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Hyperspectral sensors integration in a RPAS investigation aerial platform

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ABSTRACT

Remote sensing is the science and art of obtaining information about an object, area or phenomenon starting from the data obtained through a device or instrument without any physical contact with it. These sensors capture electromagnetic energy that comes to them from the reflection or emission of the objects on the Earth's surface, and convert it into an electronic signal that once conditioned, is recorded in some kind of support for further processing and analysis.

On the other hand, the field of remotely piloted Aircraft systems, also called drones, has undergone tremendous growth in recent years. There is a possibility to integrate these remote sensing cameras on-board of them. The result is a remote sensing system applicable in the atmospheric, terrestrial and marine environment allowing a systematic analysis of many geophysical parameters of high interest to researchers, businesses, Government and the public community.

The present document explains the integration process of remote hyperspectral sensors on-board of an unmanned aircraft system as an investigation aerial platform.

Once sensor is fully integrated in the Aircraft, next step is the qualification of the system, military or civilian. The integration ends obtaining the airworthiness certificate.

Lastly, to conclude, future lines of research are exposed.

1. Introduction

Remote sensing is defined, for our purposes, as the measurement of object properties on the Earth's surface using data acquired from Aircrafts [2]. It is therefore an attempt to measure something at a distance, rather than in situ. The major optical spectral regions used for Earth remote sensing are shown in Table 1. It's important to note that the boundaries of some atmospheric windows are not distinct and one will find small variations in these values in different references.

These particular spectral regions are of interest because they contain relatively transparent atmospheric 'windows', in which (barring clouds in the non-microwave regions) the ground can be seen from above, and because there are effective radiation detectors in these regions. Between these windows, various constituents in the atmosphere absorb radiation, e.g. water vapor and carbon dioxide absorb from 2.5–3 μm and 5–8 μm.

At the frequencies of high atmospheric transmittance, microwave and radar sensors are noted for their ability to penetrate clouds, fog, and rain, as well as an ability to provide night-time reflected imaging by virtue of their own active illumination.

Remote sensing may be split into active when a signal is first emitted from Aircrafts, and passive when information is merely recorded. Active remote sensing techniques employ an artificial source of radiation as a probe. The resulting signal that scatters back to the sensor characterizes either the atmosphere or the Earth.

In Fig. 1 radiation is emitted in a beam (labeled 1) from a moving sensor on-board of the RPA (Remotely Piloted Aircraft), and the backscattered component returned from objects on the ground (labeled 2) to the sensor is measured. The motion of the sensor platform creates an effectively larger antenna, thereby increasing the spatial resolution.

Data of the backscatter spatial distribution can be stored or sent to the GCS (Ground Control Station) (labeled 3) to be reconstructed the image by computer processing of the amplitude and phase of the returned signal.

On the other hand, passive remote sensing in all of these regions employs sensors that measure radiation naturally reflected

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Table 1
Primary spectral regions used in Earth remote sensing.

Name	Wavelength range	Radiation source	Surface property of interest
Visible (V)	0.4–0.7 µm	Solar	Reflectance
Near Infrared (NIR)	0.7–1.1 µm	Solar	Reflectance
Short Wave Infrared (SWIR)	1.1–1.35 µm 1.4–1.8 µm 2–2.5 µm	Solar	Reflectance
Mid Wave Infrared (MWIR)	3–4 µm 4.5–5 µm	Solar, thermal	Reflectance and temperature
Thermal or long wave	8–9.5 µm	Thermal	Temperature

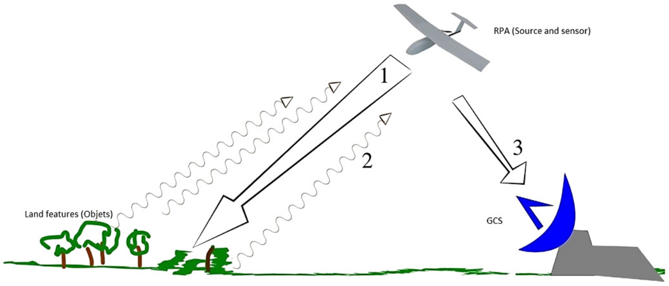

Fig. 1. Remote sensing using passive sensor system.

