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PRINCIPLES OF REMOTE SENSING AND IMAGE PRECIPITATION

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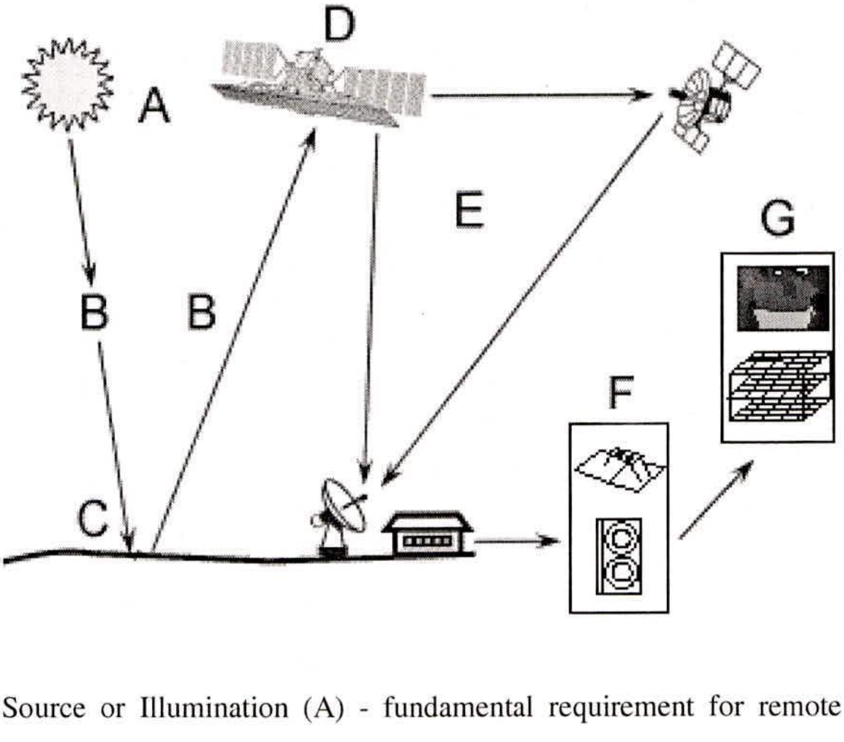
PRINCIPLES OF REMOTE SENSING AND IMAGE INTERPRETATION

Remote sensing is a technology used for obtaining information about a target through the analysis of data acquired from the target at a distance. It is composed of three parts, the targets - objects or phenomena in an area; the data acquisition - through certain instruments; and the data analysis - again by some devices. Remote sensing data acquisition can be conducted on such platforms as aircraft, satellites, balloons, rockets, space shuttles, etc. Inside or on-board these platforms, we use sensors to collect data. Sensors include aerial photographic cameras and non-photographic instruments, such as radiometers, electro-optical scanners, radar systems, etc.

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 1 illustrates the basic elements of airborne and satellite remote sensing systems.



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

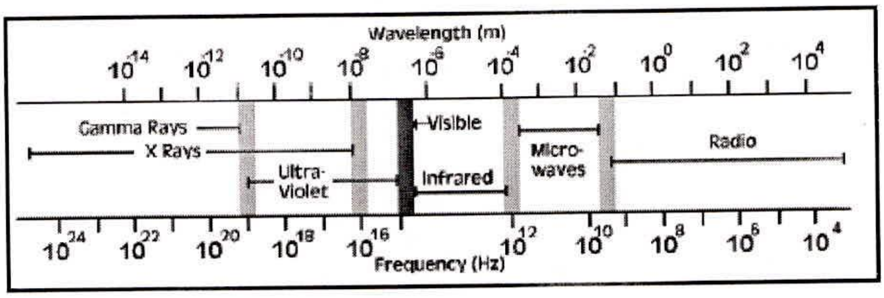
- Radiation and the Atmosphere (B) - energy will come in contact with and interact with the atmosphere it passes through - may take place a second time as the energy travels from the target to the sensor.
- Interaction with the Target (C) - once the energy makes its way to the target through the atmosphere,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

PHYSICAL PROPERTIES OF ELECTROMAGNETIC ENERGY

As was noted in the previous section, the first requirement for remote sensing is to have an energy source (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation. According to its wave properties, the electromagnetic energy is seen to travel through space as a wave at the velocity of light, i.e., 3x1010 cm/s. Wavelength is measured in meters (m) or in fractions of meters such as nanometers (nm, 10^{-9} meters), micrometers (μm 10^{-6} meters) or centimeters (cm, 10^{-2} meters). The electromagnetic spectrum, as shown in figure below, ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). There are several regions of the electromagnetic spectrum that are useful for remote sensing.

The ultraviolet (UV) portion of the spectrum has the shortest wavelengths that are practical for remote sensing. This radiation is just beyond the violet portion of the visible wavelengths. Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation.

