REMOTE SENSING PRINCIPLES AND IMAGE PROCESSING

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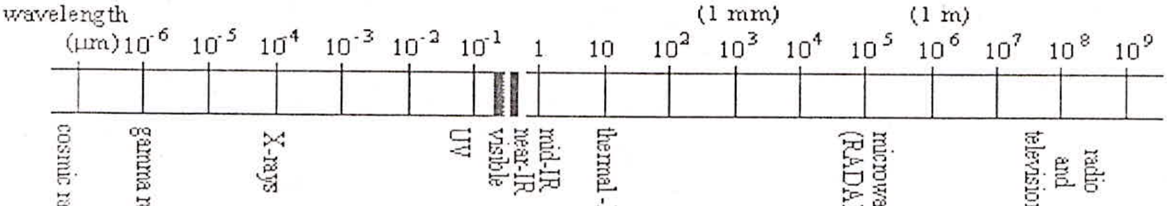
1.0 Introduction

Remote sensing, encompassing the study of satellite data, is a powerful technique for exploration, mapping and management of the earth resources. It is understood to imply the acquisition of information about an object by scientific devices called sensors without being any physical contact between the object and the sensing device.

The basic principle involved in remote sensing is that each object, depending upon its physical characters, reflects, emits and absorbs varying intensities of radiation at different EM wavelength ranges. Using information from one or more wavelength ranges, it is possible to discriminate between different types of ground objects (e.g. water, dry soil, wet soil, vegetation, rocks etc.) and map their distribution on the ground. One of the important remote sensing technique use is aerial photography. Aerial photography has essentially remained to the visible part of the electromagnetic spectrum where it is only a very small fraction of the electromagnetic spectrum. Remote sensing techniques have extended the scope of utilisation of the electromagnetic spectrum to almost its entire range.

