

AIRBORNE MULTIDIMENSIONAL INTEGRATED REMOTE SENSING SYSTEM

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Commission VI, ICWG VI

KEY WORDS: Imaging spectrometer, Three-line scanner, Laser ranger, Position & orientation subsystem

ABSTRACT:

In this paper, we present a kind of airborne multidimensional integrated remote sensing system that consists of an imaging spectrometer, a three-line scanner, a laser ranger, a position & orientation subsystem and a stabilizer PAV30. The imaging spectrometer is composed of two sets of identical push-broom high spectral imager with a field of view of 22°, which provides a field of view of 42°. The spectral range of the imaging spectrometer is from 450nm to 900nm, and its spectral resolution is 5nm. The three-line scanner is composed of two pieces of panchromatic CCD and a RGB CCD with 20° stereo angle and 10cm GSD(Ground Sample Distance) at 1000m flying height. The laser ranger can provide height data of three points every other four scanning lines of spectral imagers and those three points are calibrated to match the corresponding pixels of the spectral imagers. The post-processing attitude accuracy of POS/AV 510 used as the position & orientation subsystem, which is the aerial special exterior parameters measuring product of Canadian Applanix Corporation, is 0.005° combined with base station GPS data. The airborne multidimensional integrated remote sensing system was implemented successfully, performed the first flying experiment on April, 2005, and obtained satisfying data.

1. INTRODUCTION

Both the spatial and spectral resolutions are very important specifications for remote sensing systems. The former determines geometrical resolution power of systems; the latter determines the power of target recognizing. In the past few decades, the spatial and spectral resolutions of airborne remote sensing systems have been improved greatly. The spatial resolution reached 0.1m at 1000m flying height, and the spectral resolution up to 1nm. However, it is still very difficult to obtain good images with both high spatial and spectral resolution simultaneously, which can be registered easily, because of relative restriction of these two specifications. To fulfill the requirements, we designed this multidimensional integrated remote sensing system that can provide high spatial and spectral data synchronously. This system was supported by high-tech research and development program of China, which can survey and produce 1:2000 to 1:5000 thematic map and suitable for the regions of city layout, resource investigation, environment inspection, similar applications and so on.

2. SYSTEM DESCRIPTION

2.1 System configuration

The system consisted of multidimensional information acquisition subsystem, multidimensional information processing subsystem, performance measurements and systematic calibration subsystem. The information acquisition subsystem includes: a three-line scanner with high spatial resolution power, an imaging spectrometer with high spectral resolution power, a laser ranger, a stabilized platform and a set of attitude & position measuring device. The multidimensional information processing subsystem includes: data preprocessing module, high spatial data processing module, high spectral data processing module, and data merge processing module. The performance measurements and systematic calibration subsystem includes: comprehensive performance measurement module in the lab,

spectral and radiometric calibration in the lab and field. All the above are shown in figure 1 and 2.

As shown in figure 2, the system can be used as one set of device, also can be divided into two parts: high spatial part and high spectral part, which is flexible for different applications. When used as a whole, the system can be controlled by a computer; consequently it needs only one person to operate this instrument. And a basic external clock was divided into different frequencies to synchronize all sensors: 600Hz for three-line scanner, 50Hz for imaging spectrometer, 10Hz for laser ranger, at the same time all the working frequencies were copied to POS/AV 510, which could record attitude and position information at the rising or falling edge of the ingoing pulse according to the customized settings.

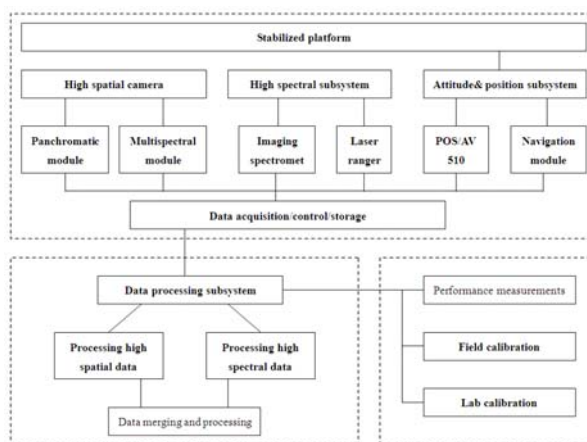


Figure 1. Functional diagram of system

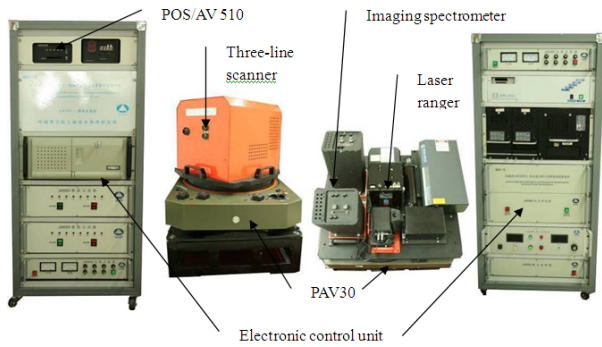


Figure 2. System overview

2.2 Technical specifications

The following list is technical specifications:

