Remote Sensing - An Overview

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INTRODUCTION

Remote sensing is the use of instruments such as cameras, telescopes, radar and satellite imagery to capture the spectral and spatial properties of objects and materials observable from a distance. Remote sensing technology expands the capabilities of human sight by allowing us to see a multitude of physical and human features over vast areas of hundreds or even thousands of square miles or kilometers. Normally, this gives rise to some form of imagery which is further processed and interpreted to produce useful data for application in agriculture, archaeology, forestry, geography, geology, planning and other fields. Information about the object concerned is obtained by a sensor system located on a satellite or aircraft, which receives electromagnetic radiation which has been either emitted by the object or has interacted with the object. Here we will consider the latter case, in which the source of radiation is not the object.

BASIC COMPONENTS OF REMOTE SENSING

The overall process of remote sensing can be broken down into five components. These components are: 1) an energy source; 2) the interaction of this energy with particles in the atmosphere; 3) subsequent interaction with the ground target; 4) energy recorded by a sensor as data; and 5) data displayed digitally for visual and numerical interpretation. Figure given below illustrates the basic elements of airborne and satellite remote sensing systems.

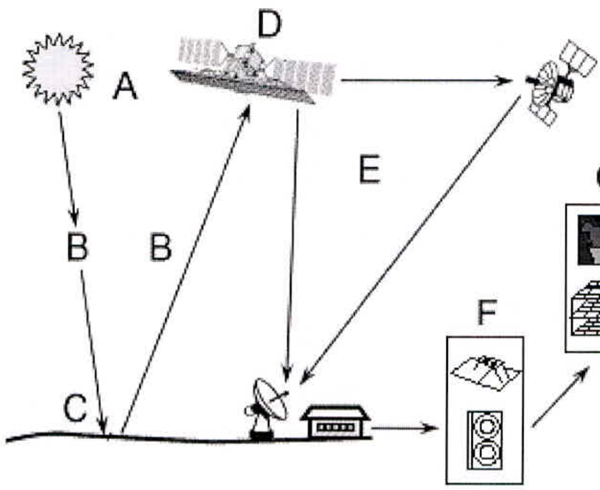

Fig.1 Basic elements of airborne and satellite remote sensing systems

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 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*, transmit 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. Table 1 lists some representative applications for different spectral bands available from existing satellites.

REFLECTANCE CHARACTERISTICS OF DIFFERENT OBJECTS

Spectral Reflectance Curves.

A surface feature's color can be characterized by the *percentage* of incoming electromagnetic energy (illumination) it reflects at each wavelength across the electromagnetic spectrum. This is its spectral reflectance curve or "spectral signature"; it is an unchanging property of the material. For example, an object such as a leaf may reflect 3% of incoming blue light, 10% of green light and 3% of red light. The amount of light it reflects depends on the amount and wavelength of incoming illumination, but the percents are constant. Unfortunately, remote sensing instruments do not record reflectance directly, rather radiance, which is the *amount* (not the percent) of electromagnetic energy received in selected wavelength bands. A change in illumination, more or less intense sun for instance, will change the radiance. Spectral signatures are often represented as plots or graphs, with wavelength on the horizontal axis, and the reflectance on the vertical axis

***Important Reflectance Curves and Critical Spectral Regions*:** While there are too many surface types to memorize all their spectral signatures, it is helpful to be familiar with the basic spectral characteristics of green vegetation, soil, and water. This in turn helps determine which regions of the spectrum are most important for distinguishing these surface types.

Spectral Reflectance of Water. Spectral reflectance of clear water is low in all portions of the spectrum. Reflectance increases in the visible portion when materials are suspended in the water. Water absorption is a phenomenon in the transmission of electromagnetic radiation through a medium containing water molecules. Water molecules are excited by radiation at certain wavelengths and tend to selectively absorb portions of the spectrum while allowing the balance of the spectrum to be transmitted with minimal effect.