The Electromagnetic Spectrum

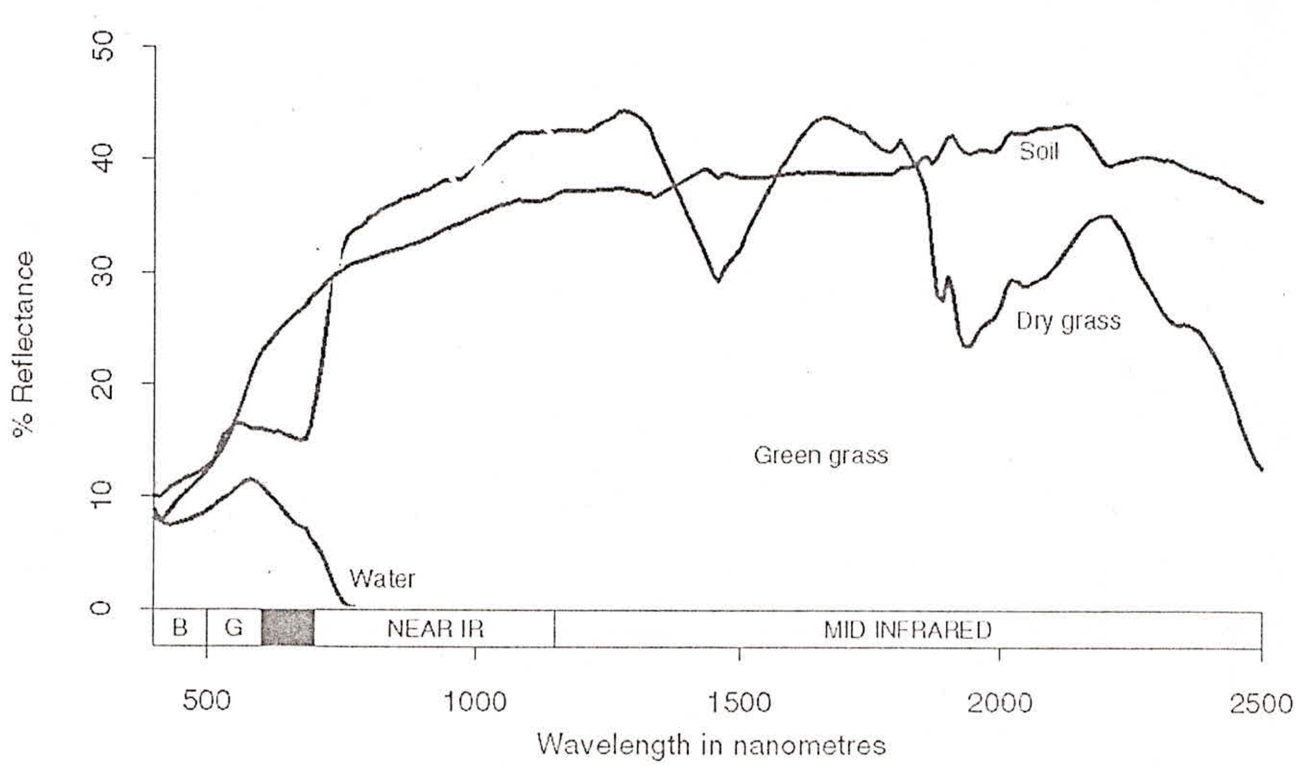


The electromagnetic radiation (EM) is the source of all signals collected by most remote sensing instruments. The source of this energy varies depending on the sensor characteristics. Most systems rely on the sun to generate all the EM energy needed to image terrestrial surfaces. These systems are called *passive sensors*. Other sensors generate their own energy, called *active sensors*, transmits that energy in a certain direction and records the portion reflected back by features within the signal path.

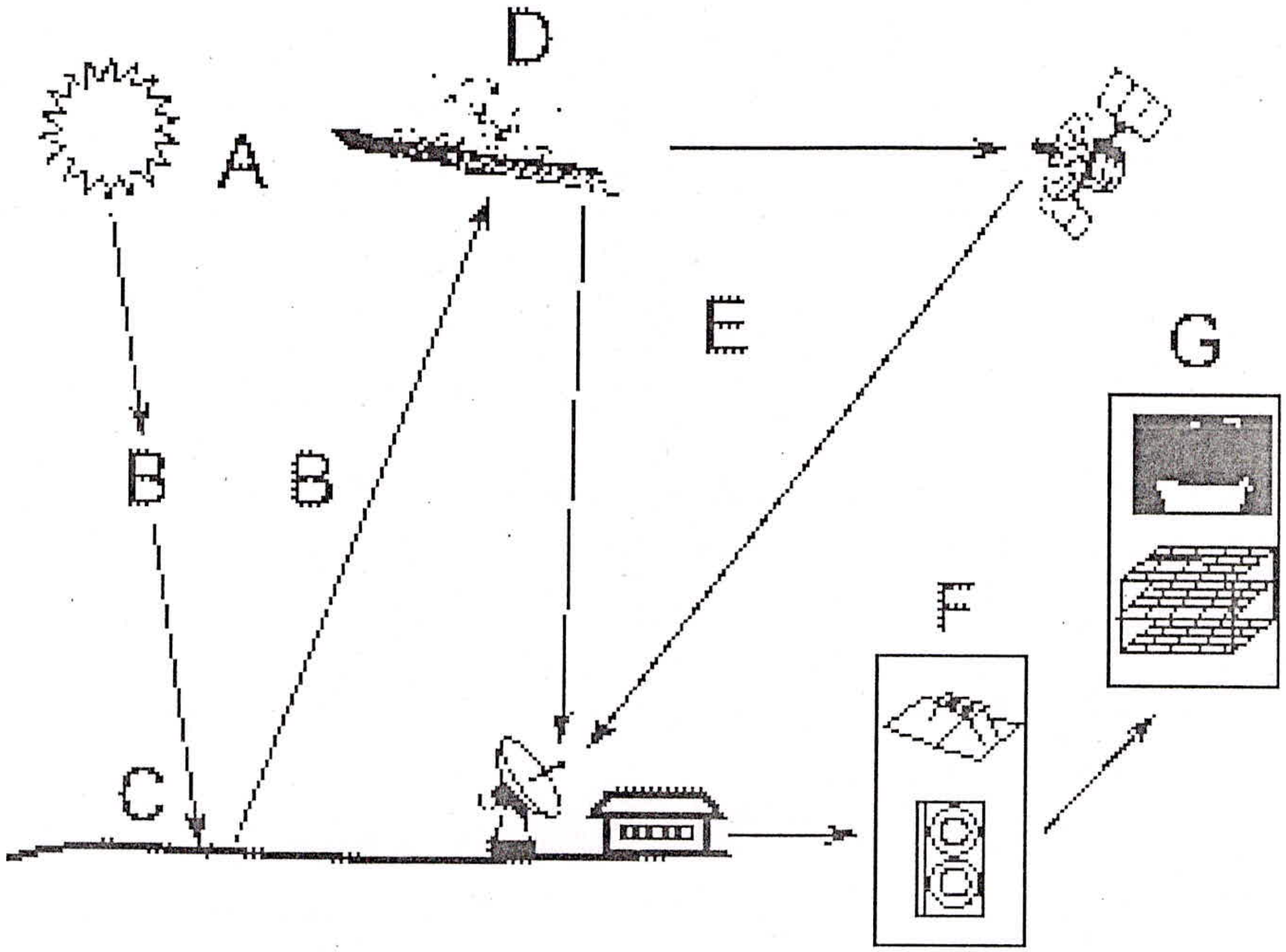
Electromagnetic energy can be generated by changes in the energy levels of electrons, acceleration of electrical charges, decay of radioactive substances, and the thermal motion of atoms and molecules. Nuclear reactions within the sun produce a full spectrum of EM radiation which is transmitted through space without major changes in its character until it reaches the atmosphere.

