AUTOMATIC ORTHORECTIFICATION OF AIRBORNE IMAGERY USING GPS/INS DATA

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ABSTRACT: Airborne imagery must be precisely orthorectified to be used as geographical information data. GPS/INS (Global Positioning System/Inertial Navigation System) and LIDAR (LIght Detection And Ranging) data were employed to automatically orthorectify airborne images. In this study, 154 frame airborne images and LIDAR vector data were acquired. LIDAR vector data were converted to raster image for employing as reference data. To derive images with constant brightness, flat field correction was applied to the whole images. The airborne images were geometrically corrected by calculating internal orientation and external orientation using GPS/INS data and then orthorectified using LIDAR digital elevation model image. The precision of orthorectified images was validated using 50 ground control points collected in arbitrary selected five images and LIDAR intensity image. In validation results, RMSE (Root Mean Square Error) was 0.365 smaller then two times of pixel spatial resolution at the surface. It is possible that the derived mosaicked airborne image by this automatic orthorectification method is employed as geographical information data.

Keywords: airborne image, LIDAR, GPS/INS, flat field correction, orthorectification

1. Introduction

Airborne imagery is used as updating ground geographical information, defining coastal line and detecting ocean red tidal. Unlike satellite imagery, the imagery obtained from aircraft has much less atmospheric noise because of their lower observation height. Generally airborne imagery has higher spatial resolution than satellite.

Images derived from digital cameras can be processed more rapidly because of skipping developing step, unlike airborne photographs using films. Digital images are acquired from a single CCD camera composed of three colors or a multispectral CCD camera. Digital multispectral images were applied for vegetation classification by intercomparison and analysis between multispectral bands (Ghitter et al., 1995; Moskal and Franklin, 2004). With airborne images, LIDAR (Light Detection And Ranging) vector data provide surface altitude and three dimension information. Koukoulas and Blackburn (2005) proposed forest structure and classification using LIDAR data and airborne images.

A spatial resolution and a single observation area of airborne digital image are determined by aircraft altitude, lens and CCD pixel density. Airborne images have the value of geographical information after geometrical correction or orthorectification that are accomplished using ground control points (GCPs) in a reference map and a target image. However thousands of airborne images can be produced for a city area because a cover area of a single airborne image is very small. Like collecting GCPs, manual process for orthorectification of many airborne images is time consuming and great expense.

GPS/INS (Global Positioning System/Inertial Navigation System) provides aircraft motion and position. This information was employed to orthorectification of airborne images (Cramer et al., 1997; Mostafa and Schwarz, 2001). However they also collected many GCPs with GPS/INS data for deriving more precise orthorectified images. This human interception for orthorectification of many images is required much expense and time, and not easy to collect GCPs in forest area and ocean because of their lower variability.

The objective of study is to orthorectify automatically frame airborne images using aircraft motion and position data from GPS/INS and LIDAR altitude data. Also this study tries to mosaic orthorectified images, minimizing human interception through exclusion of GCP collection.

2. Study Area and Observation

2.1 Study area

The campaign of airborne image acquisition is carried out in agriculture area including apple orchard and other crops 30 km away from the east of Monreal City, Quebec Province, Canada (Figure 1). The principal objective of the campaign is to obtain geographical information, crop condition and yield estimation for precision agriculture. However in this paper we will talk about only automatic orthorectification of airborne images.

Airborne images were acquired using DuncanTech MS4100 multispectral camera of Redlake and ALTM2050 (Airborne Laser Terrain Mapper 2050) LIDAR of Optech. MS4100 has three CCD for three independent spectral images. This camera can provide three bands; blue, green and red or green, red and near infrared by user choice. Also this camera provide four bands; blue, green, red and infrared (blue and green from a same CCD). In this campaign, four bands were selected for obtaining real color image and deriving vegetation condition. The four bands are in spectral region from 400 nm to 1000 nm. The CCD has 1920 columns and 1080 rows and each pixel radiometric resolution is eight bits. An image has a file size of 8.3 megabyte. NIKON F2.0 35 mm lens was used for this application, having field of view (FOV) of 23°×13 ° horizontally and vertically.