- Mapping scale: 1:2000 – 1:50000;
- FOV(Field of View): 42°;
- Spatial pixels:
 - 10200 pixels for three-line scanner
 - 1278 pixels for imaging spectrometer
 - 3 points each line for laser ranger
- Spectral range:
 - 465-680nm for panchromatic image, 1 band
 - 610-660nm, 535-585nm, 430-490nm for multispectral image, 3 bands
 - 450-900nm for hyperspectral image, 244 bands, spectral resolution better than 5nm
- Instantaneous FOV:
 - 0.1mrad for panchromatic and multispectral image
 - 0.6(across track)*1.2mrad(along track) for hyperspectral image;
- Laser distance resolution: 7.5cm;
- Scanning rate:
 - 300Hz/600Hz for three-line scanner
 - 50Hz for image spectrometer
 - 10Hz for laser range;
- Radiation resolution: 12 bits;
- Stereo angles: -21° backward, 0° nadir, 20° forward;
- Accuracy of attitude and position measurement
 - Real-time: position 4-6m, roll/pitch 0.008°, heading 0.07°;
 - Post-processing: 5-30cm, roll/pitch 0.005°, heading 0.008°;
- Stabilized platform:
 - Stabilized range in roll/pitch: ±5°;
 - Stabilized range in drift: ±30°;
 - Typical residual angular motion: <math><0.3^\circ/s</math>;
 - Typical residual deviation from vertical (nadir): ±0.5°.

3. MODULAR DESIGN OF SUBSYSTEMS

As shown in figure 2, our system employed modular design completely, wherefore every module can be implemented respectively, and also can be used separately.

3.1 Design of wide angular FOV imaging spectrometer

Generally, pushbroom imaging spectrometer has a field of view less than 30° due to pixel constraints of linear array CCDs. This limited its working efficiency and increased working cost. For higher efficiency, we combined two imaging spectrometer with

FOV 22° to achieve a wide angular FOV 42°. They were overlapped 2° FOV and fixed on a whole plate, as shown in figure 4. The dispersing optical construction employed prism-grating-prism spectrograph, shown in figure 3, which is compact and has a high optical efficiency. All CCDs were kept in a constant temperature via a cooling system to increase the signal to noise ratio.

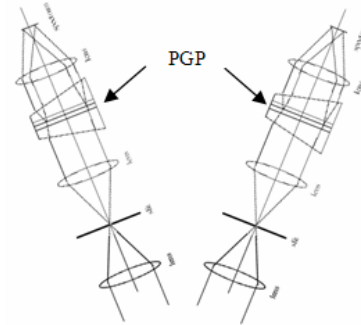


Figure 3. Schematic diagram of optical splicing

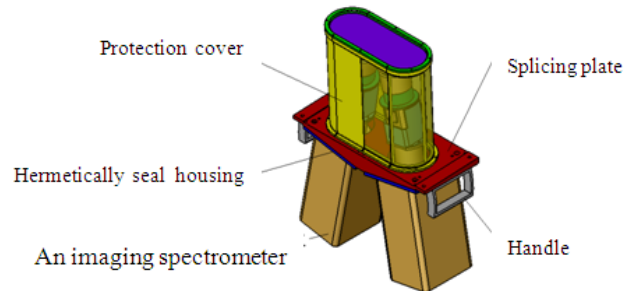


Figure 4. Wide angular FOV imaging spectrometer

3.2 Design of three-line scanner

The three-line scanner was designed according to the principle of linear stereo imaging: three CCDs image same scene respectively by forward view, nadir view and backward view approximately at the same time. The designed stereo angle was 20°, thus we can calculate and obtain three dimensional coordinates of every pixel theoretically according to photogrammetric principle. In the focal plane, we set two panchromatic CCDs, one RGB CCD that contains red channel, green channel and blue channel, namely five channels. RGB CCD was centered in the focal plane, as shown in figure 5. Two panchromatic were moving forward and backward by about the same distance, which depended on the ratio of base line and flight altitude. In this design, the ratio is 0.73 because of the restriction of flat field area of focal plane.

An objective was designed for all CCDs, whose focal length is 75mm. The CCDs is the products of Kodak Corporation. The pixel size is 7μm, whereby an instantaneous field of view of 0.1mrad was achieved.