2.0 Reflectance Characteristics of Different Objects

Reflectance is the percentage of energy reflected to the total energy incident on a body. It is the ratio between radiation off the surface (outgoing) to the total radiation incident on the surface (incoming). We see an object green because only green energy is reflected in the visible spectrum. Thus, blue coloured objects throw blue only or red coloured objects throw red only which is perceived by the eye. 'Blue', 'Green', and 'Red' are the three fundamental colours. Pure black or pure white are not a colour at all. Other colours such as magenta, violet, yellow, cyan etc. are the mixing of three basic colours RBG in different proportions. Reflectance characteristics of some of the feature are shown in figure below.



- **Basic components in remote sensing data collection**



- Energy Source or Illumination (A) - fundamental requirement for remote sensing system

- Radiation and the Atmosphere (B) - energy will come in contact with and interact with the atmosphere it passes through - may take place a second time as the energy travels from the target to the sensor.

- Interaction with the Target (C) - once the energy makes its way to the target through the atmosphere, it interacts with the target in a manner depending on the properties of both the target and the radiation.

- Recording of Energy by the Sensor (D) - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

- Transmission, Reception, and Processing (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hard copy and/or digital).

- Interpretation and Analysis.(F) - the processed image is interpreted, visually and/or digitally, to extract information about the target

- Application (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

The four resolutions of remotely sensed data

- spectral resolution - the number and dimension of specific wavelength intervals in the EM spectrum to which a sensor is sensitive

- spatial resolution - measurement of the smallest angular or linear separation between two objects that can be resolved also refers to pixel size as it relates to ground distance (IFOV)

- radiometric resolution - quantization level, sensitivity of a sensor to differences in signal strength (e.g., number of bits, integer or floating point)

- temporal resolution - how often the sensor records imagery of a particular area

Advantages of Remote Sensing

- broader perspective
- larger area
- birds eye view
- "see" beyond visible EM energy
- accessibility

Remote Sensing vs. *in situ* data collection

- digital imagery = data
- data are used in the scientific method to test hypothesis and develop models
- data - information - knowledge
- *in situ* data - personnel in the field or instrumentation in contact with object (e.g., thermometer, seismograph)
- remotely sensed data - sensor is not in direct contact
- usually collecting some form of EM energy (other force fields - sound, and ?)
- a high speed communications link between the sensor and the object or phenomenon being sensed (warp speed!)
- interaction of energy with object can reveal tremendous amount of data/information/knowledge, e.g.:
    - what is it?
    - where is it at?
    - what is it's temperature?

   - what are some of its physical characteristics?
   - what are the spatial relationships with the surrounding phenomena?
   - much more ...

- Unique Aspect of Remote Sensing Technology
   - can be used to collect data as well as create information - knowledge
   - compared to GIS, statistics, rely on data already collected

- Ubiquity of Remote Sensing
  - most natural and some cultural phenomena at or near the earth surface can be remotely sensed
    - hydrosphere, biosphere, lithosphere, atmosphere, cryosphere
    - human environments

3.0 Image Interpretation

The main objective of image interpretation i.e. to extract information about features displayed in an image. It is defined as the act of examining images for the purpose of identifying objects and finding their significance. The extraction of information depends on image analyst's experience, power of observation, imagination and patience. It also depends on his understanding of the basic principles of an image.

