EVALUATION OF SPATIAL ACCURANCY OF BIOMASS SPECTRAL DATACUBES BASED ON AISA DUAL FLIGHT CAMPAIGNS

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Abstract
In our study, hyperspectral data were collected by an AISA DUAL hyperspectral image spectroscopy system, in the wavelength range of 400-2450 channels, with different ground resolution. The radiometric and geometric calibrations were processed by Caligeo and ITT ENVI software based on boresight calibration. Band selection method was developed to reduce the noise, which allowed to collect the most reliable bands for plant properties, while, hyperspectral indices were calculated to evaluate the narrow waveband properties of hyperspectral reflectance spectra. In the first 10 months long test period of our service, 2 different GPS systems were compared. The C-MIGITS III and OxTS – RT 3003 GPS/INS systems were applied for collecting navigation data for direct geometric correction. External DGPS data were used for controlling the GPS/INS system. Several images were taken to monitor the direct georeferencing of push-broom scanner data with or without external DGPS using ground control points (GCP's). OxTS – RT 3003 was showed pixel sized accuracy of 1m without external DGPS data while the C-MIGITS III provided about 6m RMS position error, when the average flight altitude was 800-1000m and the average speed was 200-250 km/h, with minimum swath width of 500m

Keywords:_hyperspectral, dual flight campains, biomass spectral analysis

INTRODUCTION

In Hungary, the investigation of high resolution spectral characteristics of rocks, soils and vegetation cover began in 1980 in cooperation frameworks, such as the Russian coordinated INTERCOSMOS program (Kardeván et al., 1998). In the last decade, the development of advanced remote sensing methods in Hungary connected partly to space research but mainly to the application of satellite images of medium or low spatial and spectral resolution (Tamás, 2001). At that time, remote sensing related projects were carried out in several institutes focusing on different application fields like soil science (Soil Sciences and Agrochemical Research Institute of Hungarian Scientific Academy, University of Debrecen) or hydrology (Water Resources Research Institute). The application of hyperspectral remote sensing technology is quite a new one in the field of remote sensing. The Hungarian project of the HYSENS 2002 hyperspectral flight campaign was carried out by the German DLR to detect agricultural secondary salinization, and heavy metal polluted mining sites. In that case, the main factors of difficulties could result from the need for expertise in spatial statistics, image processing and the interdisciplinary character of this new scientific branch (Kardeván et al., 2003).

In 2006, an AISA DUAL airborne hyperspectral image spectroscopy (AIS) system were installed and operated in cooperation the University of Debrecen, AMTC, Department of Water and Environmental Management with the Hungarian Institute of Agricultural Engineering in Gödöllő-Hungary.

MATERIAL AND METHODS

The most important parts of the hyperspectral sensors are the spectrograph, which dissolve the electric waves arrived through the optical rift with the help of prisms and optical screen. The hyperspectral sensor consists of one optic, one spectrograph and one digital cam. The two hyperspectral sensors are assemble in a common house, therefore it is known ASIA DUAL system. The two cams can perceive in the visible wavelength, near infrared range and short wave infrared range.

The schematic steps of the hyperspectral image processing were the following: 1) Aerial and land image taking. 2) Radiometrical and geometrical corrections. 3) Noise filtering and data decrease. 4) Choosing the objective spectrum. 5) Classification. 6) Interpretation. 7) Checking (Burai and Tamás, 2004). steps 1 and 2 were made with the CaliGeo (radiometric and geometric corrections), while for steps 3 to 6, ENVI 4.6 raster based remote sensing software and 7th in ESRI ArcGIS 9.3 GIS environment were applied. The objectives of calibrating remote sensing data are to remove the effects of the atmosphere (scattering and absorption) and to convert radiance values received at the sensor to reflectance values of the land surface.