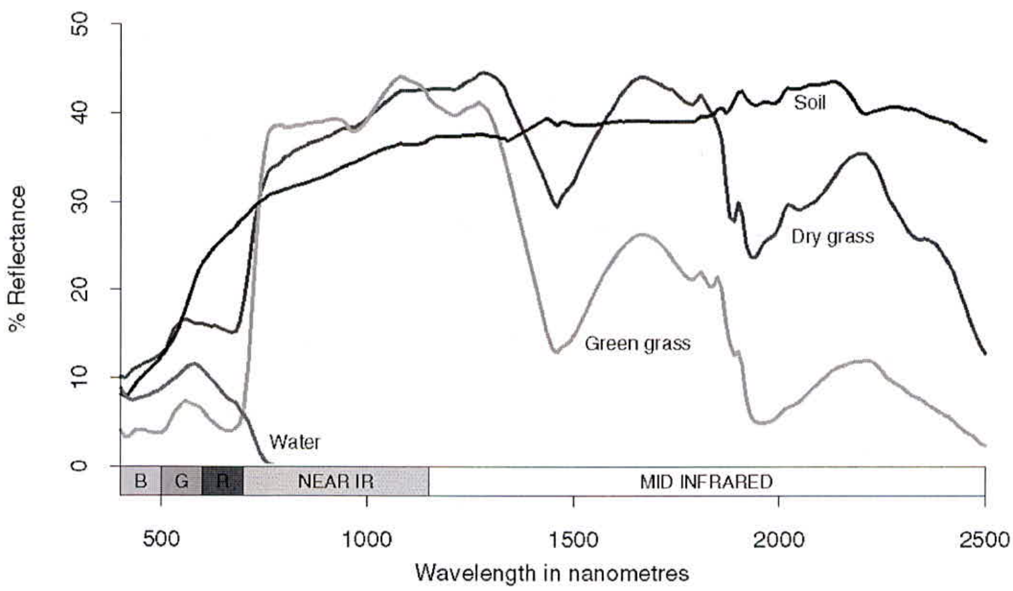

Fig. 2 Spectral reflectance curve

Strong water vapor absorption bands occur at wavelengths around 2500, 1950 and 1450 nanometers (nm), with weaker absorption around 1200 and 970 nm, and three additional sets of water-vapor absorption lines near 930, 820, and 730 nm, all in the infrared spectrum. Water has a complex absorption spectrum — the 2007 HITRAN spectroscopy database update lists more than 64,000 spectral lines corresponding to significant transitions of water vapor ranging from the microwave region to the visible spectrum

RESOLUTIONS

The four resolutions of remotely sensed data

Spectral Resolution

This is the number and dimension of specific wavelength intervals in the EM spectrum to which a sensor is sensitive. There are many possible bands that can be used by a remote sensing system. Some are ideal for one set of applications, while others are good for a different set.

Spatial Resolution

The resolution of an image can be described as the closest that two objects can be together and still be reliably distinguished. The spatial resolution of images acquired by satellite sensor systems is usually expressed in meters. A 30-meter resolution means that two objects, 30 meters long or wide sitting side by side can be separated on the image. High resolution allows distinguishing relatively small objects or those that are closely spaced. In imagery taken at 3-meter resolution, for example, cars can be distinguished from trucks, while in imagery taken at 10-meter resolution neither cars nor trucks can be identified. High spatial resolution implies imaging a small area. For an image of 1000 Pixels Square, at 20m resolution the area viewed is 20x20km, but at 1km resolution this increases to 1000x1000km (actually rather more, due to the variation in viewing angle over a large area). The latter is therefore suitable for large-scale studies.

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

REMOTE SENSING PLATFORMS

Platform is a stage to mount the camera or sensor to acquire the information about a target under investigation. Based on its altitude above earth surface, platforms may be classified as:

- Ground borne
- Air borne
- Space borne

Ground based platforms

The ground based remote sensing systems for earth resources studies are mainly used for collecting the ground truth or for laboratory simulation studies.

Air borne platforms

Aircrafts are generally used to acquire aerial photographs for photo-interpretation and photogrammetric purposes. Scanners are tested against their utility and performance from these platforms before these are flown onboard satellite missions.

Space-borne platforms

Platforms in space are not affected by the earth's atmosphere. These platforms are freely moving in their orbits around the earth, and entire earth or any part of the earth can be covered at specified intervals. The coverage mainly depends on the orbit of the satellite. It is through these space borne platforms, we get the enormous amount of remote sensing data and as such the remote sensing has gained international popularity.