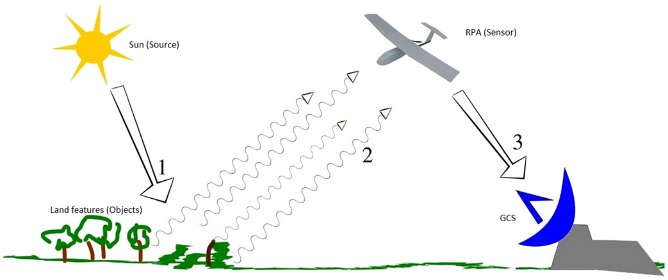

Fig. 2. Remote sensing using active sensor system.

or emitted from the ground, atmosphere, and clouds. The visible, NIR, and SWIR regions (from 0.4 µm to about 3 µm) are the solar reflection spectral range because the energy supplied by the sun at the Earth's surface exceeds that emitted by the earth itself. The MWIR region is a transition zone from solar reflection to thermal radiation. Above 5 µm, self-emitted thermal radiation from the earth generally dominates. Since this phenomenon does not depend directly on the sun as a source, TIR images can be acquired at night, as well as in the daytime.

In the following Fig. 2, radiation is emitted by the sun (labeled 1). It is reflected by the objects on the ground and the sensor on-board of the RPA measures this backscattered components returned from objects on the ground (labeled 2). In the same way as before, images can be stored or can be sent to the GCS (labeled 3) to be reconstructed the image by computer processing of the amplitude and phase of the returned signal.

1.1. *Operating principle*

The fore camera optic shows the scene onto a slit, which only passes light from a narrow line in the scene. After collimation in the concave mirror, a high-performance dispersive element separates the different wavelengths and the light is focused through the same concave mirror onto the camera focal plane. A scheme of the operating principle is shown in Fig. 3.

The net effect of the optics is for each pixel interval along the line defined by the slit, a corresponding spectrum is projected on a column of detectors on the array. The data read out from the array thus contains a slice of a hyperspectral image, with spectral information in one direction and spatial information to the other. By scanning over the scene, the camera collects slices from adjacent lines, forming a hyperspectral image or cube, with two spatial dimensions and one spectral dimension [9].

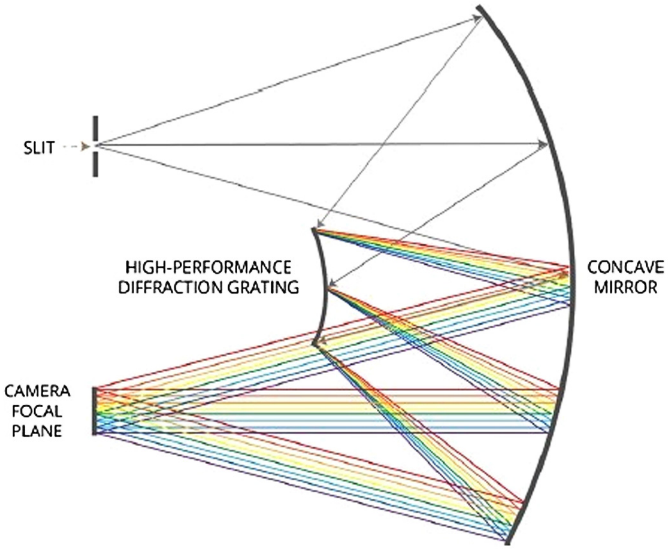

Fig. 3. Hyperspectral operating principle.

1.2. *Hyperspectral imaging*

Hyperspectral imaging, or imaging spectroscopy, combines the power of digital imaging and spectroscopy [3]. For each pixel in an image, a hyperspectral camera acquires the light intensity (radiance) for a large number (typically a few tens to several hundred) of contiguous spectral bands. Every pixel in the image thus contains a continuous spectrum (in radiance or reflectance) and can be used to characterize objects in the scene with great precision and detail.

Hyperspectral images obviously provide much more detailed information about the scene than a normal color camera, which only acquires three different spectral channels corresponding to the visual primary colors red, green and blue. Hence, hyperspectral imaging leads to a vastly improved ability to classify the objects in the scene based on their spectral properties. Differences between both kinds of images are shown in Fig. 4.

1.3. *Objective*

The main objective of the present paper is summarize the results obtained during the research for the integration of a hyperspectral sensors on a Spanish RPAS (Remotely Piloted Aircraft System), covering all the process from the preliminary studies until the certification of the IAP (Investigation Aerial Platform).