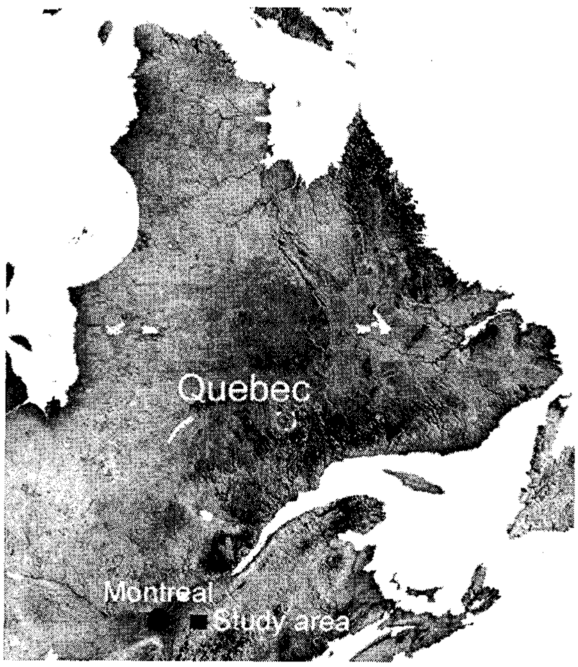

Figure 1. Study area (black filled square) in Quebec Province, Canada.

ALTM2050 LIDAR for ground observation provides vector data including surface altitude, position and intensity. LIDAR vector data are orthorectified using aircraft motion and position of GPS/INS. GPS data of aircraft have the precision smaller than a centimetre after post-process using station GPS data at the surface. GPS/INS data are produced 200 times per second for roll, pitch, yaw and position of aircraft with the error of ±0.01° and 15 cm. This sensor can observe the surface at the altitude of 2000 m and produce 50000 vectors per second. Near infrared light is employed and the maximum FOV is ±25°. The LIDAR data was used in the study as a reference data for airborne image orthorectification.

The flight height was determined at 850 m, the overlap between flight lines was 20% of the image width and the overlap between temporally sequential images was 80% of the vertical height of image. The pixel spatial resolution of image at nadir was 0.178 m horizontally and vertically. 154 multispectral images were acquired for the study area.

The FOV of LIDAR was fixed at ±15° and the first and the last returns of LIDAR were obtained for the surface. The space between LIDAR points varied from several centimetres to about one meter. For deriving reference raster image, LIDAR vector data and intensity data were converted to constant grid images with a spatial resolution of 25 cm using inverse distance weight function (Jang et al., 2006).

2.2 Flat field correction

Airborne image acquired from a digital camera could have different brightness over an image surface. This causes different quantity of incoming light between center and edge of CCD, dust between lens and CCD, and variation of CCD pixel sensitivity. As flat field correction, a pattern of brightness variation of uncorrected image is inversed and the inversed pattern is applied to the uncorrected image (Nguyen et al., 1996). The brightness of images was higher at the center of image and getting darker to the edge. The second degree polynomial equation with empirically derived coefficients was applied to the whole images in this study. An uncorrected image and corrected image were shown in Figure 2.

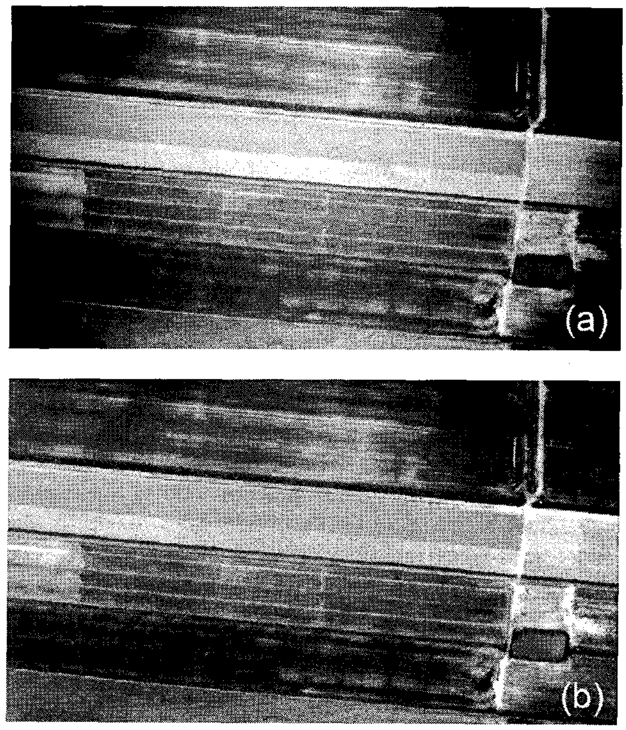

Figure 2. Flat field correction. Uncorrected image (a) and corrected image (b).

2.3 Orthorectification

The projection of airborne image depends on the distortion of lens and the direction of camera view due to aircraft motion. In this study we do not correct the distortion of lens.

Firstly each pixel of CCD is supposed to have a same cover area to a projected surface. The internal orientation was defined for pixel arranges in CCD. We derived horizontal (IOA_j) and vertical (IOA_i) angles between a given pixel (P) and nadir (CC) at the Lens for each pixel from the internal orientation (Figure 3).

