THE HYPERSPECTRAL SENSORS USED IN SATELLITE AND AERIAL REMOTE SENSING

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Abstract: *This article presents a number of issues that are related to the hyperspectral sensors which are part of new technologies for the acquisition of images in satellite and aerial remote sensing. Hyperspectral sensors are characterized by the fact that they produce records in a large number of adjacent and narrow lanes thereby providing a very high spectral resolution. In this way, interpretations and analyses can be made of the remote images at the micro-level, highlighting the features of details which could not be underlined with multispectral sensors. There are many applications that use hyperspectral images and they are related to agriculture, forestry, geology, environmental monitoring.*

Key words: *hyperspectral sensors, spectral resolution, hyperspectral curves.*

1. General Aspects

Multispectral remote sensing systems use parallel frame sensors that detect radiation in a few bands usually between three and six spectral bands in the visible spectral to middle infrared. Apart from these bands there are several types of satellite sensors that take pictures in one or two thermal bands. Therefore multispectral satellite sensors contain fewer but broader spectral bands which are not able to detect fine details on the surface of the land and which do not allow the separation of objects that present a very little difference in terms of spectral reflecting. For example, in the vegetation are many species of plants and vegetation classes that present almost similar spectral properties. As such in the case of a classification they belong to the same class or same species. Such interpretations of the data lead to erroneous results that show the limitation of multispectral sensors of working at the micro-level. Also, these sensors can't detect very small changes in the content of moisture and chlorophyll of leaves [1], [2].

Hyperspectral remote sensing sensors have the ability to acquire images in many narrow spectral bands that are found in the electromagnetic spectrum from visible, near infrared, medium infrared to thermal infrared. Hyperspectral sensors capture energy in 200 bands or more which means that they continuously cover the reflecting spectrum for each pixel in the scene. Bands characteristic for these types of sensors are continuous and narrow, allowing an in-depth examination of features and details on Earth which recorded with multispectral sensors would be lost. Hyperspectral records are based on spectroscopy in the range 0.40…2.50 μm where hyperspectral sensors are working and where absorption

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has three fundamental characteristics:

- the absorption of the transferred cargo, which occurs mostly in the visible part of the electromagnetic spectrum causes the electrons to be transferred between atoms. For example, between atoms Fe^{2+} and Fe^{3+} an atom is transferred from the atom Fe^{2+} to Fe^{3+} because of the action of light which causes oxidized objects to appear in red. Although this phenomenon can be detected with multispectral sensors such as Landsat, it may best be revealed through hyperspectral sensors;
- transmitted electron absorption occurs in the case of atoms with an incomplete electronic wrapper when light of a certain wavelength can bombard the electrons from different positions in the coating. This absorption tends to extend on more narrowed intervals than the transferred cargo and the wavelength where the absorptions are made are controlled by the position and diversity in the vicinity of atoms and not by the type of atom. This feature is used, especially in geology where mineral arrangement of atoms is well defined;
- the absorption due to vibration occurs when light, which has the same wavelength with a molecule or part of it, strikes the molecule and causes a vibration that leads to the absorption of light [6], [7].

Generally, this absorption of energy is very narrowed although depths are varied enough. Many of this absorption can be detected by multispectral sensors.

Since images can be obtained for each narrowband, hyper-spectroscopy refers to the spectroscopy of image. The term used for systems that take pictures with high spectral resolution is hyperspectral remote sensing. Hyperspectral remote sensing is a relative new technology used in the detection and identification of minerals, vegetation, artificial materials and soil background [4]. The remote hyperspectral appeared in mid 80's and since then it has been widely used by geologists for mapping minerals. Detection of the type of material is dependent on coverage and spectral resolution, relation signal / noise of the spectrometer the material density and strength of material absorption in the wave length in which the measurements are made [3].

2. Types of Hyperspectral Sensors

In the hyperspectral field there are two types of systems that take images: on aircraft and on satellites. Most hyperspectral sensors are mounted on aerial platforms and less on the satellite (Table 1) [5].

In general, the spectral range within which hyperspectral sensors on aircraft work is 380-12700 nm and for those on the satellites is 400-14400 nm. Most hyperspectral sensors record the reflected radiation in a series of bands with narrow and continuous wavelength. The number and width of bands varies from one system to another, i.e. in the range of 1-288, with widths ranging from 2-2000 nm. Unlike the sensors on aircraft, sensors on satellites have the capacity to provide global coverage at regular intervals. Further is presented a comparison between the AVIRIS air sensor and the Hyperion satellite sensor considered to be representative for the two types of systems (Table 2) [3].

