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Hyperspectral remote sensing: An imaging spectrometry for exploration of earth's resources and ecosystem management in regional Development

Dr. Madan Mohan
Associate Professor of Geography, Centre for Study of Regional Development, School of Social Sciences - III,
Jawaharlal Nehru University, New Delhi, Delhi, India

Abstract
Hyperspectral imagery contains of earth's properties which is assimilated in numerous narrow spectral bands using the visible and infrared spectrum of electro-magnetic radiation. In other words, hyperspectral imagery is comprises by hundreds of spectral bands ranging between 5-10 *μ m* and form a three-dimensional (x, y, λ) hyperspectral data cube. Furthermore, hyperspectral cubes are generated from airborne sensors or satellites as Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and Earth Observation (EO) systems by means of sensors as HYDICE, AVIRIS, and Hyperion which have been developed by NASA. Hyperspectral remote sensing was originally developed for geosciences or earth's resources exploration as geology and mining of various minerals, historical exploration of human civilisation and so on. Now, its application have also been widespread into fields of surveillance as well as ecology and environment management for sustainable development.

Keywords: electromagnetic spectrum, imaging spectrometry, multispectral imaging, hyperspectral cube, spatial resolution

1. Introduction: Imaging spectrometry

The Hyperspectral imaging is also known as imaging spectrometry. It is now a reasonably familiar concept in the field of remote sensing. It is defined as "the science of acquiring digital imagery of earth's materials in many marrow contiguous spectral bands". In other words, the Hyperspectral imagery is acquired in many narrow spectral bands using the visible and infrared spectrum of light. Hyperspectral imagery is typically collected as a data cube with spatial information collected in the x-y plane. And, the spectral information is represented in z-direction.

The Hyperspectral remote sensing combines imaging and spectroscopy in a single system which includes large data sets and require new processing techniques and methods. The Hyperspectral data sets are normally comprised by about 100 to 300 spectral bands which bandwidth is ranging between 5 – 10 *μ m.* Whereas, the multispectral data sets are normally comprised by about 5 to 10 spectral bands which bandwidth is ranging between 70 – 400 *μ m.*

The Hyperspectral imagery are sometimes referred to as "image cubes". Because these are having a large spectral dimension as well as the two spatial dimensions. For instance, the Hyperspectral cube shows an AVIRIS hyperspectral imagery of the Leadville mining district in Colorado. The spectral dimension of hyperspectral imagery is shown as the top and right faces of the cube. The front of the cube is a true colour composite, with areas containing secondary minerals from acid mine drainage highlighted in red, orange and yellow. This Hyperspectral imagery cube was processed using the ENVI software of the image processing.

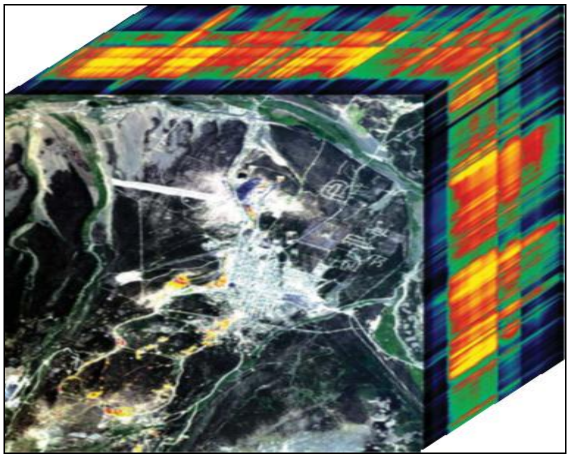

Fig 1: The Hyperspectral imagery cube of AVIRIS. The Hyperspectral imagery shows the Leadville mining district in Colorado, Canada (Zhang, Wang & Liu, 2000).

