Based on the Syllabus of CTEVT 2018

REMOTE SENSING

DIPLOMA IN ENGINEERING

II Year II Part

FOURTH SEMESTER

CTEVT

Er. Sudur Bhattarai

Remote Sensing
EG 2203 GE

Total: 8 hour /week
Year: II **Theory: 4 hours/week**
Semester: IV **Lecture: hours/week**
Practical: 4 hours/week

Course Description:
This course is designed for the students pursuing diploma in Geomatics Engineering. The course covers the fundamental concept of remote sensing

Course Objectives:
After the completion of this course, students will be able to:

- Understand the basic concepts of remote sensing Principles
- Explore and interpretation the satellite images
- Perform the simple operation with remotely sensed data
- Conceptualize the application of Remote sensing data
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Unit 1: Introduction to Remote Sensing **(6 hrs)**

1.1. Definition
1.2. Components of Remote Sensing
1.3. Applications, advantages and limitations of Remote Sensing

Unit 2: EMR interaction with Atmosphere and Earth Materials **(12hrs)**

2.1 Electro Magnetic Radiation (EMR)
2.2 EMR spectrum
2.3 Atmospheric characteristics
2.4 Atmospheric Scattering: Rayleigh, Mie & Non-selective
2.5 EMR Interaction with Water vapor and ozone
2.6 Atmospheric Windows
2.7 Significance of Atmospheric windows
2.8 EMR interaction with Earth Surface Materials
2.9 Radiance, Irradiance, Incident, Reflectance
2.10 Absorbed and Transmitted Energy Reflectance
2.11 Specular and Diffuse Reflection Surfaces
2.12 Spectral Signature curves
2.13 EMR interaction with water, soil and Earth Surface

Unit 3: Sensor and platform **(8 hrs)**

3.1 Platforms
3.2 Passive and Active sensors
3.3 Resolution: Spatial, Spectral, Radiometric and Temporal
3.4 Satellite Orbits
3.5 Orbit Parameters
3.6 Types of satellite orbits
3.7 Some operational multispectral sensors

Unit 4: Pre-processing **(10 hrs)**

4.1 Image Enhancement
4.2 Visualization of image data
4.3 Histogram and histogram operations
4.4 Filtering
4.5 Radiometric distortion and corrections
4.6 Geometric distortion and correction

Unit 5: Image analysis **(14 hrs)**

5.1 Visual Image Interpretation of Satellite Images

5.2 Digital Image Classification

5.2.1 Principles of image classification: Image Space, Feature Space, Distances and clusters in the feature space

5.2.2 Image Classification techniques

5.2.3 Pixel based classification: Unsupervised and supervised

5.2.4 Accuracy assessment

5.2.5 Validation of the result

Test and Revision **(10 hrs)**

Lab Exercise **(60 hrs)**

1. Observation of image and reading pixel data
2. Observe image bands of multi spectral images
3. Image Subsetting
4. Mosaic images
5. Image Enhancement
6. Stacking layers and prepare multi spectral images
7. Geo-reference satellite image
8. Digital Image Classification and Accuracy Assessment

Text Book

B. Bhatta, Remote Sensing and GIS, Oxford University Press, 2010. (Unit 1, 2, 5, 7, 9 & 10).

Unit 1

Introduction to Remote Sensing

Unit 1: Introduction to Remote Sensing [6 Hrs]

1.1 Definition

1.2 Components of Remote Sensing

1.3 Applications, advantages, and limitations of Remote Sensing

1.1 Definition

Remote Sensing is defined as "The art, science, and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring, and interpreting imagery and the digital representations of energy patterns derived from non-contact sensor systems." It is the technique of acquiring information about objects on the earth's surface without physically coming into contact with them.

As you read these words, you are also employing remote sensing. Your eyes are acting as sensors that respond to the light reflected from this page. The "data" your eyes acquire are impulses corresponding to the amount of light reflected from the dark and light areas on the pages. These data are analyzed, or interpreted, in your mental computer to enable you to explain the dark areas on the page as a collection of letters forming words. Beyond this, you recognize the words from sentences and you interpret the information that the sentences convey.

Likewise, our eyes, a remote sensing system make use of reflected electromagnetic radiation radiated from its source to detect and collect data of the earth's surface and form remote sensing imagery. This can be accomplished through three components: Source, sensor, and sensing. Detection and discrimination of objects or surface features mean detecting and recording radiant energy reflected or emitted by objects or surface material. Different objects return different amounts and kinds of energy in different bands of the electromagnetic spectrum, incident upon it. This unique property depends on the property of the material (structural, chemical, and physical), surface roughness, angle of incidence, intensity, and wavelength of radiant energy.

In general, it can also be termed as **"knowing without going".**

Different institutions have defined Remote Sensing in their own way. According to Canada Centre for Remote Sensing, "Remote sensing is the science (and to some extent art) of acquiring information about the earth's surface without actually being in contact with it. This is done by sensing and recording reflected and emitted energy and processing, analyzing, and applying that information."

All in all, remote sensing is the science (and to some extent, art) of acquiring information about an object, area, or phenomenon on the Earth's surface through the analysis of data acquired by a device that is not without actually being in contact with the object, area or phenomenon under investigation. The process of use of electromagnetic radiation sensors to record images of the environment, which can be interpreted to produce useful information. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.

Principles of Remote Sensing

Remote sensing is the non-contact recording of information from the ultraviolet, visible, infrared, and microwave regions of the electromagnetic spectrum by means of instruments such as cameras, scanners, lasers, linear arrays, and/or area arrays located on platforms such as aircraft or spacecraft, and the analysis of acquired information by means of visual and digital image processing. So the recording of the information by the non-contact sensors (also called remote sensors) in a remote sensing system is governed by the principles of remote sensing.

The remote sensing process is based upon the following principles:

1 Detection and discrimination of objects or surface features means detecting and recording of radiant energy reflected or emitted by objects or surface.

2 Different objects return different amount of energy in different bands of the electromagnetic spectrum. Incident upon it.

3 Depend upon the property of material (physical, structural, and chemical), surface roughness, angle of incidence, intensity and wavelength of radiant energy.

Types of remote sensing

There are two main types of remote sensing:

1. **Passive remote sensing**

In passive remote sensing, passive sensors detect natural radiation that is emitted or reflected by the object or surrounding area being observed. Reflected sunlight is the most common source of radiation measured by passive sensors.

Examples of passive remote sensors include film photography, infrared, and radiometers.

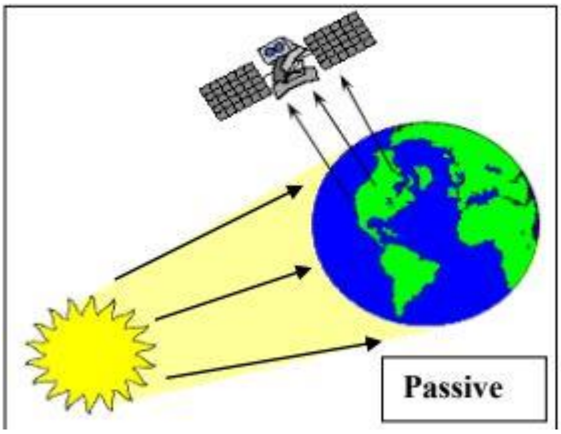


Figure 1: Passive remote sensing

2. **Active remote sensing**

The remote sensing process in which energy is emitted by the sensors to scan objects and areas is called active remote sensing. Here, the sensor then detects and measures the radiation that is reflected or backscattered from the target.

RADAR (Radio Detection and Ranging) is an example of active remote sensing where the time delay between emission and return is measured, establishing the location, height, speeds, and direction of an object.

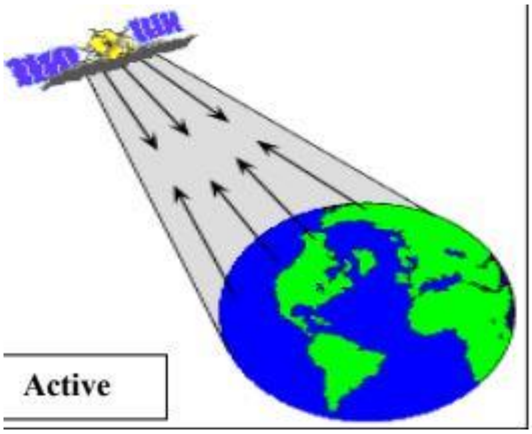


Figure 2: Active Remote Sensing

1.2 Components/Elements and Process of Remote Sensing

The following seven elements of remote sensing describe the remote sensing process from beginning to end.

a. Energy Source or Illumination (A)
b. Radiation and the Atmosphere (B)
c. Interaction with the Target (C)
d. Recording of Energy by the Sensor (D)
e. Transmission, Reception, and Processing (E)
f. Interpretation and Analysis (F)
g. Application (G)

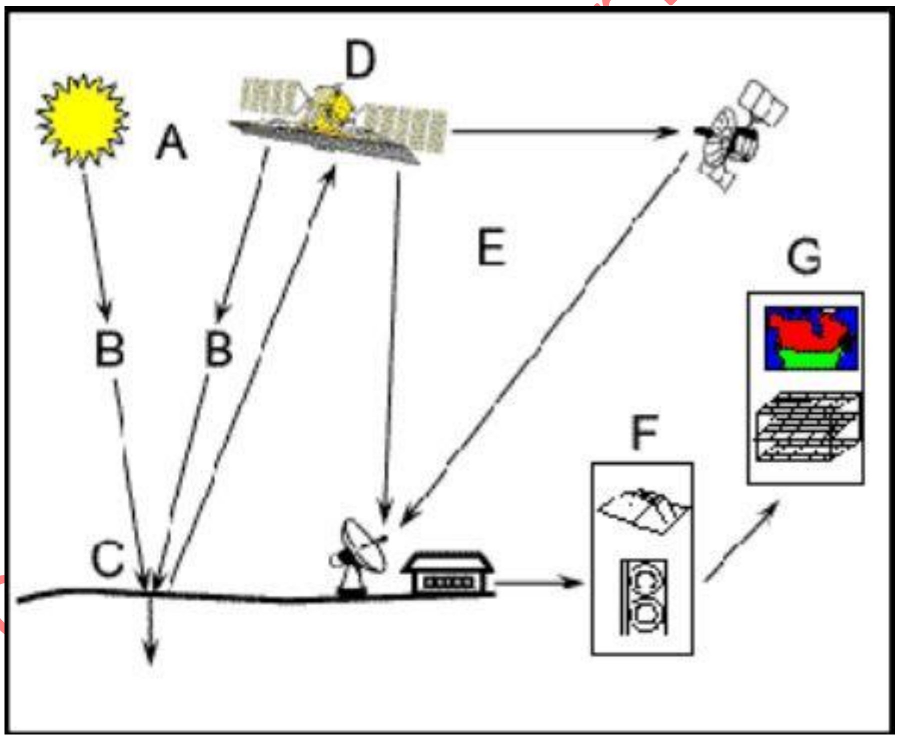


Figure 3:Remote Sensing Process

a. **Energy Source or Illumination (A)** – the first requirement for remote sensing is to have an energy source that illuminates or provides electromagnetic energy to the target of interest.
b. **Radiation and the Atmosphere (B)** – as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

c. **Interaction with the Target (C) -** once the energy makes its way to the target through the atmosphere; it interacts with the target depending on the properties of both the target and the radiation.
d. **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.
e. **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 (hardcopy and/or digital).
f. **Interpretation and Analysis (F) -** the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.
g. **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.