Depending on their altitudes and orbit these platforms may be divided in two categories:

- Geostationary
- Polar orbiting or Sun-synchronous

Geostationary satellites

An equatorial west to east satellite orbiting the earth at an altitude of 35000 km. The altitude at which it makes one revolution in 24 hours, synchronous with earth's rotation. These platforms are covering the same place and give continuous near hemispheric coverage over the same area day and night. Its coverage is limited to 70 N to 70 Latitudes and one satellite can view one third of the globe. These are mainly used for communication and meteorological applications viz GEOS, METOSAT, INTELSAT and INSAT satellites.

Sun-Synchronous satellites

An earth satellite orbit in which the orbital plane is near polar and the altitude is such that the satellite passes over all places on earth having the same latitude twice in each orbit at the same local sun-time.

Through these satellites the entire globe is covered on regular basis and gives repetitive coverage on periodic basis. All the remote sensing resources satellites may be grouped in this category. Few of these satellites are Landsat series, SPOT series, IRS series, NOAA, SEASAT, and TIROS etc.

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

Till date ISRO has launched eleven Indian Remote Sensing Satellites (IRS) starting with IRS-1A in March 1988 to IRS P-5 (CARTOSAT-1) launched in May 2005. In the area of Satellite based remote sensing in the past, the first generation satellite IRS-1A and 1B were designed, developed and launched successfully during 1988 and 1991 with multi-spectral cameras with spatial resolution of 72.5 m and 36 m. respectively. Subsequently, the second generation remote sensing satellites IRS-1C and 1D with improved spatial resolutions of 70 m in multi-spectral and 5.8 m. in Panchromatic bands and a wide field sensor with 188m resolution and 800 Km. swath, have been developed and successfully launched in 1995 and 1997 respectively. In this series recently in May 2005 CARTOSAT-1 was launched. These satellites and sensors have been described briefly in the following section.

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 Panchromatic (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.

IRS- P4

Most of the existing missions cater to land applications. IRS-P4 satellite, which is also called as Oceansat, will primarily cater to oceanographic applications. The indigenous Polar Satellite Launch Vehicle (PSLV) launched this satellite on 26th May, 1999, into polar Sun-synchronous orbit at an altitude of 720 km. The satellite has a high receptivity of 2 days. The payload includes an Ocean Colour Monitor (OCM), a Multi frequency Scanning Microwave Radiometer (MSMR) and solid state memory for recording data outside the visibility of a ground station.

IRS- P6 (RESOURCESAT-1)

IRS-P6 (RESOURCESAT-1) is launched in to the polar sun synchronous orbit on October 17, 2003. It is a state-of-art satellite mainly for agriculture applications and have a 3-band multispectral LISS-IV camera with a spatial resolution better than 6 m and a swath of around 25 km with across track steerability for selected area monitoring. An improved version of LISS-III with four bands (red, green, near IR and SWIR), all at 23 m resolution and 140 km swath will provide the essential continuity to LISS-III. Together with an advanced Wide Field Sensor (WiFS) with 80 m resolution and 1400 km swath, the payloads will greatly aid crop/vegetation and integrated land and water resources related applications.

IRS-P5 (CARTOSAT-1/2)

This satellite was launched on May 05, 2005. It has an improved sensor system that provides 2.5 m resolution with fore-aft stereo capability. This mission caters to the needs of cartographers and terrain modelling applications. The satellite will provide cadastral level information up to 1:5000 scales and will be useful for making 2.5 m contour maps. IRS Cartosat-2 has been successfully launched in January 10, 2007 by the PSLV-C7 from Satish Dhawan Space Centre, Sriharikota. The spatial resolution of the satellite is less than 1 m. The swath width is 9.6 km and radiometric resolution is10 bit.

Radar Remote Sensing

RADAR stands for "Radio Detection And Ranging". By virtue of sending out pulses of microwave electromagnetic radiation this type of instrument can be classified as an "active sensor" - it measures the time between pulses and their reflected components to determine distance. Different pulse intervals, different wavelengths, different geometry and polarizations can be combined to roughness characteristics of the earth surface. Radar uses relative long wavelengths which allow these systems to "see" through clouds, smoke, and some vegetation. Also, being an active system, it can be operated day or night. There are disadvantages, such as the non-unique spectral properties of the returned radar signal. Unlike infrared data that help us to identify different minerals or vegetation types from reflected sunlight, radar only shows the difference in the surface roughness and geometry and moisture content of the ground (the complex dielectric constant). Radar and infrared sensors are complimentary instruments and are often used together to study the same types of earth surfaces.