1. The Imaging Spectrometer

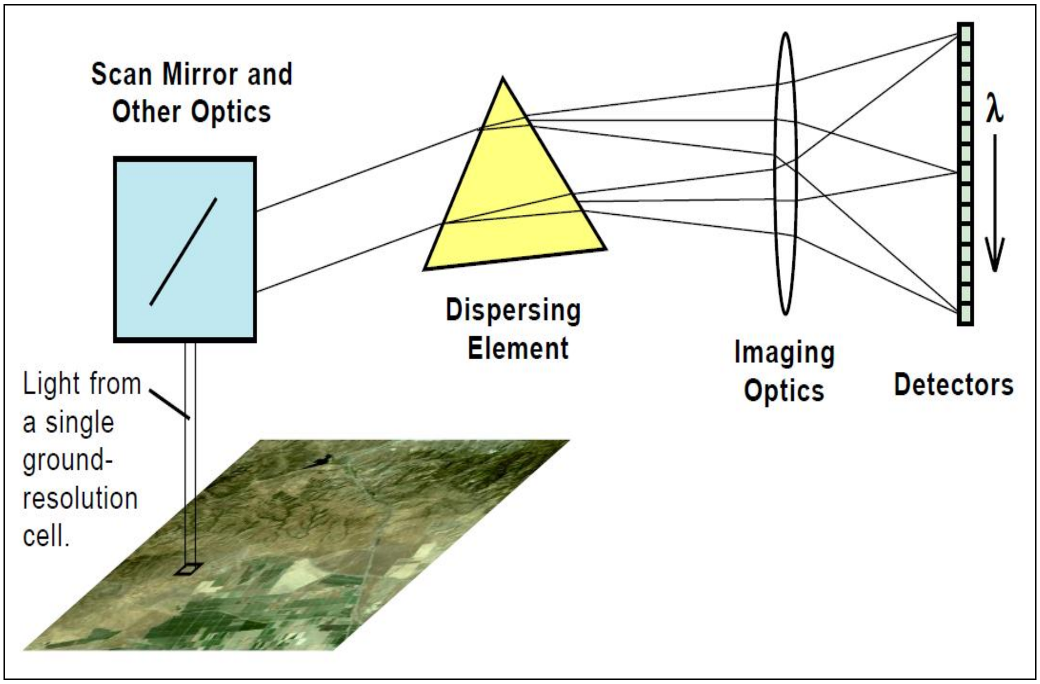

Fig 2: Schematic Diagram of the basic elements of an imaging spectrometer. Some sensors use multiple-detector arrays to measures hundreds of narrow wavelength (λ) bands in the hyperspectral imagery.

2. Spectral Reflectance

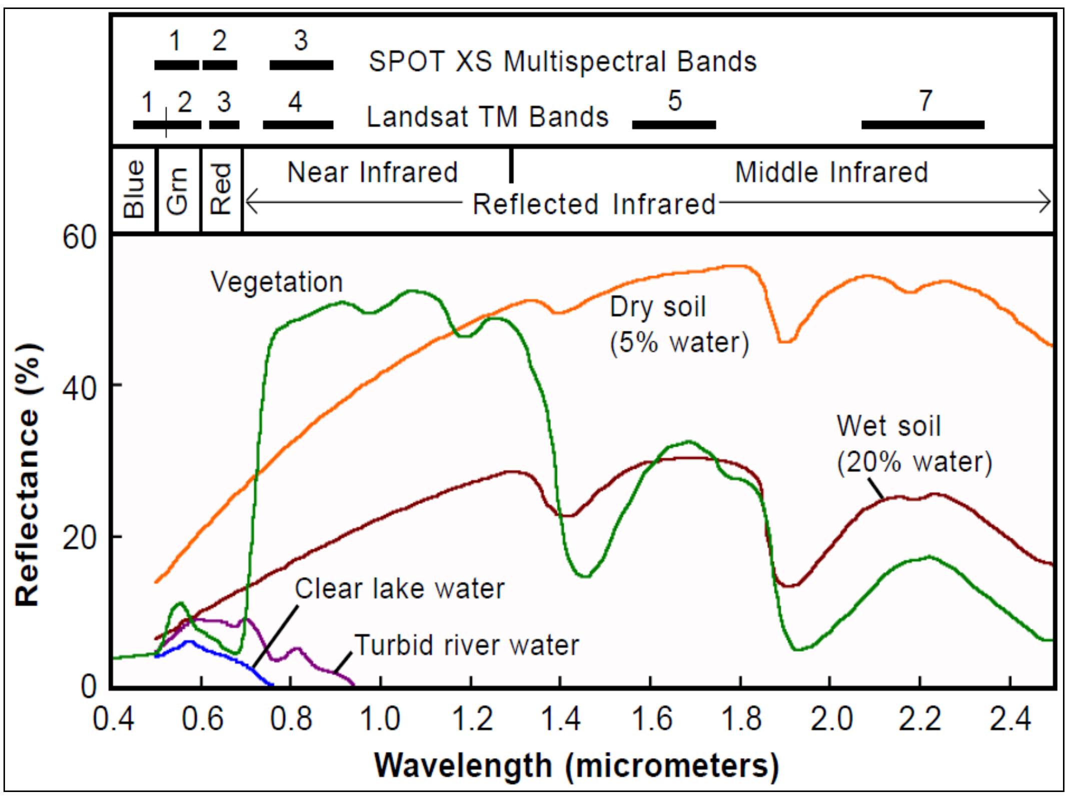

Fig 3: Spectral Reflectance by different properties of the earth.