1.3 Applications, advantages, and limitations of Remote Sensing

Applications of Remote Sensing

Remote sensing affords a practical means for accurate and continuous monitoring of the earth's natural and other resources and of determining the impact of man's activities on air, water, and land. Some of the major applications of remote sensing are as follows:

1. Agriculture
    - Early season estimation of total cropped area
    - Monitoring crop conditions using crop growth profile
    - Identification of crops and their coverage estimation in multi-cropped regions
    - Crop yield modeling
    - Cropping system/crop rotation studies
    - Command area management
    - Detection of moisture stress in crops and quantification of its effect on crop yield
    - Detection of crop violations
    - Zoom cultivation-desertification
2. Forestry
    - Improved forest-type mapping
    - Monitoring large-scale deforestation, forest fire
    - Monitoring urban forestry
    - Forest stock mapping
    - Wildlife habitat assessment
3. Land use and soils
    - Mapping land use/land cover (level III) at 1:25000 scale or better
    - Change detection
    - Identification of degraded lands/erosion-prone areas
    - Soil categorization

4. Geology
    - Lithological and structural mapping
    - Geo morphological mapping
    - Groundwater exploration
    - Engineering geological studies
    - Geo-environmental studies
    - Drainage analysis
    - Mineral exploration
    - Coal fire mapping
    - Oil field detection
5. Urban land Use
    - Urban land use level IV mapping
    - Updating of urban transport network
    - Monitoring urban sprawl
    - Identification of unauthorized structures
6. Water resources
    - Monitoring surface water bodies frequently and estimation of their spatial extent
    - Snow-cloud discrimination leading to better delineation of snow area
    - Glacier inventory
7. Coastal Environment
    - More detailed inventory of coastal land use on 1:25000 scale
    - Discrimination of coastal vegetation types
    - Monitoring sediment dynamics
    - Siting of coastal structures
8. Ocean Resources
    - Wealth of oceans/explorations/productivity
    - Potential fishing zone
    - Coral reef mapping
    - Low tide/high tide marking
9. Watershed
    - Delineation of watershed boundaries/portioning of micro watershed
    - Watershed characterization at large scale (Size, shape, drainage, land use/land cover)
    - Siting of water harvesting structures
    - Monitoring watershed development
    - Major river valley projects
10. Environment
    - Impact assessment on vegetation, water bodies
    - Siting applications
    - Loss of biological diversity/biosphere reserves/ecological hot spot areas/wet land environment
11. Street network-based application
    - Vehicle routing and scheduling
    - Location analysis-site selection-evacuation plans

12. Land parcel-based application
    - Zoning, subdivision plan review
    - Land acquisition
    - Environmental management
    - Water quality management
    - Maintenance of ownership
13. Natural resources-based applications
    - Management of wild and scenic rivers, recreation resources, flood plains, wet lands, agricultural lands, aquifers, forest, wild life, etc.
    - Environmental Impact Analyst (EIA)
    - View shed analysis
    - Hazardous or toxic facility siting
    - Ground water modeling and contamination racking
    - Wildlife analysis, migration routes planning
14. Disaster
    - Mapping flood inundated area, damage assessment
    - Disaster warning mitigation
15. Digital Elevation Model
    - Contours (>10 m)
    - Slope/Aspect Analysis
    - Large-scale thematic mapping up to 1:25000 scale

Advantages of Remote Sensing

Remote sensing is unobtrusive if the sensor is passively recording the electromagnetic energy reflected or emitted by the phenomenon of interest. Passive remote sensing does not disturb the object or area of interest.

Remote sensing devices may be programmed to collect data systematically. This systematic data collection can remove the sampling bias introduced in some investigations.

Remote sensing sensor has synoptic view. This ability of the sensor can reduce the data acquisition (and thereby cost) dramatically over a large geographic area in comparison to traditional surveying methods.

Remote sensing from satellites can be performed repeatedly at a regular time interval. This can help in monitoring several earth-surface features continuously.

Remote sensing can be used for collecting data about areas that are physically and/or politically inaccessible.

Under controlled conditions, remote sensing can provide fundamental biophysical information, including x, y location, z elevation or depth, biomass, temperature, and moisture content.

Unlike much of the surveying, the remotely sensed data may be obtained systematically over very large geographic areas rather than just single-point observations.

The generic data (multipurpose datasets) can be obtained from remote sensing technology.

Multispectral imageries can be obtained from remote sensing. Remote sensing sensors can measure energy at wavelengths beyond the range of human vision.

The global coverage can be obtained from remote sensing, where multi-resolution imageries can be deduced from remote sensing.

Imageries of the earth surface can be obtained in near-real time from remotely sensed sensors.

Limitations of Remote Sensing

Remote sensing science is not a panacea that will provide all the information needed for conducting physical, biological, or social science. It simply provides some spatial, spectral and temporal information.

Human beings select the most appropriate sensor to collect the data, specify the resolution of the data, calibrate the sensor, select the platform that will carry the sensor, determine when the data will be collected, and specify how the data is processed. Thus, human method-produced error may be introduced, as the various remote sensing instrument and mission parameters are specified.

Powerful active sensors system, such as lasers or radars that emit their own EMR, can be intrusive and affect the phenomenon being investigated.

Remote sensing instruments often become uncalibrated, resulting in uncalibrated remote sensing data. So, requires ground verification in order to proceed for further analysis of the remotely sensed data.

Remote sensor data may be expensive to collect, interpret, or analyze.

Installation and operation of remote sensing system is expensive.

Expert system is needed to extract remotely sensed data.

Exercises

1. What is Remote Sensing? Describe the types of remote sensing.
2. Explain the underlying principle of Remote Sensing.
3. Explain the remote sensing process with a neat and clean diagram.
4. What are the limitations of remote sensing?
5. **Differentiate passive and active remote sensing.**

Ans.

Difference between passive and active remote sensing

S.N	Passive Remote Sensing	Active Remote Sensing
1	Passive remote sensing does not employ any external source of energy.	Active remote sensing has its own source of energy.
2	Measures either reelected radiation from the sun or the emitted radiation from the surface.	Active sensors emit a controlled beam of energy to the surface and measure the amount of energy reflected back to the sensor.

3	Passive remote sensing suffers from variable illumination conditions of the sun and the influence of atmospheric conditions.	Active remote sensing has a controlled illumination signal.
4	In passive remote sensing, reflected radiation from the sun is recorded only during the daytime, while the emitted radiation from the earth's surface can be operated during the night.	Active remote sensors can record the reflected or emitted radiation both at day and night.

6. Differentiate remote sensing and photogrammetry

Ans.

Difference between remote sensing and photogrammetry

S.N	Basis of difference	Remote Sensing	Photogrammetry
1	Speed	Very high, high temporal resolution.	Slow, needs more time to cover an area.
2	Level of details	May go up to 50 cm (in Geo Eye -1).	May go up to 2.5 cm.
3	Weather Condition	Cloud is a big hindrance in optical data.	May work in a high and thin cloud.
4	Type of data	Less as each new data type needs new satellite launching.	High as a new data type needs new sensors to be mounted in aircraft.
5	Location	Cross-boarder images and large-swath images can be easily taken.	Cross boarder images cannot be taken without permission.
6	Post-processing	Easy because of single image covering large area.	Tough due to large number of images covering a small area.
7	Data Type	Remote sensing collects data in the form of light and colour. By detecting different wavelengths of light radiation, it can generate maps.	Instead of measuring wavelengths of radiation, photogrammetry uses imagery to measure coordinates in space.
8	Number of dimensions	Remote sensing tends to work in two dimensions. So, Remote sensing can create informative 2D maps.	Photogrammetry tends to work in three dimensions. So, photogrammetry is ideal for more complex 3D modeling.

7. Describe the applications and advantages of remote sensing in the context of Nepal.

Ans.

"Remote Sensing, its relevancy and benefits for Nepal"

Remote sensing is a group of techniques that allows for the analysis and application of data of the Earth's surface acquired by using a variety of airborne and satellite sensors. It provides a powerful way to analyze spatial data/imagery and support decision-making processes in both government and industry.

Applications of remote sensing

There are many applications remote sensing technology can provide to a developing nation like Nepal such as in natural resources management, geology, archaeology, defense and national security, and many more.

Some of the major applications of remote sensing in the context of Nepal are:

a. Forestry and Agriculture

One big area of application of remote sensing is in forestry. Forestry needs regular monitoring from its plantation to harvesting and remote sensing can play an important role in mapping and providing information on various bio-physical parameters to estimate forest biomass and tree heights.

Similarly, techniques of remote sensing are used to map and estimate the supply of agricultural production in the national economy, which is an important aspect for food security of the nation. Information obtained from remote sensing methods, provide important economic intelligence. On the supply side it will help estimate the production and help set pricing and policy goals for various produces. In situations when the yield is likely to come below expectations (e.g. drought, excessive rain etc.) it will allow policy makers to make policy adjustments in advance to cater for any impending situations or famine.

Last but not least, precision farming is another area where remote sensing is widely used. Remote sensing technology is applicable in the consolidated agricultural land.

b. Disaster Management and Mitigation

Nepal is a country endowed with several perennial river systems. Excessive rainfall during the monsoon season often add to the volume of water in the river systems and breaching of banks and flooding is often seen when the rivers descend from the hills into flatter topography of the Terai region of Nepal. In this scenario, near-real time monitoring of flood, drought events are possible with the help of high-resolution satellite data using the techniques of remote sensing. Also, remote sensing methods can be very useful in helping in providing important data for establishment of the disaster management and recovery system. Data gathered from Earth observing satellites can be used to supply important spatial information to carry out hydrologic analysis critical for the above-mentioned events.

c. Water resources and its management

From a politico-economic perspective monitoring of water resources in Nepal is important as the statistics and data thus derived can be important to negotiate business outcomes with neighboring countries or for specification in tender documents or for building of new hydroelectric plants or irrigation infrastructures. Remote sensing has potential to save huge amount of money and reduce project lead times. Both qualitative and quantitative analyses are needed for adequate monitoring of the health of the surface water systems. Nepal has often suffered in negotiation with neighboring countries because of a lack of adequate baseline data and remote sensing can be used to improve the quality of data, policy makers can use. Remote sensing equips water resource managers with authoritative and actionable information. This will then allow for more accurate assessment and management of water resources at a national level.

d. Land use planning

Remote sensing allows frequent updates of the land use land cover maps, providing valuable information for planning and visualization. The availability of consistent and reliable spatial information on land uses is critical for sustainable natural resource management. For a country like Nepal, both Land use and Land cover data are an important part of spatial infrastructure, where land use and land cover datasets are perceived using earth observation satellites. Similarly, remote sensing technology can be used to create thematic maps using variety of image classification techniques. Thematic maps provide for identification and mapping of all important land cover types present in the area. Land use thematic maps will also provide a baseline for urban and regional planning, zoning.

Advantages of remote sensing

Remote Sensing is often utilized in combination with GIS. In Nepalese context, the remote sensing technology can be best utilized in forming policy and planning decisions in both government and private sector.

