Remote Sensing Image Analysis : Part-II

B. Uma Shankar
Machine Intelligence Unit
Indian Statistical Institute,
Kolkata
Presented at Sikkim University
Sikkim

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Overview : What is Remote Sensing?

Remote sensing involves the use of instruments or sensors to "capture" the spectral and spatial relations of objects and materials observable at a distance - typically from above them. An aerial or satellite photograph is a common example of a remotely sensed (by camera and film) image.
What is Remote Sensing?

A formal definition:

Remote Sensing is the Science of deriving information about an object from measurements made at a distance from the object. (without actually coming in contact with it)
Remote sensing basic processes
Receiving station processing

Archiving

Distribution
World vegetation 1999
World vegetation 2000-2001

Source: http://www.spotimaging.fr
Platforms, sensors and images

- There are meaningful distinctions between remote sensing ‘platforms’, ‘sensors’ and ‘images’

  - **Platform**
    - The craft on which a sensing device is mounted

  - **Sensor**
    - The sensing device or instrument itself

  - **Image**
    - The image data acquired by the sensing device
Remote sensing platforms

There are three main categories of remote sensing platforms:

**Spaceborne**
- Satellite
- Shuttle

**Airborne**
- Aeroplane
- Helicopter
- Hot air balloon
- Air ship
- Tethered balloon

**Ground-based**
- Hand-held
- Raised platform

Commonest platforms
Satellite platforms

Advantages

Continuous data acquisition
- Permanent orbit

High geometric accuracy
- Stable orbit (no atmosphere)

Wide area of coverage
- High vantage point

Low data cost?

Disadvantages

Geometric distortion
- Earth curvature

High operation cost
- Launch, etc.

Low spatial detail?
- High vantage point

Cloud cover?

High data cost?
Satellite orbit

- Generally, remote sensing satellites are in low Earth orbits (LEOs), at altitudes of several hundreds of kilometres.
- These satellites orbit the Earth approximately every hour.
- Most remote sensing satellites follow a ‘polar’ orbital path (approximately north-south).
- Polar orbits maximise the area of data acquisition, exploiting the Earth’s rotation.
Main benefits of satellite remote sensing is to Have a Space View of Earth

1. Large Area Coverage
2. Repetitive Coverage
3. World Wide Converge
4. Use New Areas of Spectrum
5. Use Several Areas of the Spectrum at Once
6. Use Computers to Manipulate Data
Definition with respect to Remote Sensing practiced:

“Remote Sensing is the technology that is now the principal modus operandi (tool) by which (as targets or objects of surveillance) the Earth's surface and atmosphere, the planets, and the entire Universe are being observed, measured, and interpreted from such vantage points as the terrestrial surface, earth-orbit, and outer space.”

http://rst.gsfc.nasa.gov/ DR. NICHOLAS M. SHORT,Sr
The quantity most frequently measured in present day remote sensing systems is the electromagnetic energy emanating from the object of interest, and although there are other possibilities (e.g., Seismic waves, Sonic Waves (SODAR) and Gravitational force etc. are normally in non-image forms), our attention here is focused on systems which measure electromagnetic energy, only in image form, taken from Satellite placed in the orbits.

(Analysis of Remote Sensing Images)
Image-Analysis

Image analysis is the process of identifying objects and shapes in a photograph, drawing, video, Remotely Sensed Image, or other visual images (Digital or Non-Digital). It's used for everything from colorizing classic motion pictures to piloting cruise missiles. Image analysis is extremely demanding for computers. The simple process of identifying objects in a scene is complicated by all kinds of factors: masses of irrelevant data, objects that partially cover other objects, indistinct edges, changes in light sources and shadows, changes in the scene as objects move, and more.
Image-Analysis Continued…..

- With all these complications, it is amazing that people are able to make any sense out of the images that constantly bombard their eyes.

- But most image analysis programs require massive amounts of memory and processing power. Even with the best hardware available, today's software cannot be compared to the human visual system when it comes to general image analysis.
The purpose of acquiring remote sensing image data is to, able to identify and assess, by some means either surface materials or their spatial properties.

A major characteristic of an image in remote sensing is the wavelength band it represents. Some images are measurements of the spatial distribution of reflected solar radiation in the ultraviolet, visible and near-to-middle infrared range of wavelengths.
Others are measurements of the spatial distribution of energy emitted by the earth itself (dominant in the so called thermal infrared wavelength range).