a. Mineral Spectra

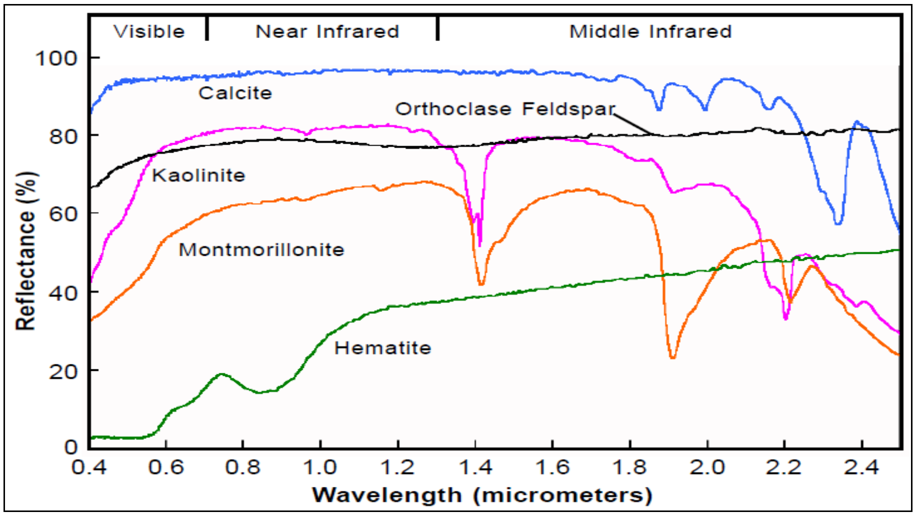

Fig 4: Spectral Reflectance by different mineral properties of the earth.

b. Plant Spectra

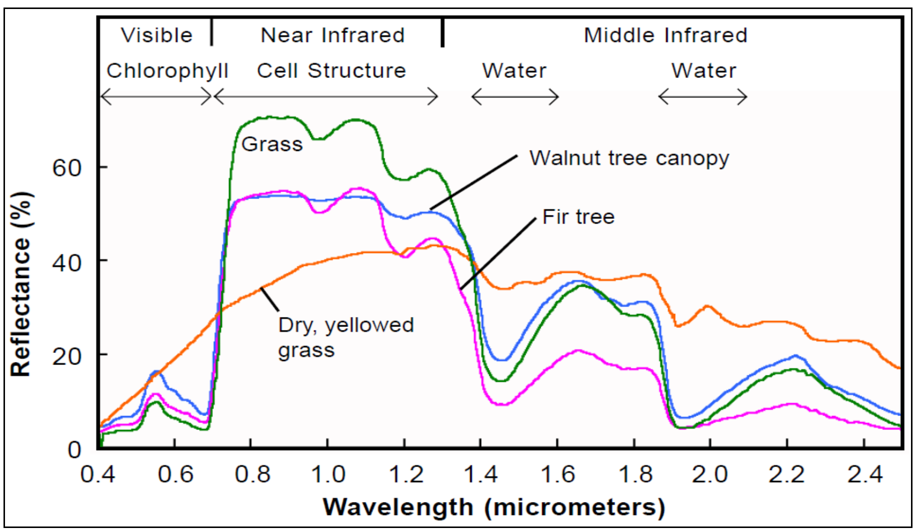

Fig 5: Spectral Reflectance by different plant species of the earth.

2. Research and Commercial Imaging Spectrometers

Sensor	Organization	Country	Number of Bands	Wavelength Range (µm)
AVIRIS	NASA	United States	224	0.4 - 2.5
AISA	Spectral Imaging Ltd.	Finland	286	0.45 - 0.9
CASI	Itres Research	Canada	288	0.43 - 0.87
DAIS 2115	GER Corp.	United States	211	0.4 - 12.0
HYMAP	Integrated Spectronics Pty Ltd	Australia	128	0.4 - 2.45
PROBE-1	Earth Search Sciences Inc.	United States	128	0.4 - 2.45

Table 1: The Hyperspectral Remote Sensing Satellites with the details of sensors, wavelength and bands.