Some of the advantages of remote sensing in the context of Nepal are as follows:

a. Provision of repetitive and consistent observation

The most important contribution that remote sensing can make is in the provision of timely and consistent information. Vital information needs to be collected over the country both over the short, the medium and the long term. The information is required for managing the natural resources as well as utilizing both renewable resources (forestry, agriculture, and water) or non-renewable resources (mining) and their economic and social impact on the country and the population. A systematic and repeat observation is also needed for environmental monitoring, planning and emergency managements in times of natural disasters, where it is evident that Nepal is vulnerable to various natural calamities (such as flooding, landslides, drought, earthquakes, etc.

b. Creating and maintaining Baseline data

The availability of accurate and timely spatial data forms the cornerstone of development. Whether it is design and alignment of highways and roads, deciding on the transmission line corridors, monitoring of agriculture, forestry or mining resources, a suitable baseline data is critical. Remote sensing provides an important starting points in creation of the baseline data sets. Creation of foundation datasets required for engineering applications such as contour maps and digital elevation models can be created by remote sensing or associated technologies (e.g. photogrammetry). Similarly, majority of GIS based spatial data layers have been created using remote sensing. Therefore, remote sensing methods provide vital information in creating such baseline data.

c. Monitoring and change detection

Remote Sensing and GIS techniques are very useful in the identification and mapping of change. One such application is finding areas with rapid urban growth or urban sprawl. Identifying change that occurs over time is an area important for many disciplines such as forestry, agriculture, environmental monitoring and many more.

Conclusion

In conclusion, remote sensing can be utilized across many disciplines and has many advantages. Nepal can leapfrog to take advantage of these technologies if operated fully.

8. How can remote sensing can be used to solve the existing problem prevailing at your local level. What could be your contribution to solve them. Sketch a brief project plan to carry out that project.

Ans. Insufficient production due to crop damage as a result of fungal and weed infestations, deficiencies of the moisture; drought, weather-related damages, weather changes, etc. are some of the severe stresses that farmers are facing in my locality-Rampur municipality of Palpa district.

Background

These problems in the field of agriculture can be mitigated through the means of remote sensing via crop monitoring and crop damage assessment. Assessment of the health of the crop, as well as early detection of crop infestations, is vital for ensuring good agricultural productivity. Stress associated with, for example, moisture deficiencies, insects, and fungal and weed infestations must be detected early enough to provide an opportunity for the farmer to mitigate. Remote sensing allows the farmer to identify areas within the field which experience difficulties, so that s/he can apply, for instance, the correct type and amount of fertilizers, insecticides, pesticides, or herbicides. Using this approach, farmers not only improve the productivity of his/her land but also reduces his/her farm input costs and minimize environmental impacts.

Similarly, remote sensing can also be employed to identify the areas victimized by drought, weather- related damages, which destroy many crops. Identifying such areas facilitates in planning and directing humanitarian aid and relief efforts, which no doubt increases in the crop production.

Study Area

Rampur is a municipality in Palpa District in Lumbini Zone of West southern Nepal. The municipality, with district headquarter-Tansen, covers an area of 123.5 Sq.km. and has the population of 11,515(2011). The municipality is surrounded by Syangja district in the north, Tanahun in north-east and Nawalprasi (now western part of Nawalprasi) in the east.

How remote sensing?

Remote sensing has a number of attributes that lend themselves to monitor the health of crops. One advantage of optical (VIR) sensing is that it can see beyond the visible wavelengths into the infrared, where wavelengths are highly sensitive to crop vigor as well as crop stress and crop damage. Remote sensing imagery also gives the required spatial overview of the land. Recent advances in communication and technology allow a farmer to observe images of his fields and make timely decisions about managing the crops. Remote sensing can aid in identifying crops affected by conditions that are too dry or wet, affected by insect, weed or fungal infestations or weather-related damages. Images can be obtained throughout the growing season to not only detect problems, but also to monitor the success of the treatment.

Healthy vegetation contains large quantities of chlorophyll, the substance that gives most vegetation its distinctive green color. In referring to healthy crops, reflectance in the blue and red parts of the spectrum is low since chlorophyll absorbs this energy. In contrast, reflectance in the green and near-infrared spectral regions is high. Stressed or damaged crops experience a decrease in chlorophyll content and changes to the internal leaf structure. The reduction in chlorophyll content results in a decrease in reflectance in the green region and internal leaf damage results in a decrease in near-infrared reflectance. These reductions in green and infrared reflectance provide early detection of crop stress. Examining the ratio of reflected infrared to red wavelengths is an excellent measure of vegetation health. This is the premise behind some vegetation indices, such as the normalized differential vegetation index (NDVI). Healthy plants have a high NDVI value because of their high reflectance of infrared light, and relatively low reflectance of red light.

Project plan for crop monitoring and crop damage assessment

As a scholar of Remote Sensing, I can prepare the crop damage assessment map of Rampur from the output derived from the satellite-based vegetation, soil moisture, stress- insects, fungal and weed infestations, rainfall pattern of every year. These images at each pixel value can be loaded on the GIS software to prepare frequency maps. The seasonal frequency maps derived, taking an account NDVI, drought occurrence and infestations due to fungus, weeds, rodents, etc. can be reclassified into the common scale based on the frequency of drought and infestations occurrence as high (drought occurs when >50% of the years), moderate (30-50%) and low drought (<30%) probability zones. The necessary plans and polices can then be formulated to direct humanitarian and relief efforts in the victimized (affected) areas, which no doubt increase the crop production in those areas.

Unit 2

EMR Interaction with Atmosphere and Earth Materials

Unit 2: EMR interaction with Atmosphere and Earth Material [12 Hrs]

2.1. Electromagnetic Radiation (EMR)
2.2. EMR Spectrum
2.3. Atmospheric Characteristics
2.4. Atmospheric Scattering: Rayleigh, Mie, and Non-Selective
2.5. EMR interaction with Water Vapor and Ozone
2.6. Atmospheric Windows
2.7. Significance of Atmospheric Windows
2.8. EMR interaction with Earth Surface Materials
2.9. Radiance, Irradiance, Incident, Reflectance
2.10 Specular and Diffuse Reflection Surfaces
2.11 Spectral Signature Curves
2.12 EMR interaction with Water, Soil, and Earth Surface

2.1 Electromagnetic Radiation (EMR)

The first requirement for remote sensing is to have an energy source to illuminate the target (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation.

Electromagnetic radiation consists of an electrical field (E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c).

All electromagnetic radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory. This theory describes the EM energy as travelling in a harmonic fashion at the velocity of light.

All electromagnetic radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory. This theory describes the EM energy as travelling in a harmonic fashion at the velocity of light.

The wavelength is the length if one wave cycle, which can be measured as the distance between successive wave crests. Wavelength is usually represented by the Greek letter lambda (λ).

Wavelength are measured in units of length- meters, when dealing with light, wavelength are in the order of nanometers (1* 10-9).

Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. Normally, this is the number of peaks that will travel past a point in one second. Frequency is measured in cycles per second. The term given to this is Hertz (Hz) named after the 19th century discoverer of radio waves- Heinrich Hertz. 1 Hz = 1 cycle per second.

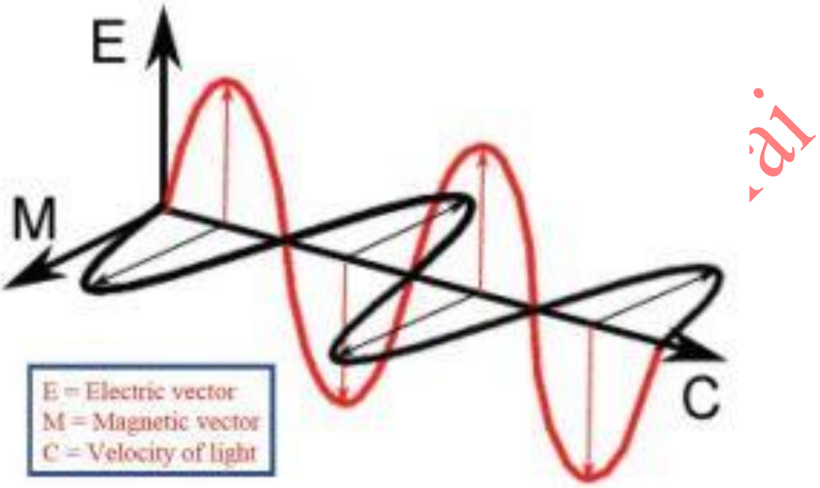


Figure 1: An electromagnetic Wave

To understand how EMR is produced, how it propagates through space, and how it interacts with other matters, it is useful to describe the electromagnetic energy using two different models: ***wave model*** *and* ***particle model.***

2.1.1. Wave Model

In the 1860s, James Clerk Maxwell conceptualized EMR as an electromagnetic energy or wave that travels through space at the speed of light, which is 3 x 108 m/s. Electromagnetic radiation is a swinging electric and magnetic field with a velocity of propagation equal to speed of light. Electric and magnetic field oscillate in space perpendicular to each other and to the direction of travel.

EM waves can transmit through a vacuum. With the sensors we can measure the following properties of electromagnetic radiation:

- wave length λ and/or the frequency v or f
- wave length λ and/or the frequency v or f
- polarization

All three of these components can be changed when radiation reacts with matter or atmosphere. For example: light of certain ranges of wavelengths can go through the atmosphere (transmission) while light of other wavelengths cannot (absorption or reflectance).

Sun light is composed of a variety of wavelengths and polarisations. In our daily experience, sun light is often absorbed, filtered or otherwise changed. For example: if something appears in a certain colour, then other wavelengths of the sun light are filtered out (absorbed) and the remaining wavelength(s) of the seen colour is/are reflected. The same is possible with polarisation planes: polarisation filters only allow to pass light swinging in a defined polarisation plane. Polarised radiation is only used in RADAR remote sensing, because here it is possible to send out polarised radiation and then observe how it reacts with matter.

The wave model provides relation between wavelength and frequency and can be expressed mathematically as

$C = \lambda . \upsilon$

Where, C = speed of Electromagnetic radiation (light)

λ = Wavelength

υ = Frequency

Therefore, Frequency and Wavelength are inversely related to each other. The shorter the wavelength, the higher the frequency and vice versa.

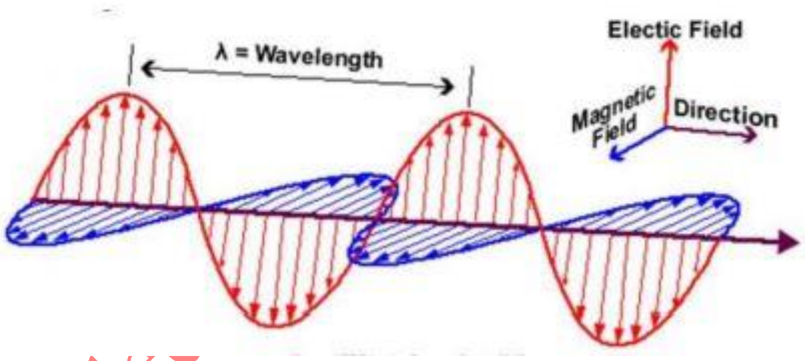


Figure 2: Electromagnetic Wave (Composed of both electric and magnetic fields at a right angle to one another)

2.1.2. Particle Model

Although many characteristics of EM energy are easily described by wave theory, another theory known as particle theory offers insight into how electromagnetic energy interacts with matter. This theory suggests that electromagnetic radiation is composed of a very small packets of energy called photon or quanta, as proposed by Einstein. The reason that photons are able to travel at light speeds is due to the fact that they have no mass. So, Einstein‟s infamous theory $E = MC^2$ cannot be used. So, Scientist Planck devised new formula which describe the relation between photon energy and frequency, which can be mathematically expressed as,

$Q = h.\upsilon$ Where, Q = energy of a quantum, joules (J)

H = Planck‟s constant, 6.626*10-34 J sec

υ = Frequency

Electromagnetic radiation shows dual nature, so we can relate wave and quantum model of electromagnetic radiation as,

