Transformation of the Hyperspectral Line Scanner into a Strip Imaging System

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ABSTRACT: Under European Commission supported scientific project: “Airborne minefield area reduction (ARC)”, that lasted from year 2001 to 2003, several electro-optical digital sensors and the acquisition systems were obtained and the acquisition software *Recorder* was developed. Among the acquired sensors, a hyperspectral line scanner *ImSpector V9* (for the wavelengths from 430 nm to 900 nm), along with an insolation collecting unit (*Fodis*), was also purchased and lately used in this project. The scanner was used for the acquisition of the reflectivity samples of the mine suspected areas over few different types of terrain whereas the quality of data was limited by several factors. This limitation was the reason to evolve the characteristics of the airborne hyperspectral remote sensing system, by use of V9 in its core, within the frame of the technologic project “System for the Multisensor Airborne Reconnaissance and Surveillance in the Crisis Situations and the Environment Protection”, in accordance with the foreseen applications. The following kinds of applications are foreseeable: a) measuring the radiance at discrete samples (static or in a direction of flight), b) measuring the reflectance at the discrete samples (static or in a direction of flight), c) imaging the radiance of the area in a form of the strip across the flight direction, d) imaging the reflectance of the area in a form of the strip across the flight direction. While during previous use (2001 – 2003), when only GPS data (1 Hz to up to 5Hz) were available, thus without capability of measuring the sensor’s orientation parameters, in a novel solution a new Position and Orientation System has been applied and combined with the parametric geocoding system program (ParGe). Mentioned achievement in advancing the features of the airborne hyperspectral remote system, enabled wider kinds of the hyperspectral imaging applications.

1 INTRODUCTION

The measurement and the acquisition of the hyperspectral data started in Croatia in 2002., [1], [3], and the simple reflectivity sampling which dominated at the beginning was transformed into an airborne imaging hyperspectral acquisition system on board of the helicopter, [9], [6], [13]. Since the radiance, what the sensor measures directly, depends on illumination intensity, geometry, surface roughness and atmospheric conditions, usefulness of the radiance measurement is limited due to its strong dependence on the illumination which is changing during the acquisition mission. In other hand, the reflectance is the ratio of the amount of the electromagnetic waves leaving/striking the target, and it represents a property of the observed matter which is equivalent under different illumination conditions. The basic measuring properties of V9 are determined by its design. Depend-
ing on its configuration, the use of different slit widths narrow slit (at the front end of the optical part of the system), enables different spectral resolutions and number of wavelengths bands in spectral range of 430 nm to 900 nm, to be used. When the scanner is directed at nadir to the ground, the area mapped below the scanner is a narrow strip whose dimensions is the function of height above ground and slit width. The V9’s associated digital camera at the output plane provides different combinations of pixel numbers and radiometric range, which dictates requirements toward the acquisition system. The spatial accuracy of the discrete measurements of the imaging depends on the dynamics of the aerial platform and the accuracy of the Position and Orientation System capable to quantify the measurements of aerial platform dynamics. While during previous use (2001 – 2003), when only GPS data were available (1 Hz or even several Hz), in a novel solution a new Position and Orientation System has been applied and combined with the parametric geocoding system program (ParGe). This process and outcomes are outlined in the next text.

2 SAMPLING THE RADIANCE AND THE REFLECTANCE

The hyperspectral line scanner ImSpector V9, with an insolation collecting unit (Fodis) and the digital acquisition unit were obtained in the frame of the scientific projects supported by the European Commission “Airborne minefield area reduction (ARC)”, (from 2001 to 2003). In the same project was developed the acquisition software Recorder, [5]. The scanner was used for the acquisition of the reflectivity samples of the mine suspected areas in several different types of terrain, [2], on board of the helicopter Bell-206, [1]. The quality of data was limited by several factors, [3]. This was the reason to advance characteristics of the airborne hyperspectral remote sensing, by use of V9, within the frame of the technologic project “System for the Multisensor Airborne Reconnaissance and Surveillance in the Crisis Situations and the Environment Protection”, in accordance to the foreseen future applications, [9], [6]. There are foreseen following kinds of applications: a) measuring the radiance at discrete samples (static or in a direction of flight), b) measuring the reflectance at the discrete samples (static or in a direction of flight), Fig. 1, c) imaging the radiance of the area in a form of the strip in the flight direction, d) imaging the reflectance of the area in a form of the strip in the flight direction. Radiance is what the sensor measures directly and it depends on illumination intensity, geometry, surface roughness and atmospheric conditions. The usefulness of the radiance is limited due to its strong dependence on the illumination which can change during the acquisition mission. Thus we did not apply a system to measure the radiance. The reflectance is the ratio of the amount of the electromagnetic waves leaving the target to the amount of the electromagnetic waves striking the target. It is a property of the observed material and is equivalent under different illumination conditions. The basic measuring properties of V9 are determined by its design and throughput of the digital acquisition system, [3]. Current configuration uses narrow slit (8.8mm x 50µm) at the front end of the optical system, enables spectral resolution of 4.4nm of nearly 106 channels in spectral range from 430 nm to 900 nm. When the scanner is directed at nadir to the ground, the area mapped below the scanner is a narrow strip that has dimensions 0.333H x 0.00208H, where H is height above ground. The V9’s associated digital camera at the output plane provides different combinations of pixel numbers and radiometric range (from 640x512 pixels, 8 bits to 1280 x 1024 pixels 12 bits) and dictates requirements toward the acquisition system.
The Fig. 3 and Fig. 4 are examples of the measurements before the advancement of the hyperspectral line sampling system into the imaging system in the frame of the technology project [9], [6].
3 THE ADVANCEMENT OF A HYPERSPECTRAL SAMPLING INTO AN IMAGING SYSTEM