The light, which our eyes can detect, is part of the visible spectrum. It is important to recognize how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us that is "invisible" to our eyes, but can be detected by other remote sensing instruments. The visible wavelengths cover a range from approximately 0.4 to 0.7 μm . The longest visible wavelength is red and the shortest is violet. Common wavelengths of what we perceive as particular colors from the visible portion of the spectrum are listed below. It is important to note that this is the only portion of the spectrum we can associate with the concept of colors.



- **Violet**: 0.4 - 0.446 µm
- **Blue**: 0.446 - 0.500 µm
- **Green**: 0.500 - 0.578 µm
- **Yellow**: 0.578 - 0.592 µm
- **Orange**: 0.592 - 0.620 µm
- **Red**: 0.620 - 0.7 µm

Blue, green, and red are the primary colors or wavelengths of the visible spectrum. They are defined as such because all other colors can be formed by combining blue, green, and red in various proportions. Sunlight is actually composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum.

The infrared (IR) region covers the wavelength range from approximately 0.7 mm to 100 mm. The infrared region can be divided into two categories based on their radiation properties - the reflected IR, and the emitted or thermal IR. Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion. The reflected IR covers wavelengths from approximately 0.7 µm to 3.0 µm . The thermal IR region is different from the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat. The thermal IR covers wavelengths from approximately 3.0 µm to 100 µm .

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.

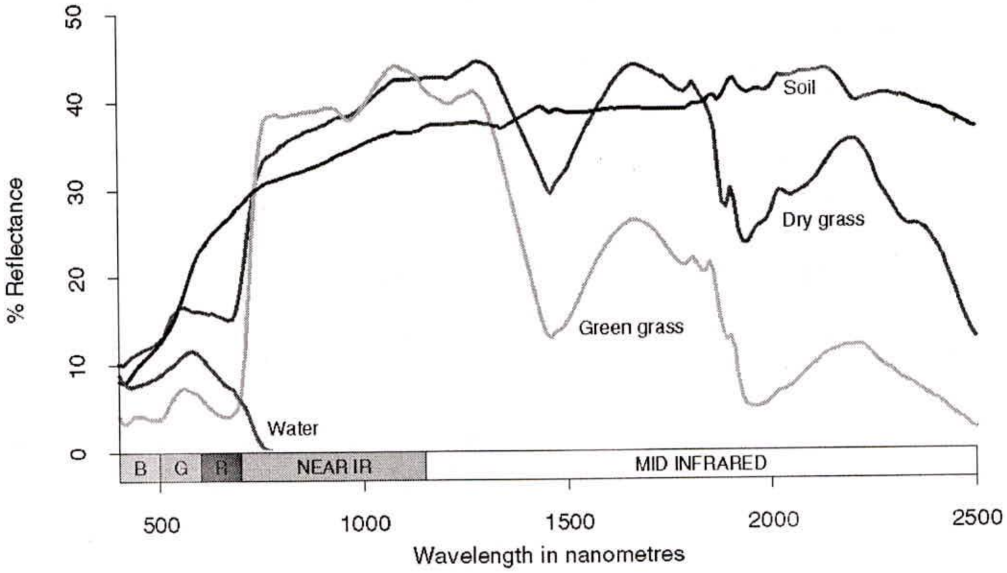
Strong water vapor absorption bands occur at wavelengths around 2500, 1950 and 1450 nanometers (nm), with weaker absorption around 1200 and 970 nm, and three additional sets of water-vapor absorption lines near 930, 820, and 730 nm, all in the infrared spectrum. Water has a complex absorption spectrum — 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, TIROS etc.

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.

IMAGE INTERPRETATION

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

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

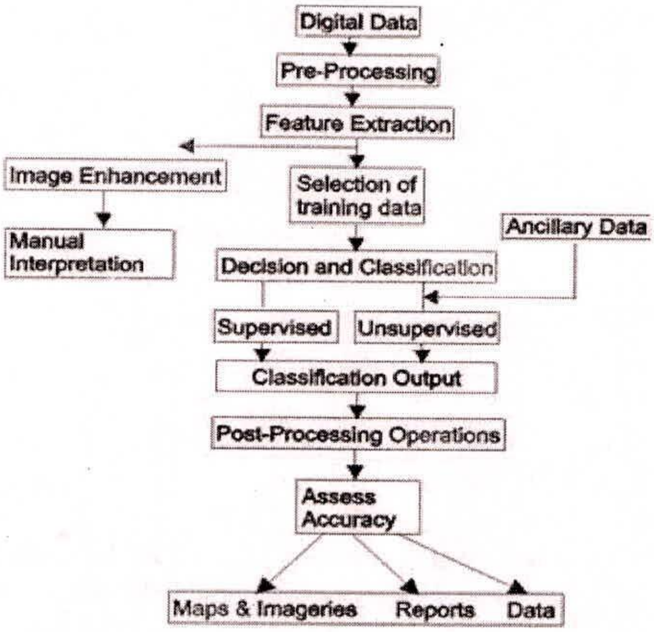
- Pre-processing
- Display and enhancement
- Information extraction

The important digital image processing functions required to analyse remotely sensed data for hydrology and water resources management applications are summarized in Table 2.