$Q = h\, C/\lambda$

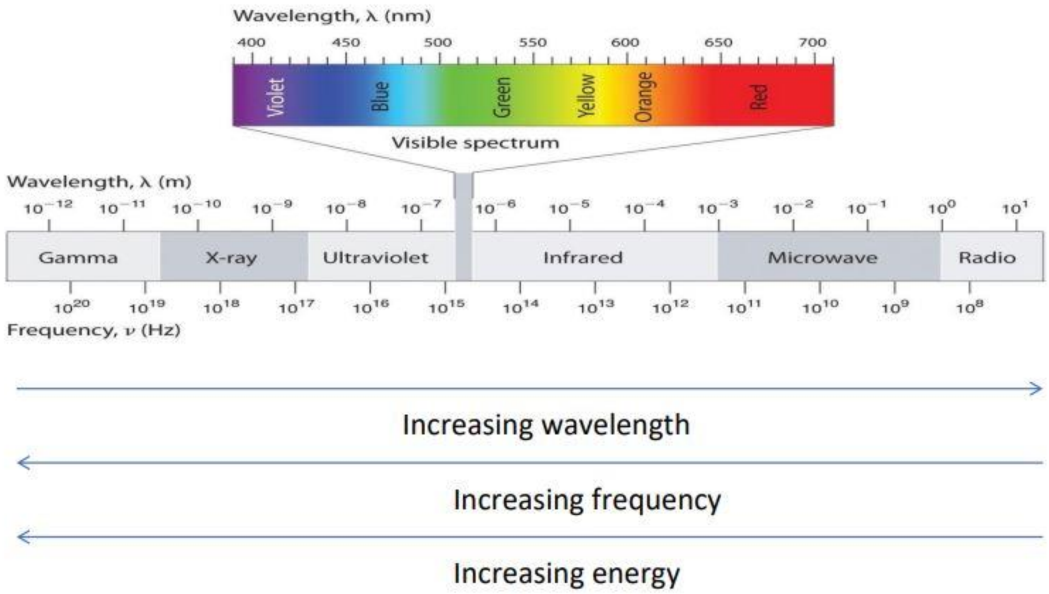
Thus, we can see that the energy of a quantum is inversely proportional to its wavelength. The longer the wavelength involved, the lower its energy content. This has important implications in remote sensing from the standpoint that naturally emitted long wavelength radiation such as microwave emission from terrain features is more difficult to sense than radiation of shorter wavelength such as emitted thermal IR energy.

2.2 Electromagnetic Spectrum

The distribution of the continuum of all radiant energies can be plotted either as a function of wavelength or frequency in a chart known as the electromagnetic spectrum. The electromagnetic spectrum ranges from the shorter wavelength (including gamma and X-rays) to longer wavelengths (including microwave and broadcast radio waves). Using spectroscopes and other radiation detection instruments, over the years, scientists have arbitrarily divided the EM spectrum into regions or intervals and applied descriptive names to them. These regions or intervals are commonly termed as bands or channels.

The light which our eyes-our 'remote sensors'-can detect is part of the visible spectrum. There are lots of radiation around us which are invisible to our eyes, but can be detected by other remote sensing instruments, and used to our advantage. The visible wavelength covers a arrange from approximately 0.4 µm to 0.7 µm.

Although the electromagnetic spectrum is spread from cosmic rays to radio waves, remote sensing is generally performed within the range of the ultraviolet to microwave region. Different bands of electromagnetic spectrum are used for different types of remote sensing.



Region	***Wavelength***	***Remarks***
Gamma ray	<0.03 nm	Incoming radiation is completely absorbed by the upper atmosphere and is not available for remote sensing.
X-ray	0.03 – 3.0 nm	Completely absorbed by atmosphere. Not employed in remote sensing.
Ultraviolet	0.03 – 0.4 μm	Incoming wavelengths less than 0.3 μm are completely absorbed by ozone in the upper atmosphere.
Photographic UV band	0.3 – 0.4 μm	Transmitted through atmosphere. Detectable with film and photodetectors, but atmospheric scattering is severe.
Visible	0.4 – 0.7 μm	Imaged with film and photodetectors. Includes reflected energy peak of earth at 0.5 μm.
Infrared	0.7 – 1.0 μm	Interaction with matter varies with wavelength. Atmospheric transmission windows are separated by absorption bands.
Reflected IR band	0.7 – 3.0 μm	Reflected solar radiation that contains no information about the thermal properties of materials. The band from 0.7 to 0.9 μm is detectable with film and is called the *photographic IR band*.
Thermal IR band	3 – 5 μm 8 – 14 μm	Principal atmospheric windows in the thermal region. Images at these wavelengths are acquired by optical-mechanical scanners and special vidicon systems but not by film.
Microwave	0.1 – 30 cm	Longer wavelengths can penetrate clouds, fog, and rain. Images may be acquired in the active or passive mode.
Radar	0.1 – 30 cm	Active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
Radio	>30 cm	Longest wavelength portion of electromagnetic spectrum. Some classified radars with very long wavelength operate in this region.

Figure 3: Electromagnetic Spectral Region

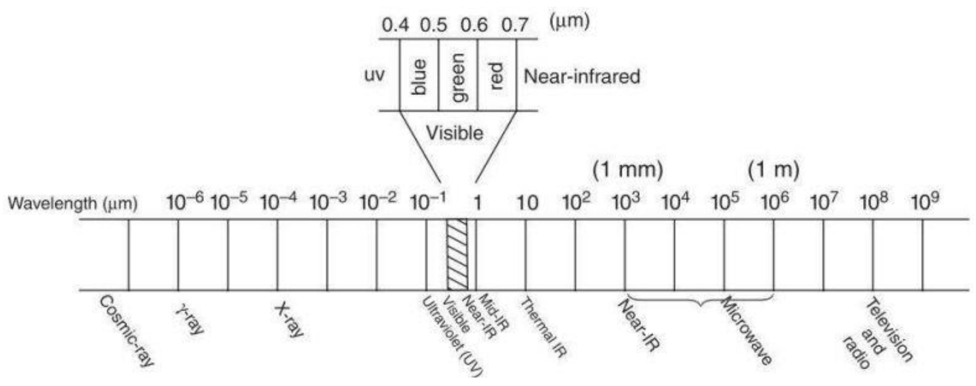


Figure 4: Electromagnetic Spectrum

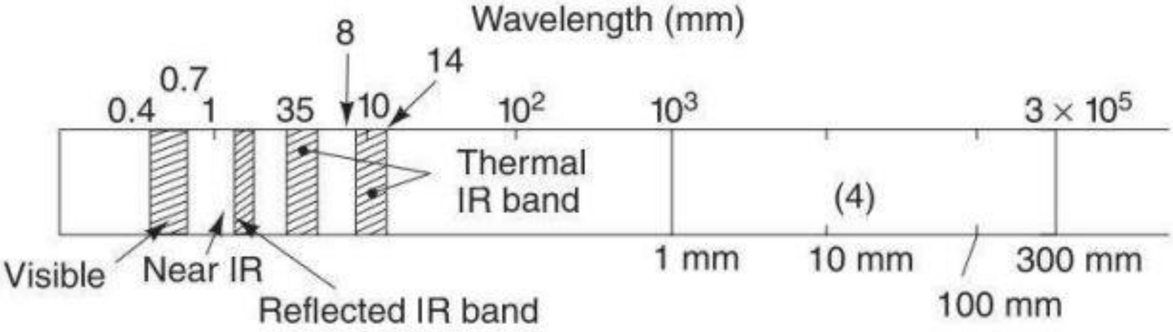


Figure 5: Expanded spectrum part used in remote sensing

The various suitable regions of electromagnetic radiations are the visible region—wavelength ranging from 0.4 to 0.7 µm (of which 0.4–0.5 µm represents the blue, 0.5–0.6 µm the green, and 0.6–0.7 µm the red region), particularly suitable for photogrammetry; the reflected infrared region—ranging from 0.7 to 3 µm (of which 0.7–1.5 µm represents the near infrared, and 1.5–3 µm the shortwave infrared), which is invisible; the thermal infrared region—ranging from 3 to 14 µm (of which 3–8 µm represents the midwave infrared, and 8–14 µm the longwave infrared), which is invisible, and can be detected by crystal detectors, and such systems work day and night; the microwave region—wavelength ranging from 1 to 300 mm and which is used in radar.

The remote-sensing systems operate in one or more of the visible, reflected-infrared, thermal-infrared, and microwave portions of the electromagnetic spectrum described above. However, the existing gases and water vapours in the atmosphere, which absorb electromagnetic energy in specific wavelength bands, influence the selection of the spectrum for use in the remote-sensing system.

One of the most important aspect is the selection of those portions of the spectrum which have a high transmission of electromagnetic radiations, called *atmospheric windows*, and their corresponding wavelengths are very suitable for remote sensing since these produce good images. In simple words, the wavelengths which are able to pass through the atmosphere without loss are called the atmospheric windows. Most remote-sensing instruments acquire data from the discrete segments of an atmospheric window by making measurements with the detectors tuned to specific wavelengths.

Region	*Wavelength (µm)*	*Principal Applications*
1. Blue	0.45–0.52	Coastal morphology and sedimentation study, soil and vegetation differentiation, conifers and deciduous vegetation discrimination
2. Green	0.52–0.60	Vigor assessment of vegetation, rock and soil discrimination, turbidity and bathymetry studies
3. Red	0.63–0.69	Plant-species differentiation
4. Near infrared	0.70–1.50	Vegetation, biomass, delineation of water feartures, landforms/geomorphic studies
5. Reflected infrared	1.55–1.75	Vegetation, moisture content, soil moisture content, snow and cloud differentiation
	2.08–2.35	Differentiation of geological materials and soil
6. Thermal IR	3.0–5.0	For hot targets, i.e., fires and volcanoes
	10.4–12.5	Thermal sensing, vegetation discrimination, vegetation stress analysis, volcanic studies
7. Microwave/ Radar (0.1–30.0 cm)	2–6 cm	Suitable for sensing crop canopies and tree leaves Useful for determining ice types
	15–30 cm	Affords greater depth penetration measured in terms of metres; can penetrate 1–2 m into a dry material to reveal underlying bedrock structure. Useful for mapping total extent of ice and for sensing tree-trunks

Figure 6: Wavelength Regions and their application in remote sensing

Ultraviolet

There are several regions of the electromagnetic spectrum which are useful for remote sensing. For most purpose, the ultraviolet or UV portion of the spectrum has the shortest wavelengths which are practical for remote sensing. This radiation is just beyond the violet portion of the visible wavelengths, hence its name. Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation.