TYPES OF IMAGING RADAR

SLAR (Side-Looking Airborne Radar) :develop by guess who in the 1950's

- airborne, fixed antenna width, sends one pulse at a time and measures what gets scattered back

- resolution determined by wavelength and antenna size (narrow antenna width = higher resolution)

SAR (Synthetic Aperture Radar)

- also developed by those responsible for SLAR, but this configuration is not dependent on the physical antenna size although to achieve higher resolution the receiving antenna components and transmitter components need to be separated.

- "synthesizes" a very broad antenna by sending multiple pulses

Radar resolution has two components; the "range" resolution and the "azimuth" resolution. These are determined by, among other factors, the width of the synthesized antenna (which is dictated by the pulse interval) and the wavelength.

INTERPRETATION OF REMOTE SENSING DATA

The main objective of image interpretation is 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. The synoptic view provided by satellite images is of great importance in water resources in detecting large features and understanding their inter-relationships.

Digital Data

In a most generalized way, a digital image is an array of numbers depicting spatial distribution of a certain field parameters (such as reflectivity of EM radiation, emissivity, temperature or some geophysical or topographical elevation. Digital image consists of discrete picture elements called pixels. Associated with each pixel is a number represented as DN (Digital Number) that depicts the average radiance of relatively small area within a scene. The range of DN values being normally 0 to 255. The size of this area effects the reproduction of details within the scene. As the pixel size is reduced more scene detail is preserved in digital representation.

Remote sensing images are recorded in digital forms and then processed by the computers to produce images for interpretation purposes. Images are available in two forms - photographic film form and digital form. Variations in the scene characteristics are represented as variations in brightness on photographic films. A particular part of scene reflecting more energy will appear bright while a different part of the same scene that reflecting less energy will appear black. Digital image consists of discrete picture elements called pixels. Associated with each pixel is a number represented as DN (Digital Number), that depicts the average radiance of relatively small area within a scene. The size of this area effects the reproduction of details within the scene. As the pixel size is reduced more scene detail is preserved in digital representation.

Data Formats for Digital Satellite Imagery

Digital data from the various satellite systems supplied to the user in the form of computer readable tapes or CD-ROM. As no worldwide standards for the storage and transfer of remotely sensed data has been agreed upon, though the CEOS (Committee on Earth Observation Satellites) format is becoming accepted as the standard. Digital remote sensing data are often organised using one of the three common formats used to organise image data . For an instance an image consisting of four spectral channels, which can be visualised as four superimposed images, with corresponding pixels in one band registering exactly to those in the other bands. These common formats are:

- Band Interleaved by Pixel (BIP)
- Band Interleaved by Line (BIL)
- Band Sequential (BQ)

Digital image analysis is usually conducted using Raster data structures - each image is treated as an array of values. It offers advantages for manipulation of pixel values by image processing system, as it is easy to find and locate pixels and their values. Disadvantages becomes apparent when one needs to represent the array of pixels as discrete patches or regions, where as

Vector data structures uses polygonal patches and their boundaries as fundamental units for analysis and manipulation. Vector format is not appropriate for digital analysis of remotely sensed data.

Analysis of remotely sensed data is done using various image processing techniques and methods that includes:

- Analog image processing
- Digital image processing.

Visual or **Analog processing** techniques is applied to hard copy data such as photographs or printouts. Image analysis in visual techniques adopts certain elements of interpretation, which are as follow:

The use of these fundamental elements of depends not only on the area being studied, but the knowledge of the analyst has of the study area. For example the texture of an object is also very useful in distinguishing objects that may appear the same if the judging solely on tone i.e., water and tree canopy, may have the same mean brightness values, but their texture is much different. Association is a very powerful image analysis tool when coupled with the general knowledge of the site. Thus we are adept at applying collateral data and personal knowledge to the task of image processing. With the combination of multi-concept of examining remotely sensed data in multi spectral, multi temporal, multi scales and in conjunction with multidisciplinary, allows us to make a verdict not only as to what an object is but also its importance. Apart from this analog image processing techniques also includes optical photogrammetric techniques allowing for precise measurement of the height, width, location, etc. of an object.