(A) Pre-processing of the Remotely Sensed Images

When remotely sensed data is received from the imaging sensors on the satellite platforms it contains flaws and deficiencies. Pre-processing refers to those operations that are preliminary to the main analysis. Preprocessing includes a wide range of operations from the very simple to extremes of abstractness and complexity. These categorized as follow:

1. Feature Extraction
2. Radiometric Corrections
3. Geometric Corrections
4. Atmospheric Correction



The techniques involved in removal of unwanted and distracting elements such as image/system noise, atmospheric interference and sensor motion from an image data occurred due to limitations in the sensing of signal digitization, or data recording or transmission process. Removal of these effects from the digital data are said to be "restored" to their correct or original condition, although we can, of course never know what are the correct values might be and must always remember that attempts to correct data what may themselves introduce errors. Thus image restoration includes the efforts to correct for both radiometric and geometric errors.

Image Arithmetic Operations

The operations of addition, subtraction, multiplication and division are performed on two or more co-registered images of the same geographical area. These techniques are applied to images from separate spectral bands from single multispectral data set or they may be individual bands from image data sets that have been collected at different dates. More complicated algebra is sometimes encountered in derivation of sea-surface temperature from multispectral thermal infrared data (so called split-window and multichannel techniques).

Addition of images is generally carried out to give dynamic range of image that equals the input images.

Band Subtraction Operation on images is sometimes carried out to co-register scenes of the same area acquired at different times for change detection.

Multiplication of images normally involves the use of a single'real' image and binary image made up of ones and zeros.

Band Ratioing or Division of images is probably the most common arithmetic operation that is most widely applied to images in geological, ecological and agricultural applications of remote sensing. Ratio Images are enhancements resulting from the division of DN values of one spectral band by corresponding DN of another band. One instigation for this is to iron out differences in scene illumination due to cloud or topographic shadow. Ratio images also bring out spectral variation in different target materials. Multiple ratio image can be used to drive red, green and blue monitor guns for color images. Interpretation of ratio images must consider that they are "intensity blind", i.e, dissimilar materials with different absolute reflectances but similar relative reflectances in the two or more utilised bands will look the same in the output image.

Other Types of Ratios and Band Arithmetic. There are a handful of ratios that highlight vegetation in a scene. The NDVI (Normalized Difference Vegetation Index) is known as the "vegetation index"; its values range from –1 to 1.

NDVI = NIR-red/NIR + red

where NDVI is the normalized difference vegetation index, NIR is the near infrared, and red is the band of wavelengths coinciding with the red region of the visible portion of the spectrum. For IRS data this equation is equivalent to:

NDVI = Band 4- Band 3/ Band 4+ Band 3

In addition to the NDVI, there is also IPVI (Infrared Percentage Vegetation Index), DVI (Difference Vegetation Index), and PVI (Perpendicular Vegetation Index) just to name a few. Variation in vegetation indices stem from the need for faster computations and the isolation of particular features.

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. 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.

CONCLUDING REMARKS

Remote sensing is now being widely regarded as a layer in the GIS. Although remote sensing is a specialized technique, it is now being accepted as a basic survey methodology and as a means of providing data for a resource database. The future progress in the hydrological sciences will depend upon the availability of adequate data for model development and validation. Remote sensing can and should play a pivotal role in this progress. The data banks should provide digitized maps and their spatial data compatible with various systems. Such data availability could significantly speed up the analysis.

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

1. 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)
2. Geometric correction (image-to-map rectification or image-to-image registration)

Display and Enhancement

3. Black & white (8-bit)
4. Color-composite display (24-bit)
5. Black & white or color density slice
6. Magnification, reduction, roam
7. Contrast manipulation (linear, non-linear)
8. Color space transformations (e.g. ROB to IHS)
9. Image algebra (band ratioing, image differencing, etc.)
10. Linear combinations (e.g., Kauth transform)
11. Spatial filtering (e.g. high, low, band-pass)
12. Edge enhancement (e.g. Sobel, Robert's, Kirsch)
13. Principal components (e.g. standardized, unstandardized)
14. Texture transforms (e.g. min-max, texture spectrum, fractal dimension)
15. Frequency transformations (e.g. Fourier, Walsh)
16. Digital elevation models (e.g. analytical hill shading)
17. Animation e.g.movies of channel detection

Remote Sensing Information Extraction

18. Pixel brightness value
19. Univariate and multivariate statistical analysis (e.g. mean, covariance)
20. Feature (band) selection (graphical and statistical)
21. Supervised classification (e.g. minimum distance, maximum likelihood)
22. Unsupervised classification (e.g. ISODATA)
23. Contextual classification

24. Incorporation of ancillary data during classification
25. Expert system image analysis
26. Neural network image analysis
27. Fuzzy logic classification
28. Hyperspectral data analysis
29. Radar image processing
30. Accuracy assessment (descriptive and analytical)

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