Yet others, particularly in the microwave band of wavelength, measure the relative return from the earth’s surface, the energy actually transmitted from the vehicle itself.

The first and second one are called passive remote sensing, where the source of energy is normally the SUN.

The other type is called active remote sensing, where source of energy is part of sensor system. (Microwave remote Sensing has some unique advantages such as penetration through clouds, and hence all weather capability and also day/night operations).
• Our aim here is to study the images taken in different bands of EM spectrum, from different satellite.
• Let us have some overview of the EM Spectrum
Electromagnetic spectrum

- EM spectrum is split into a few regions.
- Wavelength ($\lambda$) increases from left to right.
- Frequency ($f$) decreases from left to right.
- Linked by speed of light $c$:
  \[ c = \lambda \times f \]
- We only see a small portion of the EM spectrum in the wavelength 400-700nm.
Electromagnetic Spectrum
Diagram of EM spectrum
Radiative transfer basics

EM radiation is subject to four main processes;

- Reflection.
- Transmission.
- Scattering.
- Absorption (and re-emission).
Sources of RS radiance.

Remotely Sensed radiance values measured at a sensor come from various sources:

- Surface reflected
- Surface emitted
- Cloud top reflected
- Cloud emitted
- Atmospheric backscatter
Black body radiation

• The amount of radiation from an object will depend on its temperature and emissivity.
• Natural objects emissivity will vary with wavelength.
• Black-bodies are perfect radiators so emit maximum amount of radiation, defined by Planck curves.
• As the object heats up the amount of radiation it emits increases.
• The wavelength at the peak of the Planck curve decreases as objects get hotter.
Solar and terrestrial radiation

- The Sun acts like a BB at 6000K
  - This BB spectra peaks in the visible wavelengths.
- The Earth acts like a BB at around 300K.
  - BB spectral peak around 10-12µm (thermal IR)
Remote Sensing systems could measure energy emanating from the earth’s surface in any sensible range of wavelengths. However, technological considerations, the selective opacity of the earth’s atmosphere and scattering from atmospheric particulates and the significance of the data provided, exclude certain wavelengths:

- The wavelengths normally used are 0.4\(\mu m\) and 12\(\mu m\) visible/infrared range, 3mm to 300mm Microwave range
- The significance of these different ranges lies in the interaction mechanism between the electromagnetic radiation and the materials being examined.
Atmospheric absorption

- Radiance values measured by a sensor will be affected by the atmosphere.
- This happens more at certain wavelengths.
- Main absorbers are gases like water vapour and carbon dioxide.
- Some wavelength regions are affected less by atmospheric absorption. These are called window regions and can be used by RS sensors.
**EM Spectrum**

Energy Sources

- Surfs energy (at 6000 K)
- Earth's energy (at 300 K)

Atmospheric transmittance

- Transmission
- Energy blocked

Common remote sensing systems

- Human eye
- Photography
- Thermal scanners
- Multispectral scanners
- Radar and passive microwave

Spectral characteristics of energy sources, atmospheric effects, and sensing systems. Wavelength scale is logarithmic.
Spectral signatures (patterns)

- The emissivity of natural objects varies with wavelength.
- At some wavelengths they may act like a BB.
- At others they may have low emissivity.
- A spectral pattern can be generated for an object by measuring reflectance or emissivity at different wavelengths.
- These patterns can then be used to distinguish between surface types.
- The spectral pattern for a surface may change i.e. due to solar zenith angle or moisture content.
In this case, the target is a field of actively growing crops - the main components are thus vegetation, soil, and moisture. The detailed spectral signature for this composite of materials is shown in the lower right. Some fraction of the incoming solar radiation is reflected towards a sensor above (on an aircraft or spacecraft).
While it is now possible for a sensor system to almost duplicate the signature using the mode called hyperspectral remote sensing, in this example the broadband mode, initially the normal configuration for obtaining reflectance measurements and still in common use, is illustrated here. Thus the sensor employs bandpass filters to break the reflected radiation into discrete intervals (bands) of continuous wavelengths, each consisting of a segment of the EM spectrum (red, green, infrared, etc.).
The radiation consists of photons that impugn upon a plate that converts the photon energy to a voltage (photoelectric effect). At the instant of sampling this radiation, each band will have some voltage value (indicated on the dials). Assuming proper calibration of each band (channel), this voltage is a measure of the reflectance from the target, for each spectral interval. The resulting values represent a crude approximation of the spectral signature. However, even these few values may be sufficiently distinct to establish the identity of the target. Obviously, the more bands (and narrower bandwidths), the better is the discrimination.
Example spectral signatures