The measurement of the spectral characteristics of the different kinds of vegetation was performed by the ground based system, whose data agree well with [7]. The calibration of the airborne measurement of the reflectivity can be performed in accordance to [11]. The spatial accuracy of the airborne discrete measurements or those of the imaging depends on the movements of the aerial platform, accuracy of the positioning and orientation system. While in the previous use (years 2001. to 2003.) were available only GPS data (1 Hz or even several Hz), an advancement is foreseen and realized in the technology project [9], [6]. The main advancements are: a) application of the parametric geocoding and orthorectification of Airborne Scanner Data [12], b) application of the Positioning and Orientation system [13], use of the spectralon reflectance target for the calibration of the radiometry [8]. The advanced features of the airborne hyperspectral remote system enable wider kinds of the applications.

3.1 Imaging geometry requirements

To utilize the line scanner in full imaging mode, means acquiring contiguous scan lines (without gaps between them), it is necessary to find the optimum ground speed of the aircraft, which is function of desired Ground Sampling Distance (GSD) and scanner imaging frequency, according to simple equation (1), used to arrive at optimum distance per second:

$$\text{GS} = \frac{\text{GSD}}{f_i}$$

where $\text{GS} =$ Ground Speed of the aircraft in [m/s], $\text{GSD} =$ Ground Sampling Distance in [m] and $f_i =$ Imaging scan period in [s].

Additional constraint for finding the optimum ground speed is spatial resolution along the aircraft track which is determined by the line width and integration time per one scene line (=one detector frame). Actual configuration of ImSpector V9 line scanner, depending on used vertical binning of CCD operation (x1 or x2) and exposure time (i.e. 50ms), provides the integration time per scene line of 129.82ms or 90.32ms, respectively. Thus, predicted spatial resolution along track for Zagreb/Jarun Lake campaign was 1.34m. Above described mapping geometry depends on height of the aircraft above ground level (pixel scale factor) which could be obtained from a Digital Elevation Model (DEM). Finally, high imaging resolution of pushbroom scanners, both spectral and spatial, as in case of ImSpector V9 (i.e. Zagreb/Jarun Lake flight campaign using Bell B206 helicopter had produced, in average, the lines with length of 218m and 1.63m wide, with across track pixel size of 19cm at altitude of 750m; in full spectral range with bandwidth of 80 channels and with spectral resolution of 4.4nm), requires additional technology and methods for final exploitation of their produced data, by using mentioned POS and performing the direct georeferencing.

The application required a Position and Orientation System capable to measure and record inertial orientation and GPS position data at high frequency, according to general requirement for line imaging mode utilization of hyperspectral imaging scanner, which states that read-out IMU frequency should be at least of those of scanner imaging frequency. Thus, Position and Orientation System, is built around chosen tactical-grade MEMS iMAR iVRU-RSSC, so-called Vertical Reference Unit, with integrated internal GPS unit and strap-down processor. Latest mentioned proved as self-sufficient system capable to deliver at least one set of exterior orientation parameters (Roll, Pitch, Yaw, Latitude, Longitude, Altitude) for each scan line, allowing for direct georeferencing of each separate line to be performed and by time domain transforming these lines into contiguous mapping, or imaging mode (in opposite to the sampling mode performed during earlier use of the System). Transformation of the hyperspectral line scan from sampling to imaging system, along with associated Position and Orientation System, resulted in successfully production of first geocube of Zagreb/Jarun Lake area, (Fig. 5.).
4 FURTHER APPLICATION OF THE HYPERSPECTRAL IMAGING SYSTEM

Further application of the developed airborne hyperspectral imaging system could be sea oil pollution detection and measurements, [4], forest health research, research of the traffic influence of the motor ways on the environment, water quality monitoring etc.

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REFERENCES