Elements of Image Interpretation

	Black and White Tone
Primary Elements	Color
	Stereoscopic Parallax
	Size
Spatial Arrangement of	Shape
Tone & Color	Texture
	Pattern
Based on Analysis of	Height
Primary Elements	Shadow
Contextual Elements	Site

DIGITAL IMAGE PROCESSING

Image processing in the context of remote sensing refers to the management of digital images, usually satellite or digital aerial photographs. Image processing includes the display, analysis, and manipulation of digital image computer files. The derived product is typically an enhanced image or a map with accompanying statistics and metadata. Digital Image Processing is a collection of techniques for the manipulation of digital images by computers. The raw data received from the imaging sensors on the satellite platforms contains flaws and deficiencies. To overcome these flaws and deficiencies inorder to get the originality of the data, it needs to undergo several steps of processing. This will vary from image to image depending on the type of image format, initial condition of the image and the information of interest and the composition of the image scene.

Digital Image Processing undergoes three general steps:

- Pre-processing
- Display and enhancement
- Information extraction

The important digital image processing functions required to analyse remotely sensed data for hydrology and water resources management applications are summarized in Table 2. Image classification is discussed in more detail in the following sections.

Image Classification

Raw digital data can be sorted and categorized into thematic maps. Thematic maps allow the analyst to simplify the image view by assigning pixels into classes with similar spectral values. The process of categorizing pixels into broader groups is known as image classification. The advantage of classification is it allows for cost-effective mapping of the spatial distribution of similar objects (i.e., tree types in forest scenes); a subsequent statistical analysis can then follow. Thematic maps are developed by two types of classifications, supervised and unsupervised. Both types of classification rely on two primary methods, training and classifying. Training is the designation of representative pixels that define the spectral signature of the object class. Training site or training class is the term given to a group of training pixels. Classifying procedures use the training class to classify the remaining pixels in the image.

Supervised Classification. Supervised classification requires some knowledge about the scene, such as specific vegetative species. Ground truth (field data), or data from aerial photographs or maps can all be used to identify objects in the scene.

Firstly, acquire satellite data and accompanying metadata. Look for information regarding platform, projection, resolution, coverage, and, importantly, meteorological conditions before and during data acquisition. Secondly, chose the surface types to be mapped. Collect ground truth data with positional accuracy (GPS). These data are used to develop the training classes for the discriminant analysis. Ideally, it is best to time the ground truth data collection to coincide with the satellite passing overhead. Thirdly, begin the classification by performing image post-processing techniques (corrections, image mosaics, and enhancements). Select pixels in the image that are representative (and homogeneous) of the object. If GPS field data were collected, geo-register the GPS field plots onto the imagery and define the image training sites by outlining the GPS polygons. A training class contains the sum of points (pixels) or polygons (clusters of pixels).

View the spectral histogram to inspect the homogeneity of the training classes for each spectral band. Assign a color to represent each class and save the training site as a separate file.

Classification Algorithms. Image pixels are extracted into the designated classes by a computed discriminant analysis. The three types of discriminant analysis algorithms are: minimum mean distance, maximum likelihood, and parallelepiped. All use brightness plots to establish the relationship between individual pixels and the training class (or training site).

Minimum Mean Distance Minimum distance to the mean is a simple computation that classifies pixels based on their distance from the mean of the training class. It is determined by plotting the pixel brightness and calculating its Euclidean distance (using the Pythagorean Theorem) to the unassigned pixel. Pixels are assigned to the training class for which it has a minimum distance. The user designates a minimum distance threshold for an acceptable distance; pixels with distance values above the designated threshold will be classified as unknown.

Parallelepiped In a parallelepiped computation, unassigned pixels are grouped into a class when their brightness values fall within a range of the training mean. An acceptable digital number range is established by setting the maximum and minimum class range to plus and minus the standard deviation from the training mean. The pixel brightness value simply needs to fall within the class range, and is not based on its Euclidean distance. It is possible for a pixel to have a brightness value close to a class and not fall within its acceptable range. Likewise, a pixel may be far from a class mean, but fall within the range and therefore be grouped with that class. This type of classification can create training site overlap, causing some pixels to be misclassified.

Maximum Likelihood Maximum Likelihood is computationally complex. It establishes the variance and covariance about the mean of the training classes. This algorithm then statistically calculates the probability of an unassigned pixel belonging to each class. The pixel is then assigned to the class for which it has the highest probability.