4.0 Visual Interpretation

It is a traditional method for extracting information on various natural resources. There are certain fundamental photo elements or image characteristics seen on the image which aid in the visual interpretation of satellite imagery. Tone/colour; texture, shadow, shape, size, location and season etc. and their association are some of the basic image characteristics on which visual interpretation is based. Some of the shortcomings of the visual interpretation are:

- it is difficult to get consistent result from different interpreters
- it is difficult to achieve precise registration of multi-band and temporal images

- human can only detect the difference between 8-16 different shades of gray however the range of gray values recorded on the film is limited. Thus nowadays we go for digital image processing.

5.0 Digital Image Processing

Any pictorial image can also be represented in digital form, so that the patterns of image brightness forms an array of numeric values which can be conveniently added, subtracted, multiplied, divided, and in general subjected to statistical manipulations that are difficult or impossible, if the image is available in pictorial form. Digital analysis encompasses a broad set of operations by which remotely sensed data are subjected to operations that yield information or enhanced data. It must be remembered that digital analyst is not totally free from human interactions. It requires significant inputs from the analyst while making decisions, thus providing information at faster rate, with high quality output, when compared with manual interpretations.

Image processing systems require various input/output devices, central processing unit (CPU), data storage devices and system consoles for man-machine interaction. Adequate image display facilities are important in the processing of an image.

The image processing software required in remote sensing applications can be broadly, grouped such as Data input routines, Pre-processing routines, Image display routines, Image enhancement and filtering routines, Classification routines, Image output routines.

An idealized sequence for digital analysis can be broken up into four specific groups;

(a) Pre-processing

(b) Enhancement,

(c) Analysis and Classification, and

(d) Data Presentation.

Preprocessing

Pre-processing operations prepare satellite data for subsequent analysis, usually by attempts to correct or compensate for systematic errors. The pre-processing operations display the data as a means of inspecting characteristics and quality, present histograms, scattergrams or statistical summaries that permit the operator to assess image quality and thereby determine subsequent preprocessing steps (if any) that may be necessary. In addition, they compensate for radiometric and geometric errors.

Enhancement

Image enhancement is the modification of an image to alter its impact on the viewer. Therefore, enhancement operations are normally performed on image data prior to visual interpretation efforts. They increase the apparent contrast between the features in the scene and thus improve its interpretability.

Most of the individual scenes consequently make use of only a small portion of the full dynamic range. To produce an image with the optimum contrast, it is important to utilize the full brightness range of the display medium. If the range of image values are uniformly expanded to occupy the total range of the display device, then this process is referred to as linear stretch.

Analysis & Classification

One of the most often used methods of information extraction is multispectral classification. The process of multispectral classification may be performed using either of the two methods: supervised or unsupervised method.

In a supervised classification, the identity and location of some of the landcover types, such as urban, agriculture, wetland, and forest, are known a priori through a combination of field work, analysis of aerial photography, maps, and personal experience. The analyst attempts to locate specific sites in the remotely sensed data that represent homogeneous examples of these known land-cover types. These areas commonly referred to as training sites because the spectral characteristics of these known areas are used to "train" the classification algorithm for land cover mapping of the remainder of the image. Every pixel both within and outside these training sites is then evaluated and assigned to the class of which it has the highest likelihood of being a member.

In an unsupervised classification, the identities of land cover types to be specified as classes within a scene are generally not known a priori because either the ground truth data are not available or surface features within the scene are not well defined. The computer is required to group (cluster) pixel data into different spectral classes, according to some statistically determined criteria, and it is then the responsibility of the analyst to label these clusters into various classes.

Advantages of digital image processing

- Cost-effective for large geographic areas
- Cost-effective for repetitive interpretations
- Cost-effective for standard image formats
- Consistent results
- Simultaneous interpretations of several channels
- Complex interpretation algorithms possible
- Speed may be an advantage
- Explore alternatives
- Compatible with other digital data

Disadvantages of digital processing:

- Expensive for small areas
- Expensive for one-time interpretations
- Start-up costs may be high
- Requires elaborate, single-purpose equipment
- Accuracy may be difficult to evaluate
- Requires standard image formats
- Data may be expensive, or not available

- Preprocessing may be required
- May require large support staff

6.0 Remote Sensing Satellite Programs

LANDSAT Programme: Till date, the Landsat programme has provided the most extensively used remote sensing data, the world over. Its chief plank has been in delivering unrestricted global data of good geometric accuracy. Under the Landsat programme till date six satellites (Landsat - 1,2,3,4,5 & 6) have been launched (Landsat-6 having failed). These satellites have been placed in near-polar, near-circular, sun-synchronous orbit. In this configuration, as the satellite orbits in the north-south plane, the Earth below spins around its axis, from west to east. Thus, different parts of the globe are 'seen' by the satellite during different north-south passes. The remote sensing data are acquired in the descending node, i.e. as the satellite moves from the north pole to south pole. The L - 1,2,3 were placed at an altitude of 918 km with a repeat cycle of 18 days, and L-4,5 at an altitude of 705 km with a repeat cycle of 16 days.