The Hyperion EO-1 sensor was launched in November 2000 by NASA with the purpose of taking hyperspectral images from space in order to create mineralogical mapping. Hyperion is a hyperspectral satellite sensor which works in the spectral range 0.40…2.50 μm with 242 bands which have a spectral resolution of about 10 nm and a spatial resolution of 30 meters, the data is taken from an altitude of 705 km. Hyperion is a push-broom instrument that takes pictures with a radiometric resolution

Main hyperspectral sensors on aircraft and satellites Table 1

Hyperspectral sensors on satellites			
Types of sensors	**Producer**	**Number of bands**	**Spectral range [µm]**
FTHSI on MightySat II	Air Force Research	256	0.35-1.05
Hyperion on EO-1	NASA Guddard Space Flight Center	242	0.40-2.50
Hyperspectral sensors on aircrafts			
AVIRIS (Airborne Visible Infrared Imaging Spectrometer)	NASA Jet Propulsion Lab.	224	0.40-2.50
HYDICE (Hyperspectral Digital Imagery Collection Experiment)	Naval Research Lab.	210	0.40-2.50
PROBE-1	Earth Search Sciences Inc.	128	0.40-2.50
CASI (Compact Airborne Spectrographic Imager)	ITRES Research Limited	Over 228	0.40-1.00
HyMap	Integrated Spectronics	100 la 200	Visible to termal infrared
EPS-H (Environmental Protection System)	GER Corporation	VIS/NIR (76), SWIR1 (32), SWIR2 (32), TIR (12)	VIS/NIR (0.43-1.05) SWIR1 (1.50-1.80) SWIR2 (2.00-2.50) TIR (8-12.50)
DAIS 7915 (Digital Airborne Imaging Spectrometer)	GER Corporation (Geophysical and Environmental Research Imaging Spectrometer)	VIS/NIR (32), SWIR1 (8), SWIR2 (32), MIR (1), TIR (12)	VIS/NIR (0.43-1.05) SWIR1 (1.50-1.80) SWIR2 (2.00-2.50) MIR (3.00-5.00) TIR (8.70-12.30)
DAIS 21115 (Digital Airborne Imaging Spectrometer)	GER Corporation	VIS/NIR (76), SWIR1 (64), SWIR2 (64), MIR (1), TIR (6)	VIS/NIR (0.40-1.00) SWIR1 (1.00-1.80) SWIR2 (2.00-2.50) MIR (3.00-5.00) TIR (8.00-12.00)
AISA (Airborne Imaging Spectrometer)	Spectral Imaging	Over 288	0.43-1.00

of 8 bits, the band having a width of 7.5 km and being perpendicular on the movement of the satellite. The system used for taking images is formed of two spectrometers: one working in the visible/near infrared (VNIR) (0.4…1.0 µm) and one in short-wave infrared (SWIR) (0.9…2.5 µm). The data are calibrated using both the radiation measured before the mission and when the images are taken [3].

Airborne Visible Sensor/Infrared Imaging Spectrometer (AVIRIS) are new in terms of hyperspectral systems attached to planes. The AVIRIS sensor, developed by NASA/Jet

Comparison between the AVIRIS and Hyperion sensors Table 2

HSI Sensor	Spectral resolution [nm]	Spaţial resolution [m]	Swath width [km]	SWIR SNR
AVIRIS-High Altitude	10	20	12	~500 : 1
Hyperion	10	20	7.5	~50 : 1

Propulsion Laboratory (JPL), is working in bands of 224, with a spectral resolution of about 10 nm and covering the spectral range from 0.40 to 2.50 µm. The sensor is a Whiskbroom system that uses a scanning system for acquiring data on the transverse direction of advancement. Four off-axis double-pass Schmidt spectrometers capture light from foreoptics using optical fiber and send it to four linear panels, one for each spectrometer, which have a strong sensitivity in the range 0.4…0.7 µm, 0.7…1.2 µm, 1.2…1.8 µm and 1.8…2.5 µm. AVIRIS sensor takes images from an altitude of 20 km with a spatial resolution of 20 meters, from a band whose width is of 10.5 kilometers. Starting with 1998, the sensor is mounted on a Twin Otter aircraft flying at low altitude, taking pictures with a spatial resolution ranging between 2 and 4 meters [3].