Technical information of applied ASIA DUAL hyperspectral system as follows:

- Push-broom hyperspectral imagery sensor with the fibre optic radiation meters (FODIS)
- Miniature integrated GPS/INS sensor, which serves the position, height and momentary situation (pith, roll, yaw) of plane
- Compact PC-based data collector and mobile receiver unit
- CaliGeo software runs as a separate software package under the ENVI software package to do the spectral and geometrical corrections
- The parameters of the hyperspectral image:
- Wavelength: 400-2450 nm (EAGLE: 400-970 nm and HAWK: 970-2450 nm)
  - Spectral sample taking: 1,2-10 nm
  - Ground resolution: 0,4-3 m (with plane)

The Eagle camera takes images in visible and near infrared range (VNIR), while Hawk operates in the middle infrared range (SWIR). By means of establishing of two camera a DUAL system were installed. The full range 400-2450 nm, which can be set 1,25-10 nm wavelength band and maximum 498 spectral channels. Two sensors can also be operated separately, so it makes possible to utilize the wider wavelength of higher resolution (1024 pixels) VNIR sensor. The technical specification of the DUAL sensor scanner is introduced in Figure 1.

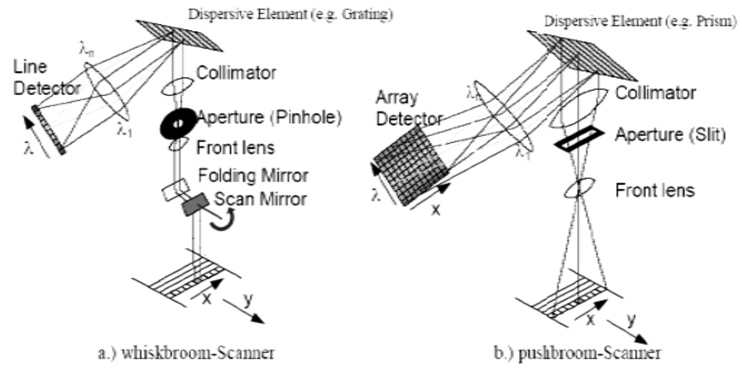

Fig. 1. The scanning methods of Ares-Hymap(left) and AISA DUAL (right) (source: Specim)

In a whiskbroom system- Ares-HYMAP, only a linear detector array is required. A scanner is used in the cross-track y direction, one pixel at a time. AISA DUAL use an array detector along-track x direction for imaging.

AISA DUAL systems can be used in two operating modes:full hyperspectral data acquisition or multispectral data acquisition at programmable wavebands. All the optics (fore optics and imaging spectrograph) and the detector assembly are temperature-stabilized. The AISA system included push broom imaging sensors, consisting of a hyperspectral and high-performance GPS/INS sensor and a data acquisition unit housed in a rugged PC. A real-time fiber optic down welling irradiance sensor (FODIS) on top of pilot cabin was integrated into the sensors to monitor the illumination conditions. Auxiliary components included a mount to connect the sensor to the GPS/INS unit, and regulated the power supply. The technical parameters of the AISA DUAL camera system is summarized in Table 1.

Table 1.

Technical specification of AISA DUAL hyperspectral camera

Specification	**VNIR (EAGLE)**				**SWIR (HAWK)**
Sensors characteristics					
Spectral range	400-970nm				970-2450nm
Spectral resolution	2.9nm				8.5nm
Spectral binning options	none	2x	4×	8×	none
Spectral sampling	1.25nm	2.5nm	5nm	10nm	6nm
Fore optics					
#spatial pixels	320		1024		320
FOV	24		37,7		24
IFOV	0.075 degrees		0.075 degrees		0.075 degrees
Swath with	0.65×altitude		0.65×altitude		0.39×altitude
Electrical characteristics					
Radiometric resolution	12 bits (CCD)				14 bits (MCT)
SNR	350:1 (peak)				800:1 (peak)
Image rate	Up to 100images/s				

Our data base also contained topographic maps, true-color airborne images and field surveys, and supporting data for fruit tree sub-species, irrigated and non irrigated areas, different fertilizer doses to distinguish between impacts of different fruit trees and peach varieties.

RESULTS AND DISCUSSION

The photogrammetric accuracy is as an important border condition that can give high influence for error propagation process and the absolute value of the overall total root mean square. It was a high-performance, integrated 3-axial inertial navigation sensor for monitoring the aircraft position and attitude. The systems include a CaliGeo control and operation software, which allows data acquisition settings to be tailored for individual flight mission requirements. Calibrating imaging spectroscopy data to surface reflectance is an integral part of the data analysis process, and is vital if accurate results are to be obtained (Green et al., 1998).