The Landsat have carried on-board two main sensors, Multispectral Scanning System (MSS) and Thematic Mapper (TM), both being OM-line scanners and producing ground scenes of nominally 185*185 km size. The MSS sensor has been a regular payload of the Landsat and has made this programme a tremendous success. The TM is an advanced multispectral scanner used in Landsat 4 & 5 missions. TM operates in seven wavelength bands, out of which six are in the solar reflection region and one in thermal-IR region.

SPOT Programme: The French satellite system SPOT is a typical second generation earth resources satellite. These satellites have been placed in near-polar sun-synchronous 830 km high orbit with a repeat cycle of 26 days. The sensor here is called HRV (High Resolution Visible) which is a CCD-line scanner. The HRV's acquire data in two interesting modes: (a) panchromatic mode in a swath of 60 km with ground resolution of 10*10 m and (b) multispectral mode, in three channels (green, red and infrared) with a ground resolution of 20*20 m in a swath width of 60 km. Further, the HRV's can be tilted to acquire data in off-nadir viewing mode, for more frequent repetitive coverage, and for stereoscopy.

Indian Space Programme

Remote sensing is an important part of the Indian Space Programme and the Department of Space (DOS), Government of India is the realization of the National Natural Resources Management System (NNRMS), The National Resources Information System (NRIS) and the Integrated Mission for Sustainable Development (IMSD) and they together exploit space technology for applications in the areas of communication, broadcasting, meteorology, disaster warning search and rescue operations and remote sensing.

Space Mission Objectives

Continues space based remote sensing services to user community.

For operating systems for data reception, recording, processing generation of data products.

Develop new areas of user applications to take full advantage of enhanced capabilities of new versions of IRS series like - IRS-1C/1D.

Remote Sensing Satellite Missions

Under the Indian Remote Sensing Satellite (IRS) programme, the Indian Space Research Organisation (ISRO) has launched a series of land observation satellites, named as: Bhaskara 1 and 2

Experimental Remote Sensing Satellites launched on June 1979 and November 1981 respectively.

IRS-1A and IRS-1B

These were the operational first generation remote sensing satellites.

- Launched on March 1988 and August 1991,
- Altitude of 904 km,
- Placed in near-polar, sun-synchronous orbit,
- Ground Resolution of 72.5 mt and 36.25 mt respectively,
- Repetitive Time of 22 days,
- Life of 3 years, (IRS-1B still working) and

Sensors with two linear Imaging Scanning Sensors (LISS-I and LISS-II) for providing data in four spectral bands: Visible, Infra Red (IR) and Near Infra Red (NIR).

IRS-P2

The satellite was launched in October 1994, on the indigenously developed Polar Satellite Launch Vehicle (PSLV-D2). It carried a modified LISS camera.

IRS-1C and IRS-1D

These were the first of the second generation, operational, multi-sensor satellite missions with better resolution.

- Launched on 1995 and 29 September 1997 from Sriharikota,
- Altitude of 817 km and 780 km,
- Placed in near-polar, sun-synchronous orbit, whereas there have been some problems with the orbit of IRS-1D,
- Resolution of 5.2-5.8 mt and 188 mt respectively.
- Repetitive time of 22 days,
- Life of 3 years,
- Sensors with Panochromatic (PAN) and LISS-III cameras.

IRS-P3

Launched on April 1996 on PSLV-D3, had two imaging sensing sensors and one non-imaging sensors i.e. WiFs, with a resolution of 188 mt and swath of 810 km.

Future IRS Satellite Missions

Keeping in view the rapid developments taking place in space technology and increasing application of remote sensing and GIS techniques Indian Space Research Organisation has planned a number of future satellite IRS missions :

- IRS-P4 (OCEANSAT-1), has recently been launched.
- IRS-P5 (CARTOSAT-1)
- IRS-P6 (to be launched by 2000 by PSLV).

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