3. The Features of Hyperspectral Images

Although many hyperspectral sensors are working in hundreds of bands, not the number of bands defines the sensor as being hyperspectral. The criteria underlying the classification of sensors as hyperspectral are band width and the continuous nature of the records. For example, a sensor that only works in 20 bands may be considered hyperspectral if all these bands are adjacent and with a 10 nm width, for example. If the sensor works in 20 bands with a width of 100 nm or if they are not adjacent because between them there are bands that do not produce records, the sensor cannot be considered hyperspectral.

Spatial resolution of satellite systems is fixed, to take the example of Hyperion, at 30 m. In the case of the aircraft systems these depend on the height of flight and may have the size of pixel of sub metric to 10 feet. Spectral resolution can be defined by the length of the continuous wave that can be detected in the electromagnetic spectrum. In the remote sensing sensors the band width of 0.2 µm in the visible near-infrared range can be considered low spectral resolution and a width of 0.01 µm as a high spectral resolution (Table 3) [9].

It is stated that differentiation between hyperspectral sensors and multispectral ones is not the spatial resolutions between the two types of sensors but between spectral resolutions. Currently hyperspectral images purchased by satellite systems have a spatial resolution of 30 m or finer while aircraft systems purchases data with high spatial resolution, of the order of 5 m or finer.

Information registration is performed on hyperspectral curves that enable acquisition of detailed data on materials and other details on the surface of Earth. These curves are continuous curves and contain spectral information which measure the reflecting of land, its details, that of water or air in the visible wavelength and near infrared. Curves also record the fine details of the phenomenon of absorption and using them a rigorous analysis of surface composition on large areas can be made [10], [11].

Hyperspectral images are more appropriate for detailed analyses than using hyperspectral data materials that have an immediate or similar spectral as they may convey separate information that

Characteristics of hyperspectral images Table 3

Name	Spectral interval [μm]	Number of bands	Spectral interval [nm]	IFOV [mrad]	FOV [degrees]	Produce	Data Availability
MAIS	0.44-11.80	71	20/600	3	90	China	1991
AVIRIS	0.40-2.50	224	10	1	30	JPL, U.S.A	1987
GERIS	0.40-2.50	63	25/120/16	2.5	90	GER Corp. U.S.A.	1987
CASI	0.40-1.00	288	2.9	1	35	ITRES, Canada	1989
MIVIS	0.43-12.70	102	20/50/400	2	70	Daedalus Enterprise Inc., U.S.A	-

can be obtained at the subpixel. Obviously, for the processing of such data, appropriate programs are necessary [8]. Hyperspectral images contain spectral features specific for the atmosphere which is why, before the processing itself, it is necessary to remove them. In this sense there are a number of methods from them, the most used being embedded in the ATREM (Atmosphere Removal) used to eliminate the atmosphere effects from AVIRIS and Hydice images. This program was designed to determine the scaled surface reflectance from hyperspectral images. The program takes into account that the surface is horizontal and that it shows Lambertinian reflecting. If the ground topography is known then scaled surface reflectance can be converted into actual reflected surface. The ATREM model is a good approximation of the radiometric image corrections, but achieving a calibration of the reflecting area by in situ measures leads to improving the final results [6], [7].

4. Conclusions

Applications in which hyperspectral images can be used are multiple due to their ability to separate the recorded data. In this sense hyperspectral images can be used in agriculture, forestry, geology, environmental monitoring etc. Within these applications, the data are used to determine chemical concentrations in leaves, vegetation stress, mapping the expansion of different species of plants, the surfaces contaminated by mining waste and other pollutants, water color mapping to determine and identify the presence of microorganisms and localization of the sources of pollution.

Compared with multispectral satellite images, which can be used in mapping the areas covered with forest, hyperspectral images may be used in the mapping of species in a brush.

Hyperspectral images are also used in detection and mapping of a wide range of materials which have reflective close characteristics. For example, these images are used by geologists for mapping minerals and highlighting the properties of soil including moisture, organic content and salinity. In army they are used to identify military cars that partially depend on the canopy trees and on the detection of certain targets.

Regarding the cost of these records the price of images taken with the air system is between 250 and 1000 dollars and those taken with the satellite systems can exceed 2500 dollars on the scene.

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