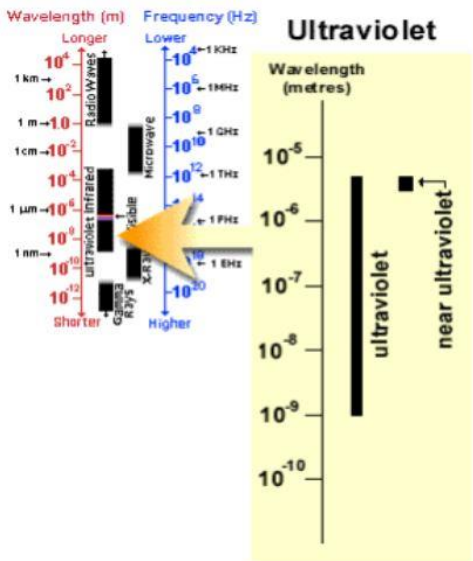


Figure 7: Ultraviolet Range of electromagnetic spectrum

Visible

The light which our eyes can detect is part of the visible spectrum. It is important to note that this is the only portion of spectrum we can associate with the concept of colour. 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 visible spectrum are listed below:

- Violet: 0.4 - 0.446 μm
- Blue: 0.446 – 0.5 μm
- Green: 0.5 – 0.578 μm
- Yellow: 0.578 – 0.592 μm
- Orange: 0.592 – 0.62 μm
- Red : 0.62 – 0.7 μm

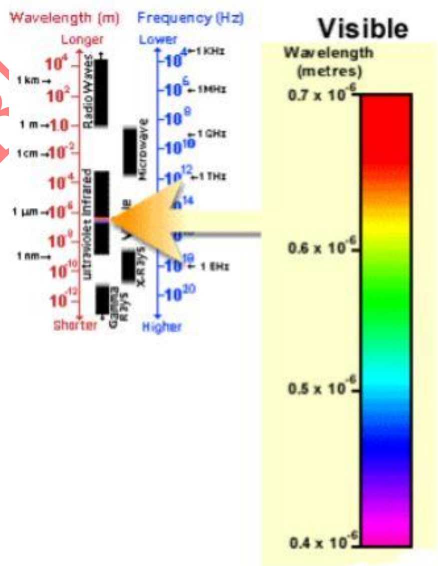


Figure 8: Visible Light Range of electromagnetic spectrum

Infrared

The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength ranges from approximately 0.7 μm to 100 μm which is more that 100 times as wide as visible portion. The infrared region can be divided into two categories based on their radiation properties- the reflected IR, and the emitted or thermal IR. The reflected IR covers wavelengths from approximately 0.7 μm to 3.0 μm, is used for remote sensing purpose in ways similar to radiation in visible spectrum. The thermal IR region is essentially due to 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.

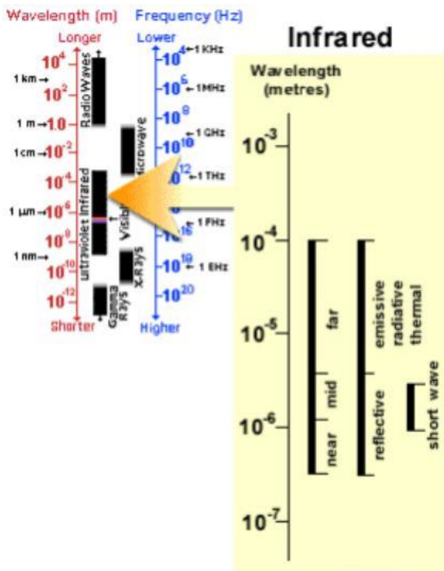


Figure 9:Infrared Range of Electromagnetic

Microwave

The portion of the spectrum of more recent interest to remote sensing is the microwave regions from about 1 mm to 1 m. This covers longest wavelengths used for remote sensing. The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts.

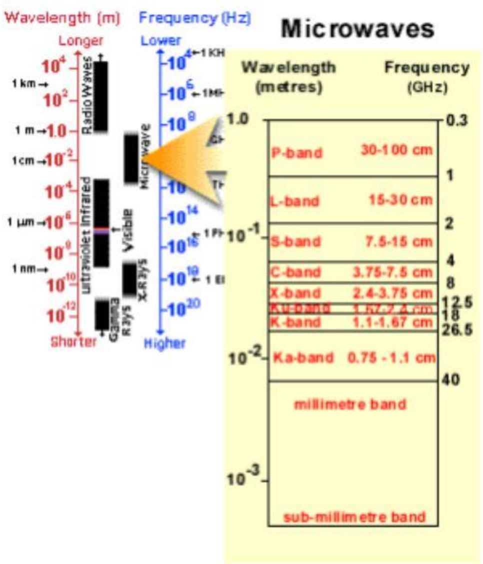


Figure 10: Microwave range of electromagnetic spectrum

2.3 Atmospheric Characteristics

An atmosphere is a blanket of gases that surrounds Earth. It is held near the surface of the planet by Earth's gravitational attraction. Atmosphere is a protective layer of gases that shelters all life on Earth, keeping temperatures within a relatively small range and blocking out harmful rays of sunlight.

The atmosphere has five distinct layers that are determined by the changes in temperature that happen with increasing altitude. Layers of Earth's atmosphere are divided into five different layers as:

- Exosphere
- Thermosphere
- Mesosphere
- Stratosphere
- Troposphere

Characteristics of the Atmosphere:

- Helps retain the sun's heat and prevents it from escaping back into space.
- Protects life from harmful radiation from the sun.
- Plays a major role in Earth's water cycle.
- Helps keep the climate on Earth moderate.
- As altitude increases in the atmosphere, pressure decreases. The atmosphere exerts 14.7 lbs per square inch of pressure on at sea level due to the force of gravity on the column of air above us.
- Denser gases predominate the lower layers. This is due to the gravitational pull exercised by the earth.
- There is horizontal variation in the atmosphere also. Heavier gases are least over the equator and predominate polar areas.
- The composition of the atmosphere is fairly uniform up to the height of 6 km.

2.4 Atmospheric Scattering: Rayleigh, Mie, and Non-Selective

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere.

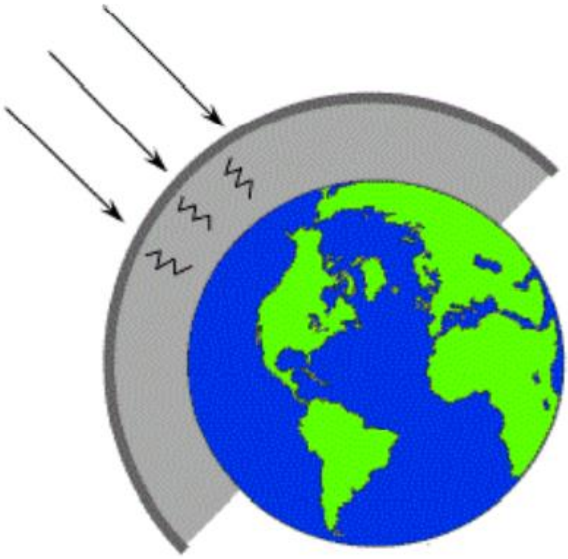


Figure 11: Scattering on Earth surface

There are three (3) types of scattering which take place.

I. **Rayleigh scattering**

Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation. These could be particles such as small specks of dust or nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wave lengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere. The fact that the sky appears "blue" during the day and raddish during sunset or sunrise is because of this phenomenon. The fact that the sky appears “blue” during the day is that, as sunlight passes through the atmosphere, the shorter wavelengths (i.e. blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths. At sunrise and sunset, the light has to travel farther through the atmosphere than at midday and the scattering of the shorter wavelengths is more complere; this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.

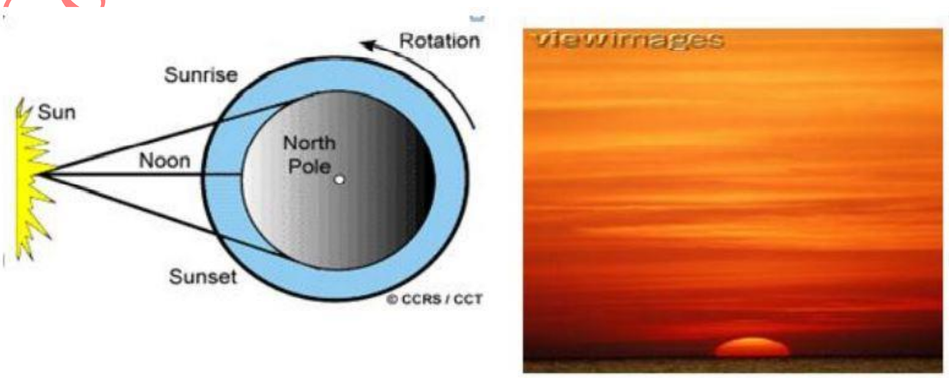


Figure 12:Rayleigh scattering

II. **Mie Scattering**

Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation. Dust, smoke and water vapors are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and when cloud conditions are overcast.

III. Non-Selective Scattering

Nonselective scattering occurs when the particles are much larger than the wavelength of the radiation. Water droplets and large dust particles can cause this type of scattering. Nonselective scattering gets its name from the fact that all wavelengths are scattered about equally. This type of scattering causes fog and clouds to appear white to our eyes because blue, green, and red light are all scattered in approximately equal quantities (blue+green+red light = white light).

Figure 13: Non-selective scattering

2.5 EMR interaction with Water Vapor and Ozone

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapor are the three main atmospheric constituents which absorb radiation.

Water vapour in the atmosphere absorbs much of the incoming long wave infrared and shortwave microwave radiation. The presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e. high humidity).

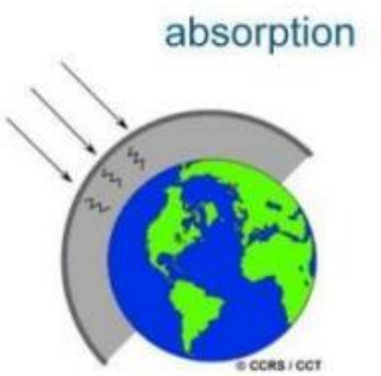


Figure 14: Absorption on Earth's Surface

Ozone serves to absorb the harmful (to most living things) ultraviolet radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight. You may have heard carbon dioxide referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere.

2.6 Atmospheric Windows

The atmosphere selectively transmits energy of certain wavelengths. The spectral bands for which the atmosphere is relatively transparent are known as **atmospheric windows**.

Atmospheric windows are present in the visible part (.4 μm - .76 μm) and the infrared regions of the EM spectrum. In the visible part, transmission is mainly affected by ozone absorption and by molecular scattering. The atmosphere is transparent again beyond about λ= 1mm, the region used for microwave remote sensing.

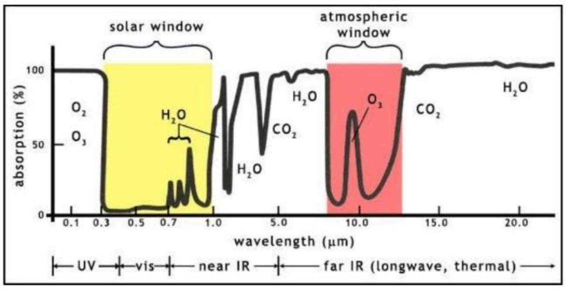
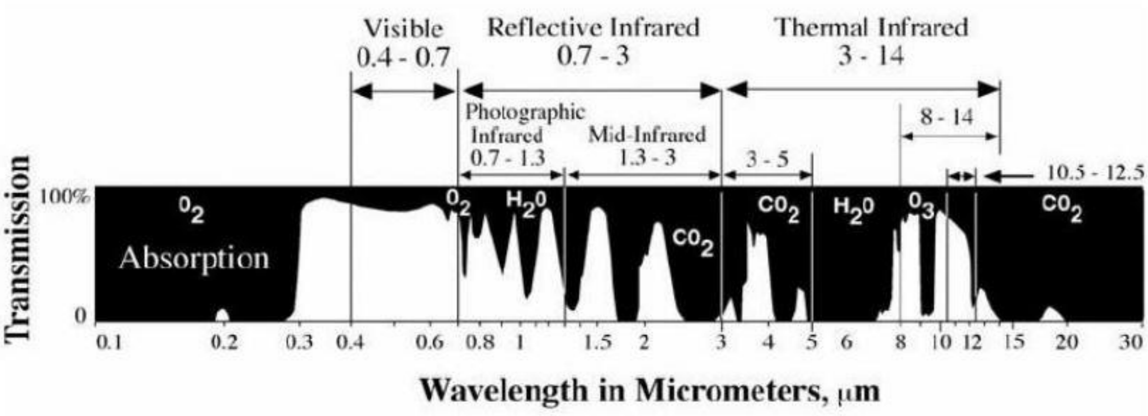
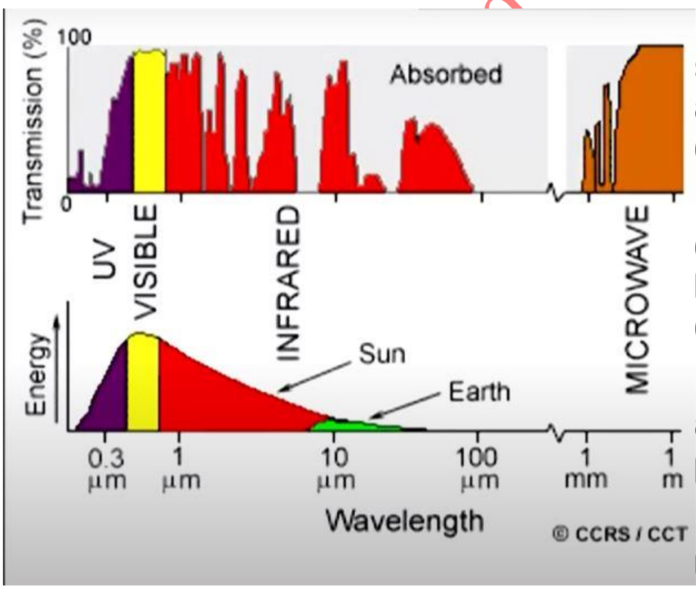


