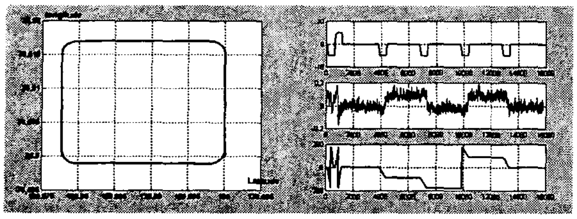
An simulation was conducted to investigate (D)GPS/INS integration. Figure 5 shows trajectory and true attitude for the simulation test.

The sampling rate for GPS measurements is 1 Hz , while IMU sampling rate is 50Hz. Figure 6 shows low cost INS performance- position and attitude. In figure 6, low cost one cannot meet the system requirements because if its divergence.



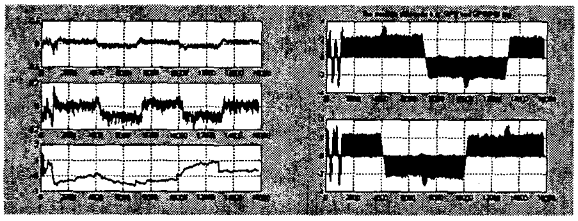
[Figure 6] Low cost INS position and attitude

Figure 7 presents the (D)GPS/INS solution. As indicated in this figure, the (D)GPS information improves the performance of SDINS since it makes rectangular trajectory. But in this integration, we rule out the horizontal states that are updated from (D)GPS data directly.



[Figure 7] (D)GPS/INS integration

The attitude and position parameters are important information for determination of exterior orientation. From this test, It should be noted that there are much improved performance in terms of GPS and INS integration as mentioned above. The difference between true values and integrated values are illustrated figure 8.



[Figure 8] differences between true and(D) GPS/INS

From figure 8, position errors are approximately 0.15m and attitude errors are approximately 0.012degree since we assumed low cost IMU(bias - 0.03 degree/hour). Even though, for low cost IMU, we generated appropriate trajectory and attitude info.

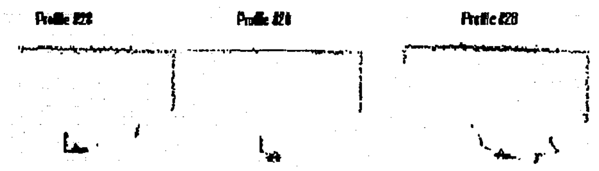
4.2 CCD calibration and Laser range data

Calibration of camera is the process of determining its interior parameters. We consider only radial distortion neglecting tangential distortion. For CCD calibration, We considered points correspondences between images of the fixed target. We installed 3-D calibration targets, The multi stereo images taken from different view points changing the camera orientation and position were acquired. By using self-calibration technique, the initial values for the intrinsic camera parameters are acquired in addition to the estimates for the extrinsic parameters. Table 2 sums out the result of camera parameters by using (D)GPS/INS.

[Table 2] exterior orientation of camera

	Camera 1	Camera 2
X(m)	236492.6	236492.2
Y(m)	326874.0	326874.9
Z(m)	57.19009	56.66144
Omega(rad)	0.8953	0.644972
Phi(rad)	0.940886	1.086801
Kappa(rad)	-0.38995	-0.20999

The laser profiles taken by three laser scanners are shown in figure 9. This is the laser range data from scanner to the wall in the office.



[Figure 9] Laser scanner profile

Third Scanner captures most of the data. First and second scanner data have some occlusion because of windows in the office. By combing all three profiles, we can recover and improve the data quality. In addition, the orientation of laser scanner is referenced from (D)GPS/INS no matter where the 4S-Van acquire the data.

4. Conclusion and future works

We have developed (D)GPS/INS technique and which can apply in the field of laser mapping. For implementation of laser mapping, the orientation and position of image sensor can be acquired directly or indirectly. In our 4S-Van, We adopted (D)GPS/INS for determination of exterior orientation and self-calibration for image sensor calibration. For the remaining work, we have to develop the centralized (D)GPS/INS integration for better performance and the laser data processing and merging with CCD texture images. By implementation of laser mapping system, we can construct GIS DB and urban 3-D modeling.

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