In the first 10 months long test period of our service, 2 different GPS systems were compared. The C-MIGITS III and OxTS – RT 3003 GPS/INS systems were applied for collecting navigation data for direct geometric correction. External DGPS data were used for controlling the GPS/INS system. Several images were taken to monitor the direct georeferencing of push-broom scanner data with or without external DGPS using ground control points (GCP's). OxTS – RT 3003 was showed pixel sized accuracy of 1m without external DGPS data while the C-MIGITS III provided about 6m RMS position error, when the average flight altitude was 800-1000m and the average speed was 200-250 km/h, with minimum swath width of 500m (Table 2).

Table 2.

Geometric accuracy of the test images

GPS/IMU system	# of images	GCP points	max. RMSE	min. RMSE	RMSE
C-migits-III	6	28	14,01	4,81	6,10
OxTS RT3003	6	28	4,44	0,31	3,03

During the hyperspectral test term, 127 hyperspectral images were prepared at different places. In case of larger areas images having high resolution (0,5-1,5 m), should have been taken, where the correct geometry of the bands were very important elements because of the right mosaics. Ground Control Point (GCP) was supplied to the controlling of the direct geometry.

An OxTS RT3003 GPS/IMU system was applied with high punctuality in the course of the airborne survey of the examined test area near the town Siófok (Soltész et al. 2004). The CaliGeo and ENVI software were applied for post-processing and transforming the raw AISA data into radiometric corrected and georeferenced images. The FODIS data were scattered, too, where the roll or pitch value were more than zero. After dropping out the inadequate values, trend line was calculated for processing FODIS ratio of all bands.

After the geometric and radiometric correction the hyperspectral n-dimensional data cube was made, which was then ready for classification. This data cube contains all geographical and spectral data changing pixel by pixel (Figure 2.)

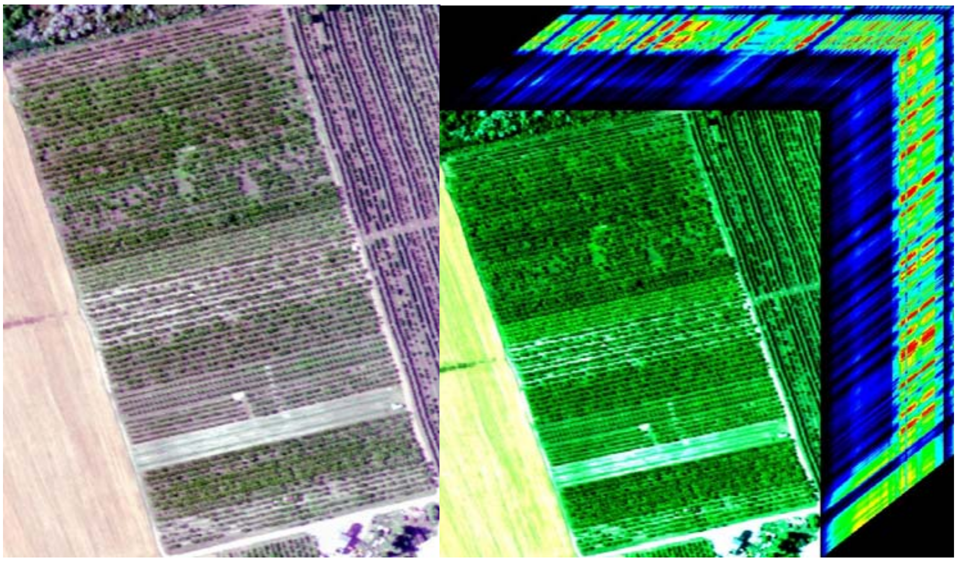

Fig. 2. Physical space (peach trees) and 69 dimensional spectral spaces were integrated by N-dimensional data cube

Based on figure 2, can be observe traditional visible channels and also near infrared channels.

Spectral reflectance curve is typical for every object, but in mixed surface, the spectral data are also mixed. Before classifications, spectrally clean, not mixed pixels of the objects should be found. These are the spectrally not correlated pixels called endmembers that are spectrally matched to similar spectral curves in the spectral space.

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