Figure 15; Atmospheric Window for various wavelengths of EMR

Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors are called atmospheric windows. The regions of spectrum useful for remote sensing are:

- Visible window: 0.4-0.9µm
- Near infrared window: 1.5-1.75µm, 2-2.4µm
- Far infrared window: 3-5µm, 8-14µm





➢Parts of the spectrum which are not severely influenced by atmospheric absorption are useful to remote sensors, are called atmospheric windows.

➢The visible portion of the spectrum, to which our eyes are most sensitive, corresponds to both an atmospheric window and the peak energy level of the sun.

➢Energy emitted by the Earth corresponds to a window around 10 μm in the thermal IR portion of the spectrum.

➢The large window at wavelengths beyond 1 mm is associated with the microwave region.

2.7 Significance of Atmospheric Windows

The atmospheric windows are wavelengths at which electromagnetic radiation from the sun will penetrate the Earth's atmosphere. Remote sensing projects must be conducted in wavelengths that occur within atmospheric windows. Outside of these windows, there is simply no radiation from the sun to detect as the atmosphere has blocked it. Consequently, the remote sensing process cannot be held outside the atmospheric window and further study, research using remote sensing technology cannot be done. Therefore, remote sensing projects are only possible due to the atmospheric windows. Both passive and active remote sensing technologies do best if they operate within atmospheric windows. In this way, atmospheric windows have a crucial role in remote sensing.

Engineers always keep the atmospheric window in mind when they design a sensor. They need to know which spectral bands sensors can measure.

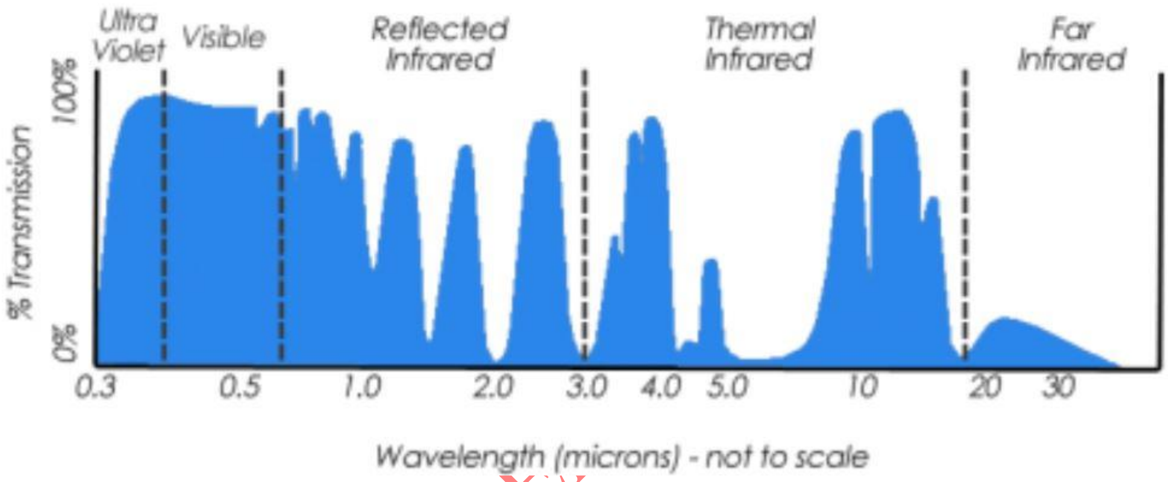


Figure 16: Atmospheric window for various wavelengths of EMR.

The graph above shows the Earth's "atmospheric window". The EM radiation (in blue) is what sensors are capable of seeing on Earth.

Our eyes can see red, green, and blue which is visible light. Healthy vegetation (or chlorophyll) reflects more green light. However, it absorbs more red and blue light. That is why our eyes see plants as green. But engineers design sensors to detect non-visible light as well. For example, vegetation reflects near-infrared (NIR) which is invisible to the human eye. But sensors can pick up this spectral information.

Remote sensing not only takes advantage of the visible spectrum (red, green, and blue) but also non-visible light. This is why engineers keep in mind atmospheric windows in the design process.

2.8 EMR interaction with Earth Surface Materials

Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface. When electromagnetic energy is incident on any given earth surface feature, three fundamental energy interactions with the feature are possible as illustrated in figure 17. These are:

- **absorption (A)**
- **transmission (T)**

- **reflection(R)**

Applying the principle of conservation of energy, we can state the interrelationship among these three energy interactions as,

$$EI (\lambda) = ER (\lambda) + EA (\lambda) + ET (\lambda)$$

Where,

EI = incident energy

ER = reflected energy

EA = absorbed energy

ET = transmitted energy

with all energy components being a function of wavelength λ.

In this equation, the proportions of each will depend on the wavelength of the energy and the material and condition of the feature.

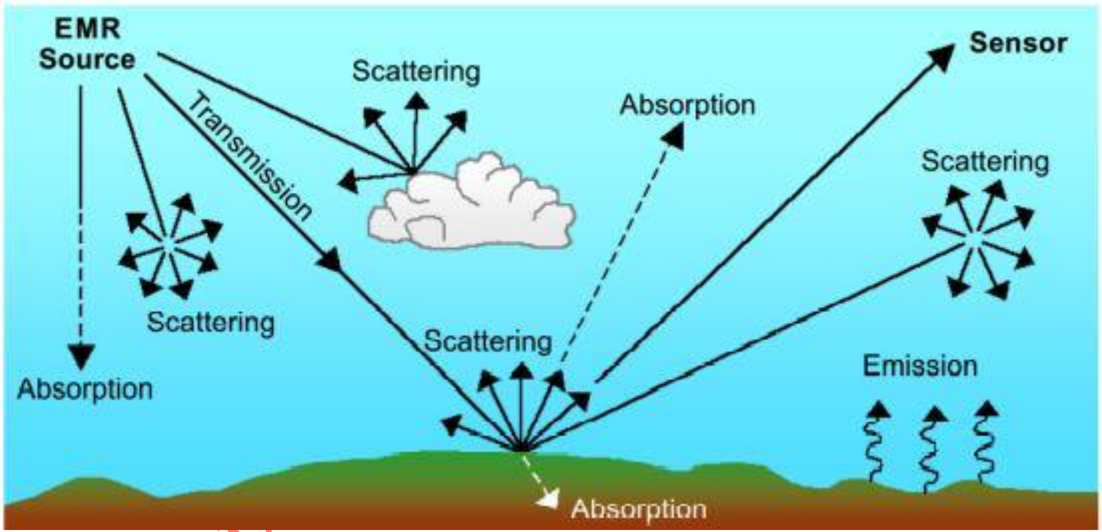


Figure 17:Typical EMR interaction in the Atmosphere and Earth's Surface.

Absorption (A) occurs when radiation (energy) is absorbed into the target while **Transmission (T)** occurs when radiation passes through a target. **Reflection (R)** occurs when radiation "bounces" off the target and is redirected. In remote sensing, we are most interested in

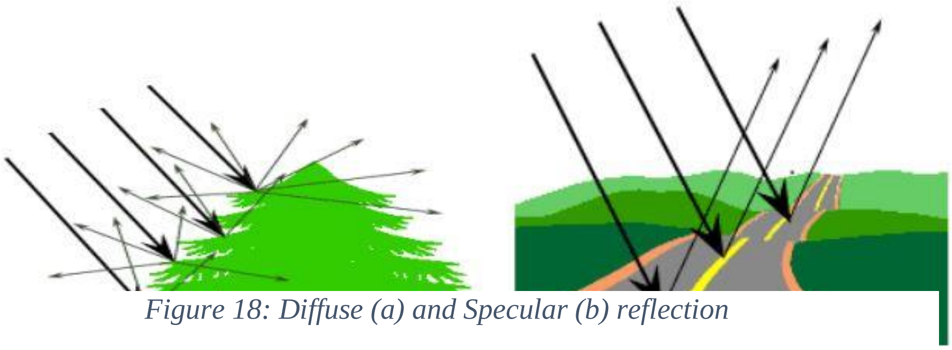


Figure 18: Diffuse (a) and Specular (b) reflection

measuring the radiation reflected from targets. We refer to two types of reflection, which represent the two extreme ends of the way in which energy is reflected from a target: **specular reflection** and **diffuse reflection**.

When a surface is smooth we get **specular or mirror-like reflection** where all (or almost all) of the energy is directed away from the surface in a single direction. **Diffuse reflection** occurs when the surface is rough and the energy is reflected almost uniformly in all directions.

Most of earth surface features lies somewhere between perfectly specular or perfectly diffuse reflectors. Whether a particular target reflects specularly or diffusely, depends on the surface roughness of the feature, its atomic and molecular structure in comparison to the wavelength of the incoming radiation.

If the wavelengths are much smaller than the surface variations or the particle sizes that make up the surface, diffuse reflection will dominate. For example, fine-grained sand would appear fairly smooth to long wavelength microwaves but would appear quite rough to the visible wavelengths.

2.9 Radiance, Irradiance, Incident, Reflectance

First requirement of RS is to have source of energy to illuminate the target unless emitted by the target. Sensors need a source of energy to illuminate the earth's surface. Natural source of energy is sun. This energy is in the form of electromagnetic radiation.

Radiance

Radiance is the variable directly measured by remote sensing instruments. Basically, you can think of radiance as how much light the instrument "sees" from the object being observed. When looking through an atmosphere, some light scattered by the atmosphere will be seen by the instrument and included in the observed radiance of the target. An atmosphere will also absorb light, which will decrease the observed radiance.

Radiance most often has units of watt/square meter.

Radiance describes the intensity of optical radiation emitted or reflected from a certain location on an emitting or reflecting surface in a particular direction.

Irradiance

Irradiance describes the amount of radiant power impinging upon a surface per unit area. Generally, the surface element can be oriented at any angle towards the direction of the beam. However, irradiance is maximized when the surface element is perpendicular to the beam.

Irradiance makes it possible, to characterize the light power which reaches a surface perpendicular to the light source per unit area.

Incident Energy

The EM radiation that actually makes it to Earth is incident energy (Ei). From here, Earth's features reflect, absorb and transmit different proportions of energy.