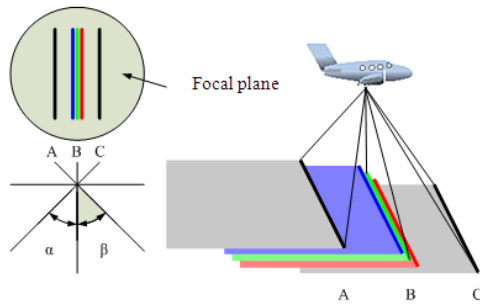


Figure 5. Construction of focal plane and principle of stereo imaging

3.3 Design of laser ranger

Laser module gave three footprints every other four hyperspectral image lines, shown in figure 6. The laser footprints were registered strictly with the hyperspectral image pixels, which was fulfilled by opto-mechanical design as a whole consideration and calibration in the lab.

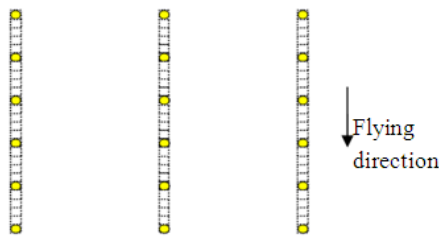


Figure 6. Registration of laser footprints and hyperspectral pixels

Laser module didn't employ any scan components, but adopted two beam splitters to obtain three desired points from a laser beam, shown in figure 7. The original laser beam was divided into three equivalent portions by energy. The right and left beam were directed at $\pm 11^\circ$ with respect to central vertical beam.

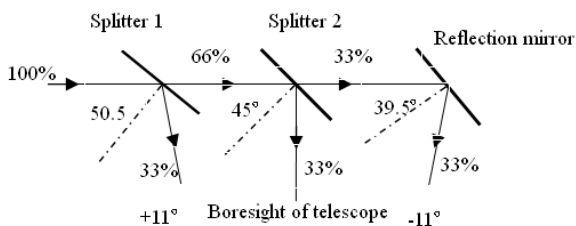


Figure 7. Drawing of laser beam splitting

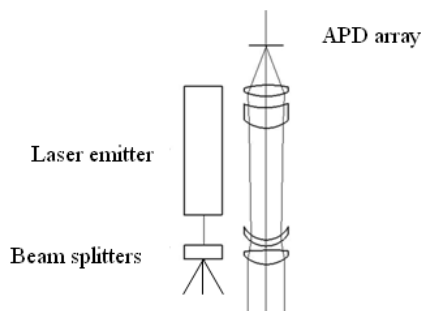


Figure 8. Optical construction of emitting and receiving

The energy of laser emitter in our system is less than 100mJ, the divergence angle is better than 3 mrad, the repetition frequency is 20Hz, and the central spectrum 1064 μm . The optical aperture of receiving optics is 60 mm, and IFOV 4mrad, shown in figure 8. The left part emits laser beam, and the right part receives reflection beam, then is converted into electronic signal through APD (Avalanche Photodiode). A precise time interval measuring board was deployed to arbitrate and calculate the time interval between emitted pulse and received pulse, which ensured the distance resolution of 7.5cm.

3.4 Stabilized platform and attitude & position measurement subsystem

It is pretty common to deploy stabilized platform and attitude & position device in photogrammetric and remote sensing system nowadays. In virtually, this is not the best method, perhaps a high enough precise three dimensional stabilized platform is better in theory, however the former is still more reasonable and flexible on account of current situation of research, development and cost.

In our system, the stabilized platform, PAV30 of Leica Corporation, was employed to stabilize imaging sensors. Though the accuracy of PAV30, $\pm 5^\circ$, is not very high, it is enough for general airborne application and basically ensures that there are no big gaps during and between flight strips, which is very important for a successful application.

Moreover, we installed a start-of-the-art GPS/INS system, POS AV/510, developed by Applanix Corporation. POS AV/510 device can provide real-time and post-processing delivery of attitude and position with excellent accuracy and precision. It operates using combined IMU (Inertial Measurement Unit) and GPS (Global Positioning System) receiver. The position information from the GPS system and the 3-axis attitude and position data from IMU are combined in a tightly Kalman filter to provide x, y and z position values as well as roll, pitch and true heading. The stated accuracy is 5-30 cm in position, 18" in roll and pitch, 28.8" in true heading when operated with differential GPS and made a post-process.

All sensors, including one of POS AV/510, are bolted directly to platform frame, and must be prohibited from any relative motions among them.

3.5 Data acquisition and storage subsystem

In this system, we employed a master control computer to operate all sensors, as shown in figure 9. The connection interface between the master computer and sensors is local network. The operator interface controls work mode and status of all sensors, and also receives some image data to monitor through net cables. After commencing to acquiring data, all sensor modules sent an event pulse, which marked the exposure moment of every scan line, into POS AV/510.