![Graph showing spectral signatures](image)

- **Dry bare soil (Gray-brown)**
- **Vegetation (Green)**
- **Water (Clear)**

Reflectance (%) vs. Wavelength (μm)
Spectral Signatures

[Graph showing spectral signatures of different land areas, including Pinewoods, Grasslands, Red Sand Pit, Silty Water, Grass, Tree, Sugar Beet, Wheat Stubble, Fallow Fields, Concrete, Asphalt, Bare Soil, Gravel, Shingles.]
Signature
Vegetation indices

- Plants absorb radiation in the blue and red regions of the EM spectrum.
- But in the near-IR they are very reflective.
- This change in reflectance is distinctive and can be used to identify vegetation cover.
- Band ratios using the red and near-IR channels are often used. Using a ratio also helps to remove variations due to solar zenith angle.
- Common one is
  
  \[ \text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})} \]
Example Landsat data

Near-IR

Combined (432)*

* False colour combining bands 4 (nearIR), 3 (red) and 2 (green).
It is generally agreed that Landsat, set the stage for the advent of these other satellite systems in that it demonstrated the power and versatility of multispectral imagery for observing the Earth for purposes of monitoring its natural and manmade features over time, from which the many applications of remote sensing have now become important in managing our planet’s "health" and the utilization of its resources. Since 1972, six Landsats have been orbited successfully. Here is the history of this highly successful program.
IRS-1A Calcutta Image FCC using Band-4,3,2 (i.e., NIR R & G)
The four bands of IRS images
Original Image in band-4 (NIR)
In Brief

• Remote sensing data provides useful information for monitoring and management of natural resources.

• Remote Sensing of the Earth and its environment is one of the major applications of space technology.

• Using Remote Sensing images the other applications are identifying man-made objects particularly objects of military interest, Urban planning, Digital elevation map (DEM), Cartography, Change Detection etc..
Why Remote Sensing images pose new Challenges for image processing paradigm?

- Data Volume
- Poorly illuminated images
- Coarse resolution (spatially)
- Composed of two many objects in one or few pixels
- Source of light/energy is not under control
- Geometry is distorted
- Radiometric distortion due to atmospheric effect etc.

**Advantages:**

The images can be acquired in multiple bands, with multiple resolutions and temporal images (repeated images)
Space Imaging's IKONOS satellite

IKONOS was launched successfully on September 24, 1999. This is the first in a new generation of satellites collecting very high resolution image data. IKONOS has a 1 meter resolution panchromatic sensor and a 4 meter resolution multispectral sensor. The satellite is an agile platform meaning that it can position itself to collect imagery for your specific area of interest.
## IKONOS Specifications

<table>
<thead>
<tr>
<th>Product Name)</th>
<th>Spatial Resolution</th>
<th>Spectral Bands (Micrometers)</th>
<th>Dynamic Range</th>
</tr>
</thead>
</table>
| IKONOS 4 meter Multispectral | 4 meter | Band 1: 0.45 - 0.53 (Blue)  
Band 2: 0.52 - 0.61 (Green)  
Band 3: 0.64 - 0.72 (Red)  
Band 4: 0.77 - 0.88 (Near Infrared) | 11 Bit (2048 levels) |
| IKONOS 1 meter Panchromatic | 1 meter | Pan Band: 0.45 - 0.90 | 11 Bit (2048 levels) |
| IKONOS 1 meter Panchromatic fused with 4 meter Multispectral | 1 meter | Band 1: 0.45 - 0.53 (Blue)  
Band 2: 0.52 - 0.61 (Green)  
Band 3: 0.64 - 0.72 (Red)  
Band 4: 0.77 - 0.88 (Near Infrared) | 11 Bit (2048 levels) |

http://www.ersi.ca/ikonos.html
Benefits: The imagery supplied by the IKONOS satellites will show a level of detail that is far superior to any currently operational commercial Satellites.