Reflectance

Reflectance is the ratio of the amount of electromagnetic flux reflected by a surface to the total amount of electromagnetic flux incident on the surface. Reflectance is expressed in percentage.

An object appears green because it reflects only wavelengths corresponding to green color in the visible spectrum. Thus, blue-colored objects absorb all light waves except those pertaining to blue color, and so on.

Spectral Reflectancy

Spectral reflectancy is a unique property of any object for reflection, absorption and transmission which produce a unique spectral signature of reflectance for any object in different wavelength region. It is due to difference in spectral characteristics of objects.

Reflectance measurement can be carried out in a lab (spectral libraries or in a field using spectrometer).

The reflectance with respect to the wavelength is called **spectral reflectance. Spectral reflectance curve** shows a portion of incident energy that is reflected as a function of wave length. Different materials show different spectral signature because of their unique properties.

2.10 Specular and Diffuse Reflection Surfaces

(Refer 2.8 EMR interaction with Earth Surface Materials)

2.11 Spectral Signature Curves

The spectral signature of a material may be defined in the solar-reflective region by its reflectance as a function of wavelength, measured at an appropriate spectral resolution.

The curve that is represented to show the relation of wavelength of radiation reflected with reflectance is said as the spectral signature curve.

Spectral Reflectance Curve of Different Materials

By measuring the energy that is reflected (or emitted) by each target on the earth‟s surface over a variety of different wave lengths, we can build up a spectral reflectance curve for each object.

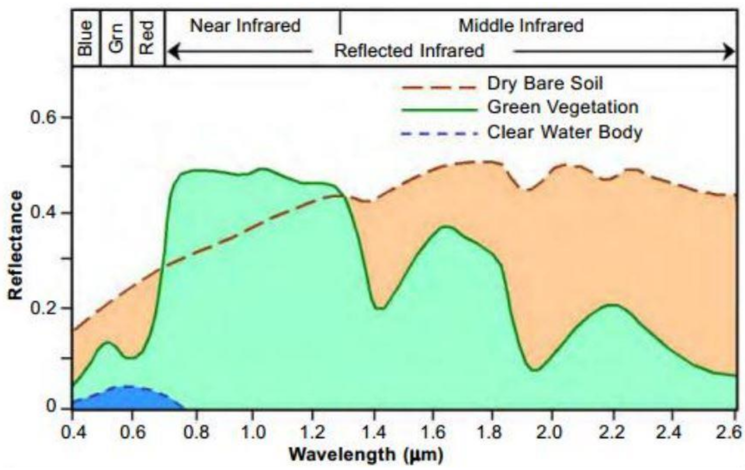
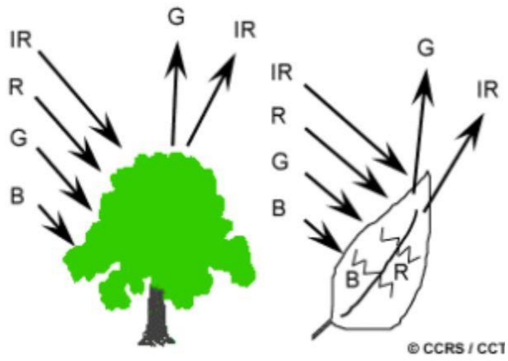


Figure 19: Spectral Reflectance curve of different material (Water, Soil and Vegetation)

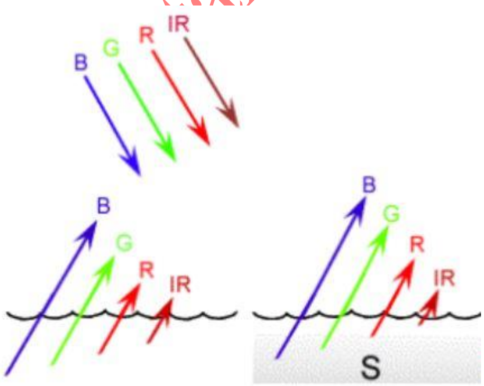
2.12 EMR interaction with Water, Soil, and Earth Surface

a. Leaves: A chemical compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths. Leaves appear "greenest" to us in the summer, when chlorophyll content is at its maximum. In autumn, there is less chlorophyll in the leaves, so there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear red or yellow (yellow is a combination of red and green wavelengths). The internal structure of healthy leaves act as excellent diffuse reflectors of near-infrared wavelengths. If our eyes were sensitive to near-infrared, trees would appear extremely bright to us at these wavelengths. In fact, measuring and monitoring the near-IR reflectance is one way that scientists can determine how healthy (or unhealthy) vegetation may be.



b. Water

Longer wavelength visible and near-infrared radiation is absorbed more by water than shorter visible wavelengths. Thus water typically looks blue or blue-green due to stronger reflectance at these shorter wavelengths, and darker if viewed at red or near-infrared wavelengths. If there are suspended sediment present in the upper layers of the water body, then this will allow better reflectivity and a brighter appearance of the water. The apparent colour of the water will show a slight shift to longer wavelengths. Suspended sediment (S) can be easily confused with shallow (but clear) water, since these two phenomena appear very similar.



Chlorophyll in algae absorbs more of the blue wavelengths and reflects the green, making the water appear more green in colour when algae is present.

The spectral reflectance of water mainly depends on:

- Material suspended on them
- Water depth
- Presence of oil
- Industrial waste
- Soil concentration

2.13 Energy Interaction in the atmosphere

Irrespective of its source, electromagnetic radiation used for remote sensing should travel through some distance, or path length, of the Earth's atmosphere. Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of Scattering, Absorption and Transmission.

A. Scattering

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere.

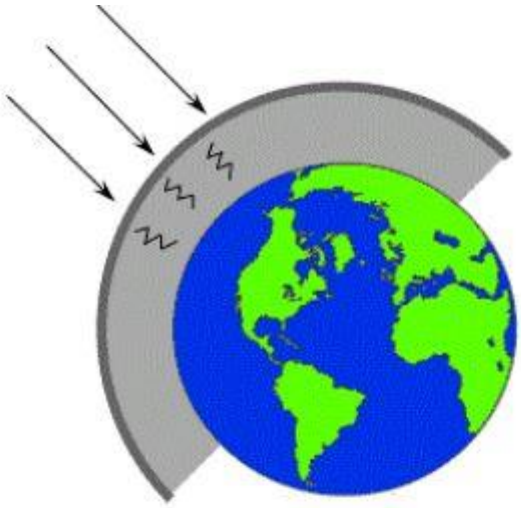


Figure 20: Scattering on Earth surface

There are three (3) types of scattering which take place.

- *Rayleigh scattering*

  (Refer Above)

- Mie scattering

  (Refer Above)

- Nonselective scattering

  (Refer Above)

B. Absorption

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapor are the three main atmospheric constituents which absorb radiation.

Ozone serves to absorb the harmful (to most living things) ultraviolet radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight. You may have heard carbon dioxide referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere.

Water vapour in the atmosphere absorbs much of the incoming long wave infrared and shortwave microwave radiation. The presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e. high humidity).

C. Transmission

Transmission is that process in the atmosphere in which the energy besides absorbed and scattered are transmitted through the atmosphere and reach to the earth surface. Atmospheric window allows energy to be transmitted

Exercises

Q.No.1 What is electromagnetic radiation? What role does electromagnetic radiation play in remote sensing?

Ans.

Electromagnetic radiation:

(Refer Note)

Role of electromagnetic radiation in remote sensing:

The first requirement for remote sensing is to have an energy source to illuminate the target; unless the remotely sensed energy is being emitted by the target itself. Just as our eyes need objects to be illuminated by light so that we can see them, sensors also need a source of energy to illuminate the earth's surface. The sun (natural source) and artificial energy sources are used in remote sensing. Whether the energy is radiated from an external (natural or artificial) source or emitted from the object itself, it is in the form of electromagnetic radiation, which illuminates things and makes remote sensing (acquiring information about things from distance) possible.

Q.No.2 Completely illustrate how visible, infrared and microwave part of the spectrum is used in remote sensing with the different specific bands.

Q.No.3 Define atmospheric window and its importance in remote sensing.

Q.No.4 What is the electromagnetic spectrum?

Q.No.5 What are the two models of electromagnetic radiation? Explain each of them.

Q.No.6 Derive the relation amongst the wavelength, frequency, and the energy content of the photon.

Q.No.7 Explain various interactions of incident EM energy with the atmosphere.

Q.No.8 What is the spectral reflectance curve and what are its utilities in remote sensing?

Q.No.9 Discuss the spectral reflectance characteristics of water and vegetation in different spectral bands.

Q. No10 Describe the relations among wavelength, frequency, and energy.

Q. No11 Derive the wavelength for the frequency of 40 GHZ and derive the frequency for the wavelength of 1.19 cm. Consider the velocity of light as $3*10^8$ m/s.

Q.No.12 Calculate the energy content in the photons for the wavelength of 1.2 cm.

Q.No. 13 Calculate the frequency and amount of radiant energy for the wavelength of 1 mm. Consider the speed of light as $3*10^8$ m/s, and plank's constant as $6.6260*10^{-34}$ J.

Q.No. 14 Why water appears very dark and vegetation appears extremely bright compared to other earth surface features on the image captured in NIR band? If we have three images of a forested land captured in red, green, and blue bands, how can we identify in which band which image has been captured?

Q.No 15 Explain the electromagnetic spectrum with proper illustration and designation of bands in respect of remote sensing.

Q.No 16 Differentiate Rayleigh, Mie and Non-Selective Scattering.

Q.No 17 Why does the sky appears "blue" during the day and “reddish” during sunset or sunrise?

Q.No 18 Why does the fog and clouds appear white to our eyes?

Q.No 19 What are the characteristics of the atmosphere?

Q.No 20 Explain the different regions of the electromagnetic spectrum with their prominent features.

Q.No 21 Explain different wavelength regions used in remote sensing and their application.

Q.No. 22 Explain EMR interaction with water vapor and ozone.

Q.No 23 Explain the interaction of EM energy with target.

Q.No 24 What is specular reflection and diffuse reflection? Explain the conditions of specular and diffuse reflection. At what condition diffuse reflection will dominate over specular reflection.

Q.No 25 How is the reflection from earth surface features lies? At what factors does the reflection from the target depends upon?

Q.No 26 Write short notes on following topics

a. EMR
b. Wavelength
c. Frequency
d. Radiance
e. Irradiance
f. Incident Energy
g. Reflectance
h. Spectral reflectancy
i. Spectral reflectance
j. Spectral reflectance curve
k. Specular and Diffuse Reflection Surfaces
l. Spectral signature
m. Spectral signature curve

Q.No 27 What is spectral reflectance curve? Explain the spectral reflectance curve of the vegetation and water with the spectral reflectance curve.

Q.No 28 Why do the leaves appear "greenest" to us in the summer, while in autumn, appear red or yellow?

Unit 3

Sensor and Platform

Unit 3: Sensor and Platform **[8 Hrs.]**

3.1. Platforms
3.2. Passive and Active Sensors
3.3. Resolution: Spatial, Spectral, Radiometric, and Temporal
3.4. Satellite Orbits
3.5. Orbit Parameters
3.6. Types of satellite orbits
3.7. Some operational multispectral sensors

3.1. Platforms

Sensors used in RS can be operated at altitudes ranging from just a few centimeters above the ground-using field equipment- to those far beyond the atmosphere. Very often the sensor is mounted on a moving vehicle such as an aircraft or a satellite. Occasionally, static platforms are used. For example, a spectrometer mounted on a pole to monitor a specific crop over a whole season.