The external orientation was obtained by projecting the internal orientation to the surface using aircraft motion and position data of GPS/INS. LIDAR altitude image was applied for geometrically corrected images by the external orientation to orthorectify airborne image. The finally derived orthorectified images have 0.201 m of a pixel spatial resolution at the surface.

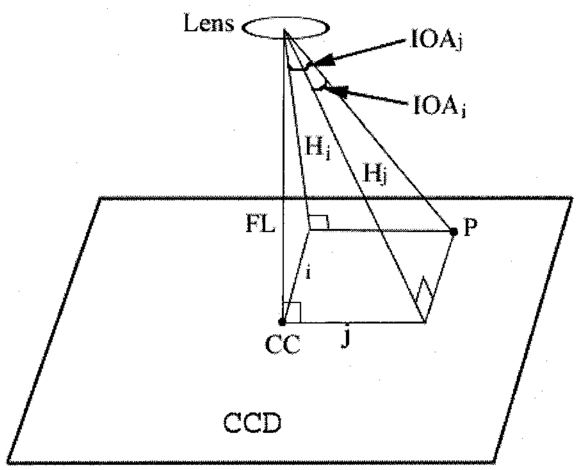

Figure 3. Schematic description of internal orientation of airborne image.

3. Validation and Discussion

The LIDAR intensity image converted from vector data was employed to collect GCPs for validation of orthorectified images. Five images of 154 images were arbitrary selected. The five images were superposed on LIDAR intensity image for collecting 10 GCPs per image (Figure 4). The position deviations were calculated between 50 GCPs of LIDAR intensity image and five images for the validation of orthorectification (Table 1).

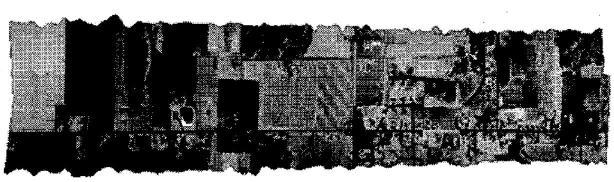

Figure 4. Five airborne images superposed on LIDAR intensity image.

The maximum residual of horizontal position between 50 GCPs of LIDAR intensity image and five images was 0.852 m, the minimum was 0.078 m and the overall RMSE (Root Mean Square Error) was only 0.365 m smaller than two times of a pixel spatial resolution at the surface. This precision was higher than the results of Mostafa and Schwarz (2001) who provided 0.4 m of RMSE using PCI orthoengine. They obtained airborne images from an aircraft at the altitude of 400 – 500 m but the airborne images of this study were acquired from the altitude of 850 m. Generally the higher aircraft altitude is, the lower precision of airborne image is. The orthorectified images by Mostafa and Schwarz (2001) were derived using manual method with much time but the orthorectification of airborne images in this study were accomplished through the automatic process.

The 154 orthorectified airborne images were mosaicked to a single image. Vertically central 30 % portion of each image was employed for mosaic because the overlap between temporal sequential images was 80 % (Figure 5). Darker area was found in Figure 5 because shadow was existed when the airborne campaign was carried out.

Table 1. Validation results of five orthorectified images. RMSE is root mean square error.

	Minimum residual	Maximum residual	RMSE
Image 1	0.078	0.652	0.252
Image 2	0.122	0.821	0.356
Image 3	0.098	0.573	0.421
Image 4	0.172	0.765	0.478
Image 5	0.157	0.852	0.342
Total	0.078	0.852	0.365

Figure 5. Mosaicked image of orthorectified airborne images.

4. Conclusions

In this study for providing precisely orthorectified airborne images which are widely employed as geographical information data for land and ocean applications, large number of airborne images were orthorectified more precisely using aircraft motion and position from GPS/INS and surface altitude data of LIDAR vectors. The altitude and intensity data of LIDAR vectors were converted to constant grid raster image for airborne image orthorectification and validation. Brightness of raw airborne images was not constant in a single image because of variation of incoming reflected light on CCD layer. Flat field correction was applied to obtain images with constant brightness.

Internal orientation was firstly defined for every pixel of CCD. As geometrical correction, external orientation was determined using GPS/INS data based on the internal orientation and then coordinates were defined to all the pixels. Finally the given coordinates were orthorectified using LIDAR altitude image. The validation of orthorectified airborne images was carried out using collected 50 GCPs from five images and LIDAR intensity image. The overall RMSE was 0.365 m smaller than two times of a pixel spatial resolution at the surface. For production of a single image, 30 % central portion of each image was mosaicked. With the precisely orthorectified mosaicked image will be used as useful geographical information data.

The orthorectification method developed in this study is valuable for the industry of airborne image because of the higher spatial precision and the automatic process. However distortion of lens and contrast variation between images are needed to be corrected for higher spatial precision and quality of airborne images.

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