Some of the advantages of this imagery are:

- Highest spatial resolution available from a commercial imaging satellite
- Full dynamic range with 11-bit data (8-bit data for image processing software with file format limitations)
- Spectral content that provides information-rich imagery of Earth features
- Revisit frequency that enables clients to update databases regularly
- Flexible image collection to allow efficient data collection over specific target areas
- Superior Image Quality
This panchromatic image of Atlanta, Georgia highlights the image's usefulness in the utility industry. Professionals can use the image for site analysis, access determination, encroachments, and regional planning. The area shown is 500 x 500m.
This true color image collected by the IKONOS satellite on December 27, 1999 shows Atlanta. The image highlights usages ranging from monitoring urban growth, determining impervious and pervious surfaces to classifying urban environments. The area shown is approximately 5,500 x 5,500m.
Resourcesat-1, the latest remote sensing satellite of the Indian Space Research Organisation (ISRO).

Resourcesat-1 was launched into space October 17 by ISRO’s Polar Satellite Launch Vehicle (PSLV-05), from the Satish Dhawan Space Centre at Sriharikota in Andhra Pradesh.

The multi-spectral high spatial resolution camera, the linear imaging self-scanner-4 (LISS-4), provides a spatial resolution of 5.8m and a swath of 23km.

The camera operates in visible and near infra Red spectral bands. The LISS-4 can also be operated in monochromatic (black and white) mode providing a spatial resolution of 5.8m and a swath of 70km.

Also it has LISS-3 with Spatial resolution 23m and AWiFS- A multi-spectral advanced wide field sensor with a spatial resolution of 56m, provides a swath of 740km. It operates in visible, near infra Red and Short wave infra red spectral bands. And has the capability to take the imagery of the world repeatedly every five days with a very high radiometric resolution.
The Resourcesat-1 LISS-IV Multispectral (Mx) image of part of Kuwait, which is situated in the upper Persian Gulf. The cities seen in the image are Hawalli, and As Salimiyah. The data is acquired on 29 October, 2003 in 5m spatial resolution and a 7 bit radiometric resolution.
The Resourcesat-1 LISS-IV Multispectral (Mx) image of part of Ahmedabad city, India. The image is acquired on 23rd November, 2003 in 5m spatial resolution and a 7 bit radiometric resolution.
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Software used

Software used: ERDAS Imagine and ArcGIS.

ERDAS: ERDAS is a raster image processing software that can be used to display, enhance, geo-reference, classify, and produce a layout map of an images. ERDAS will be used as the main software for this course.

ArcGIS: ArcGIS is a vector GIS software that can be used to geo-reference satellite image and produce a map from the image through on screen digitization.
Remote sensing web sites

- http://www.esrin.esa.it - European Space Agency
- http://geo.arc.nasa.gov - NASA program
- http://www.spot.com - French satellite SPOT
- http://www.nasda.go.jp/ - Japan space agency
- http://www.rka.ru/ - Russian Space Agency (RSA)
- http://www.coresw.com - Russian imagery source
- http://www.space.gc.ca/ - Canadian Space Agency (CSA)
- http://www.inpe.br/ - National Institute for Space Research (Brazil)
- http://www.man.ac.uk - Manshester Univ.
- http://www.idrisi.clarku.edu - Idrisi site
- http://www.brevard.cc.fl.us/BTR_Labs/bober/martin/rs/overview.htm - Dr. Martin McClinton, (*.ppt) format (V. Good)

http://rst.gsfc.nasa.gov/ DR. NICHOLAS M. SHORT, Sr

Checking and modification required.
Remote Sensing Organizations

- **ISPRS** - International Society for Photogrammetry and Remote Sensing
- **IGARSS** - International Geosciences And Remote Sensing Symposium
- **NASA** - National Aeronautic and Space Administration (USA)
- **ESA** - European Space Agency (Europe)
- **NASDA** - National Space Development Agency (Japan)
- **CNES** - Centre National d'Etudes Spatiales (France)
- **DARA** - German Space Agency
- **CSA** - Canadian Space Agency
- **NRSA** - National Remote Sensing Agency of India
Reference

- B. Tso and P.M. Mather, Classification Methods for Remotely Sensed Data, 2001
• C. M. Bishop, Pattern Recognition and Machine Learning, 2007.
Thanks!