Unsupervised Classification. Unsupervised classification does not require prior knowledge. This type of classification relies on a computed algorithm that clusters pixels based on their inherent spectral similarities.

Steps Required for Unsupervised Classification,

The user designates 1) the number of classes, 2) the maximum number of iterations, 3) the maximum number of times a pixel can be moved from one cluster to another with each iteration, 4) the minimum distance from the mean, and 5) the maximum standard deviation allowable. The program will iterate and recalculate the cluster data until it reaches the iteration threshold designated by the user. Each cluster is chosen by the algorithm and will be evenly distributed across the spectral range maintained by the pixels in the scene. The resulting classification image will approximate that which would be produced with the use of a minimum mean distance classifier (see above, "classification algorithm"). When the iteration threshold has been reached the program may require you to rename and save the data clusters as a new file. The display will automatically assign a color to each class; it is possible to alter the color assignments to match an existing color scheme (i.e., blue = water, green = vegetation, red = urban) after the file has been saved.

Advantages of Using Unsupervised Classification

Unsupervised classification is useful for evaluating areas where you have little or no knowledge of the site. It can be used as an initial tool to assess the scene prior to a supervised classification. Unlike supervised classification, which requires the user to hand select the training sites, the unsupervised classification is unbiased in its geographical assessment of pixels.

Disadvantages of Using Unsupervised Classification

The lack of information about a scene can make the necessary algorithm decisions difficult. For instance, without knowledge of a scene, a user may have to experiment with the number of spectral clusters to assign. The unsupervised classification is not sensitive to covariation and variations in the spectral signature to objects. The algorithm may mistakenly separate pixels with slightly different spectral values and assign them to a unique cluster when they, in fact, represent a spectral continuum of a group of similar objects.

Table 1 Remote Sensing Applications for different Spectral bands

Spectral band m	Applications
Blue (0.45 -0.50) Green (0.50- 0.60) Red (0.60- 0.70	Water penetration, land use, vegetation characteristics, sediment Green reflectance of healthy vegetation Vegetation discrimination because of red chlorophyll absorption
Panchromatic (0.50 -0.75) Reflective Infrared (0.75 -0.90)	Mapping, land use, stereo pairs Biomass, crop identification, soil-crop, land-water boundaries
Mid-infrared (1.5 -.1.75) Mid-infrared (2.0- 2.35)	Plant turgidity, droughts, clouds, snow-ice discrimination Geology, rock formations
Thermal infrared (10 -12.5)	Relative temperature, thermal discharges, vegetation classification, moisture studies, thermal inertia
Microwave- Short wave (0.1- 5 cm)	Snow cover, depth, vegetation water content
Microwave-Long wave (5- 24 cm)	Melting snow, soil moisture, water-land boundaries, penetrate Vegetation .

Table 2 Image processing functions required to analyze remote sensor data for hydrology and water management applications.

Preprocessing

Radiometric correction of error introduced by the sensor system electronics and/or environmental effects (includes relative image-to-image normalization and absolute radiometric correction of atmospheric attenuation)

Geometric correction (image-to-map rectification or image-to-image registration)
Display and Enhancement
Black & white (8-bit)
Color-composite display (24-bit)
Black & white or color density slice
Magnification, reduction, roam
Contrast manipulation (linear, non-linear)
Color space transformations (e.g. ROB to IHS)
Image algebra (band ratioing, image differencing, etc.)
Linear combinations (e.g., Kauth transform)
Spatial filtering (e.g. high, low, band-pass)
Edge enhancement (e.g. Sobel, Robert's, Kirsch)
Principal components (e.g. standardized, unstandardized)
Texture transforms (e.g. min-max, texture spectrum, fractal dimension)

Frequency transformations (e.g. Fourier, Walsh)
Digital elevation models (e.g. analytical hill shading)
Animation e.g.movies of channel detection

Remote Sensing Information Extraction
Pixel brightness value
Univariate and multivariate statistical analysis (e.g. mean, covariance)
Feature (band) selection (graphical and statistical)
Supervised classification (e.g. minimum distance, maximum likelihood)
Unsupervised classification (e.g. ISODATA)
Contextual classification
Incorporation of ancillary data during classification
Expert system image analysis
Neural network image analysis
Fuzzy logic classification
Hyperspectral data analysis
Radar image processing
Accuracy assessment (descriptive and analytical)

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