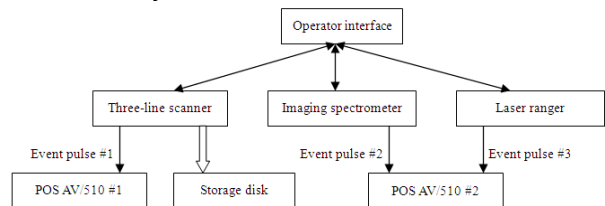


Figure 9. Working flow of data acquisition and storage

The hyperspectral and laser data are can be stored in a 200GB

disk for 4 hours flying. However, the three-line scanner data can not be stored like this. The data rate of three-line scanner is 35MByte/s, and the data amount will be up to 500GB for 4 hours flying. On account of this, we decided to employ advanced SCSI programming interface to transfer data, which skips windows' file system to store data into the RAID disks directly. The capacity of extending RAID disks achieves 560GB, and we deployed two sets of the storage device, hence it can fulfil the requirements of 4 hours continuous work.

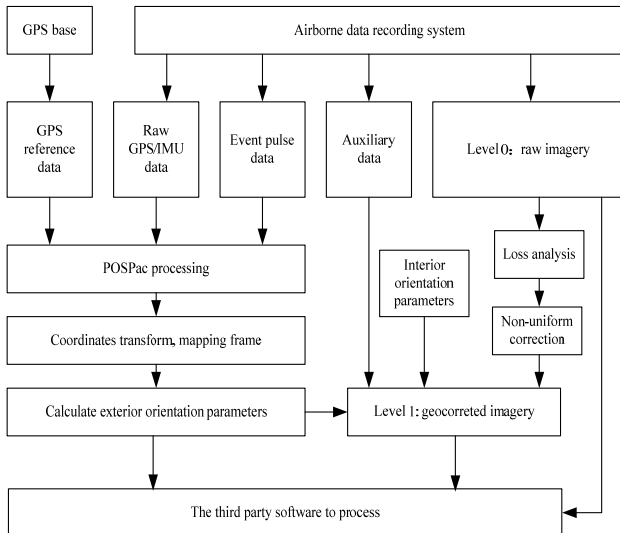


Figure 10. The flow diagram of geocorrection



Figure 11. Raw and geocorrected hyperspectral imagery



Figure 12. Raw and geocorrected high spatial imagery

3.6 Digital processing subsystem

After a successful flight, we obtained high spatial data, hyperspectral data, laser ranging data, attitude and position data, and all other required auxiliary data. Therefore, the data processing subsystem also contains following modules: high spatial program module, hyperspectral program module, laser program module and attitude & position program module, as

well as a program module to merge all sensors and extract the required information. Attitude & position program module is POSPac software developed by Applanix Corporation. Figure 10 indicates the working flow to process the high spatial data.

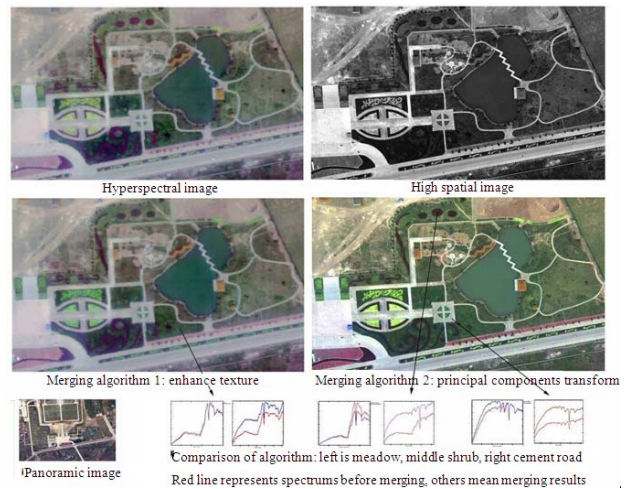


Figure 13. Diagram of imagery merging. The top left is hyperspectral images, the top right high spatial images, the middle left merging results through filter algorithm in frequency domain, the middle right another merging results through principle components transformation, at the bottom is the comparison of spectrum curve before and after merging.

4. SUMMARY AND CONCLUSIONS

Airborne multidimensional integrated remote sensing system was finished on 2005. This system can provide high ground resolution panchromatic and multispectral imagery and hyperspectral imagery as well as laser ranging data simultaneously in one flight. The imaging operation is controlled by appropriate software implemented in the master computer connected to all sensors via net cables. The distortions caused by the flight dynamics of the aircraft are rectified using the high precise information extracted from the position and attitude measurement device developed by Applanix Corporation. The standard data format is provided for users' convenience to apply the commercial processing software.

ACKNOWLEDGEMENTS

Great thanks to my colleagues who participated and made great contributions in this project, including Li Zhang, Yuwei Chen, Peixin Hu, Binla Zhang and Qimin Lu et al. Special thanks are expressed to Mrs. Kangmei Fang for her contributions to optical calibrations in this system.

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