3. Hyperspectral Remote Sensing Sensor Platforms

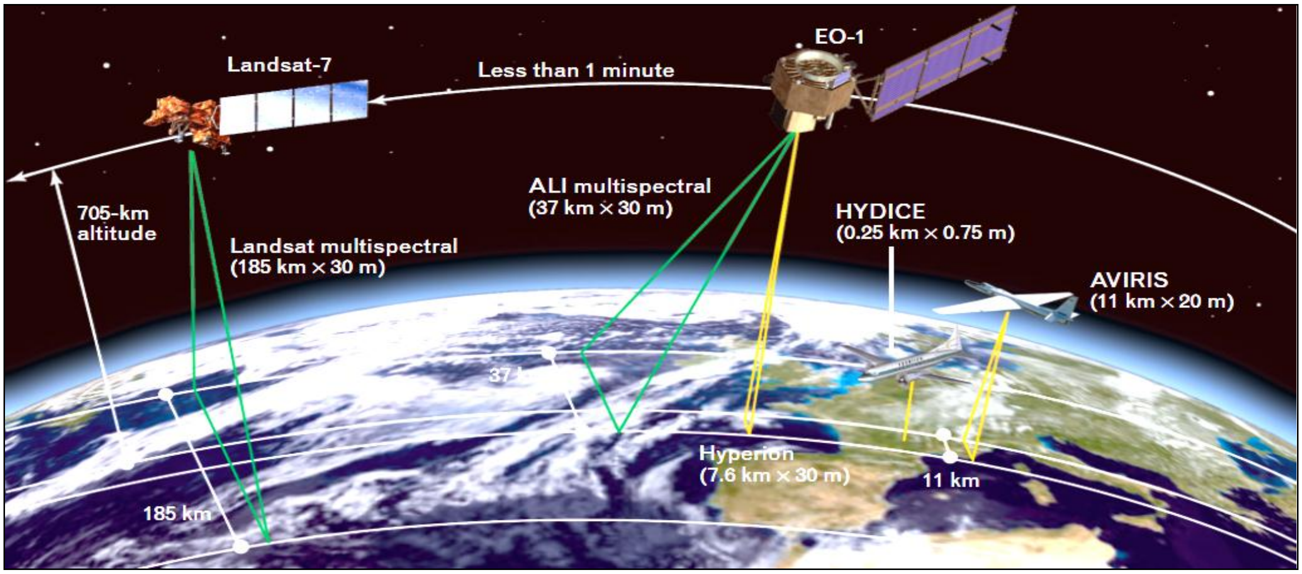

Fig 6: Hyperspectral remote sensing sensor platforms with the altitude and area coverage regimes for HYDICE, AVIRIS, and Hyperion (on EO-1) (Shaw and Burke, 2003).

4. Hyperspectral Imagery Processing

1. Band Selection
2. Geometric Corrections
3. Radiometric Normalisation
   a. Line correction
   b. Atmospheric correction
4. Terrain Normalisation
5. Calibration – surface reflectance or temperature

5. Visualization of Hyperspectral Imagery

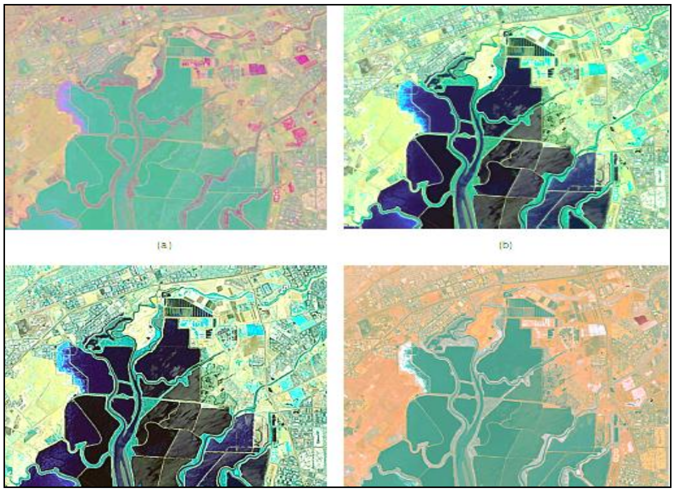

Fig 7: The Visualization of hyperspectral AVIRIS imagery. Top left (a), right (b); and bottom left (c), right (d) based on the PCA and the other methods of imagery processing, respectively (Cloutis, 1996).

6. Applications of Hyper-spectral Imagery

1. Atmosphere – vapour, cloud aerosols
2. Hydrology – sediments/ organic loads
3. Snow/ Ice – grain size, melting
4. Energy – chlorophyll, cellulose, pigments
5. Geology – minerals and soils
6. Coastal – phytoplankton, organic, sediments
7. Ecology – vegetation, plant species
8. Commercial – mineral exploration, agriculture & forestry

7. Advantages of Hyperspectral Data

1. Enhanced ability for spectral discrimination
2. Chemical and molecular analyses
3. Physiological and biogeochemical analyses of biomass
4. Chemical and mineral analyses of water
5. Geological and mineralogical analyses

8. Hyperspectral Remote Sensing: Opportunities and Future Prospects

The Hyperspectral imagery provides opportunities to extract more detailed information in comparison to using traditional multispectral imagery. The availability of commercial hyperspectral analysis tools is good which are continually becoming easier and more effective for use. There are currently many operating airborne hyperspectral sensors. These spaceborne hyperspectral sensor is providing imagery for the various purposes.

Besides this, the future of hyperspectral remote sensing is promising. Because the newly commissioned hyperspectral sensors provide more imagery alternatives. Besides this, the newly developed image processing algorithms provide more analytical tools. So, the hyperspectral remote sensing is becoming one of the essential technologies for geospatial research, exploration, and monitoring of the natural resources and their management.

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