The place where the sensor resides, remote from the target or surface being observed is **platform.** In order for a sensor to collect and record energy reflected or emitted from a target or surface, it must reside on a stable platform removed from the target or surface being observed. Very often sensor is mounted on a moving vehicle which we call a platform. Platforms for remote sensors may be situated on the ground, on an aircraft or balloon (or some other platform within the Earth's atmosphere), or on a spacecraft or satellite outside of the Earth's atmosphere.

3.1.1. Remote sensing Platforms

There are three main categories of remote sensing platforms.

a. **Ground-Based RS Platform**
Ground-based sensors are often used to record detailed information about the surface which is compared with information collected from aircraft or satellite sensors. In some cases, this can be used to better characterize the target which is being imaged by these other sensors, making it possible to better understand the information in the imagery. Sensors may be placed on a ladder, scaffolding, tall building, cherry-picker, crane, etc.

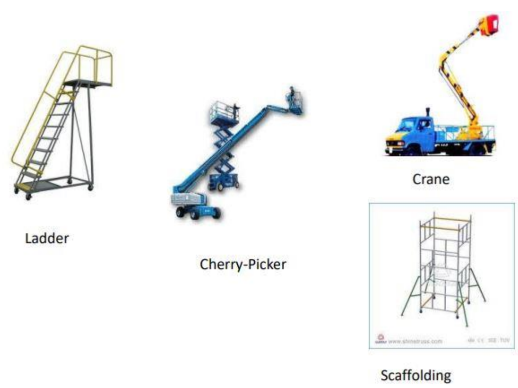


Figure 1: Ground-based remote sensing platform

b. **Airborne Remote Sensing Platform**

Airborne remote sensing is carried out using different types of aircrafts like helicopter, aeroplane etc. As the sensors is mounted on the aircraft an altitude of the aircraft is carefully chosen as it influences the scale and the resolution of the image. Orientation of an aircraft is another factor which affects the geometrical characteristics of the remote sensing data. Since sensors are placed at lower altitude less spatial coverage is achieved.Ex. AVIRIS(Airborne Visible Infrared Imaging Spectrometer).

Figure 2: Airborne Remote Sensing Platform

c. **Spaceborne Remote Sensing Platform**

Spaceborne remote sensing is carried out using sensors that are mounted on satellite, space vehicles and space shuttles. The monitoring capabilities of the sensor are determined by satellite's orbit. Different types of orbits are required to achieve continuous monitoring of the phenomenon. Since sensors are placed at higher altitude more spatial coverage is achieved.

Figure 3: Spaceborne RS platform

Comparison between aerial and satellite surveys

A key advantage of aerial surveys is that they can be "targeted". The survey can be undertaken at exactly the required time and required spatial resolution by having the aircraft fly at the required altitude. Moreover, in comparison with civilian satellite RS, we can acquire images of much higher spatial resolution, enabling recognition of objects of much smaller size. We can achieve a pixel size on the ground as small as 5 cm with current aerial survey cameras.

Satellites have the advantage of continuity over aerial surveys. Example: Meteosat-9 delivers a new image of the same area every 15 minutes and it has done so every day for many years. Satellites provide high temporal resolution at low cost but with low spatial resolution.

Aerial surveys have been restricted in some countries where access to satellite RS data is commonly easier.

3.2. Sensor

A sensor is a device that measures and records the electromagnetic energy that is reflected from or emitted by the earth's surface. The sensor thus detects the amount of energy emitted/reflected from the earth's surface.

The sensor can be differentiated according to the source of energy and mode of scanning.

A. Depending upon the source of energy

i. Active Sensor

ii. Passive Sensor

An **active sensor** is a sensing device that requires an external source of power to operate which simply detects and responds to some type of input from the physical environment. The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.

An advantage of **active sensors** is that they can be used at any time of the day as it does not require natural light.

Normally longer wavelengths are used by the **active sensor** so there is less effect of dust, smoke, and other particles in the atmosphere. Measurements are more controlled in this type of sensor as they don't depend on varying illumination conditions. These sensors can also examine wavelengths that are not sufficiently provided by the sun (microwaves).

Examples of other **active sensor**-based technologies include scanning electron microscopes, LiDAR, radar, GPS, x-ray, sonar.

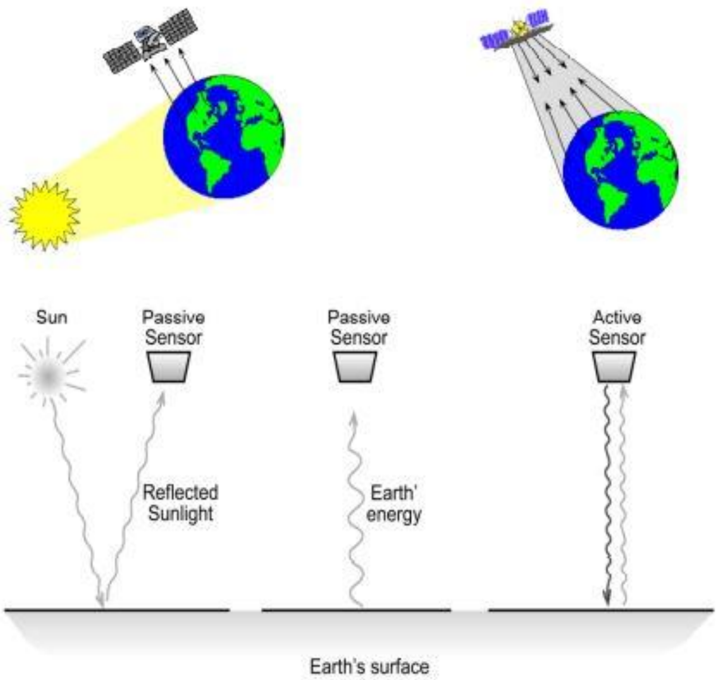


Figure 4: Passive and Active Remote Sensing

Remote sensing systems which measure energy that is naturally available are called **passive sensors**. The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then re-emitted, as it is for thermal infrared wavelengths. For all reflected energy, this can only take place during the time when the sun is illuminating the Earth. As there is no reflected energy available from the sun at night. On the other hand, energy that is naturally emitted (such as thermal infrared) can be detected day or night, as long as the amount of energy is large enough to be recorded. Normally shorter wavelengths are used by the **passive sensor** therefore clouds, dust, smoke, and other particles in the atmosphere can block reflected energy from target to sensor. Measurements of **passive sensor** are less controlled because of varying illumination condition. Multispectral and hyperspectral are example passive remote sensing products.

A camera provides an excellent example of both **passive and active sensors**. During a bright sunny day, enough sunlight is illuminating the targets and then reflecting toward the camera lens, that the camera simply records the radiation provided (passive mode). On a cloudy day or inside a room, there is often not enough sunlight for the camera to record the targets adequately. Instead, it uses its own energy source - a flash - to illuminate the targets and record the radiation reflected from them (active mode).

B. Depending upon the method of scanning

a. Across track scanning sensor (Whiskbroom)

The whiskbroom sensor unlike the push broom sensor uses rotating mechanisms to scan a pixel array across its Field-of-View covering a ground swath. Whiskbroom scanner is a combination of a single detector and a rotating mirror arranged in such a way that the detector beam sweeps in a straight line across the track of the satellite path at each rotation of the earth. As the platform moves forward over the Earth, successive scans build up a two-dimensional image of the Earth´s surface. The scan pixel array consists of only a single spatial pixel. Note, however, that for multi-spectral systems a prism splits the incoming light into different spectral bands that record energy in separate detectors that all represent the same small area on the ground. The mirror moves back and forth, to collect measurements from one pixel in the image at a time. The moving parts make this type of sensor expensive and more likely to wear out. This creates spatial distortions which must be corrected by image pre-processing.

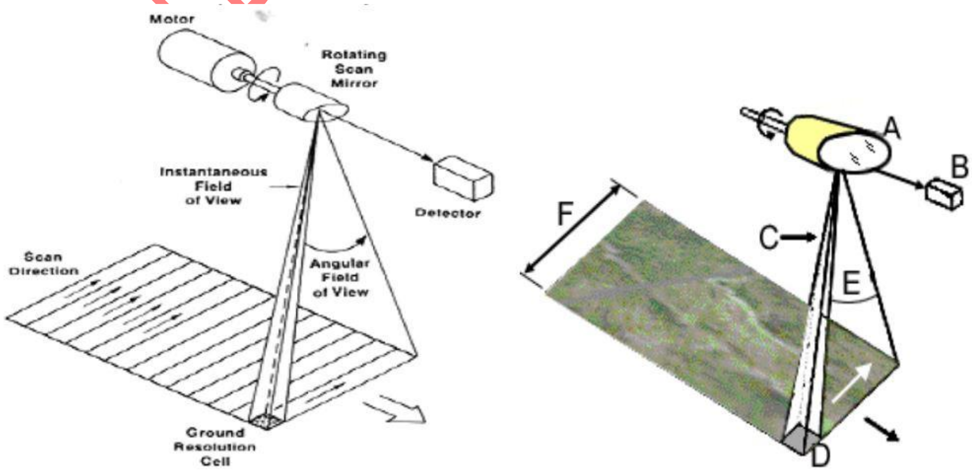


Figure 5: Cross-Track (Whisk Broom) Sensor

b. Along track scanning system (push broom)

A push broom sensor is a digital collector with a linear collection array made up of a line of elements, or picture elements (pixels), at the focal plane to scan over a two-dimensional scene. Instead of a scanning mirror, push broom sensor use these linear arrays of detectors that are "pushed" along in the flight track direction. Image is built up by the movement of the satellite along its orbital track. As the platform travels along its trajectory, a strip image of the terrain is acquired as the array sweeps forward, one line for each framelet imaged by the array. Area array can also be used for multi-spectral remote sensing. The push broom sensor records one entire line at a time this enables a longer period of measurement over an area resulting in less noise and relatively stable geometry. They have higher reliability and a longer life expectancy than whiskbroom. It has higher spatial and radiometric resolution with high geometric integrity.

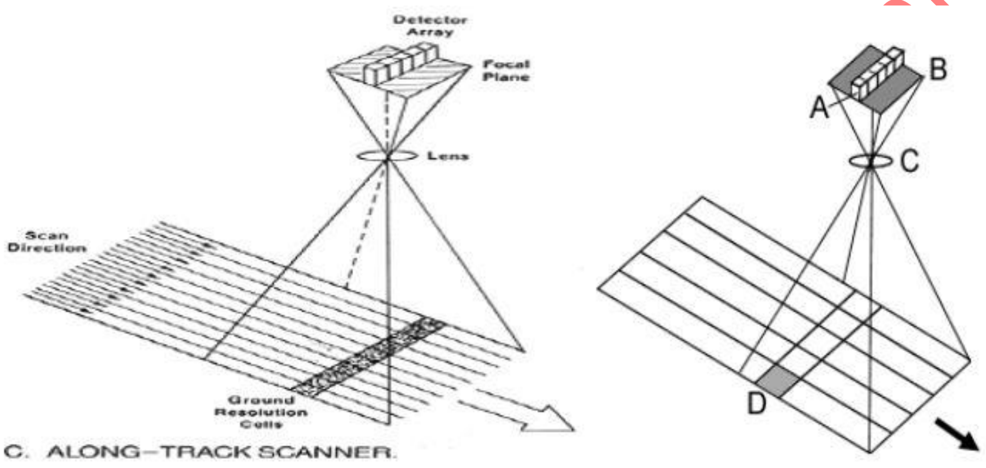


Figure 6: Along track (Push-Broom) Sensor

Whiskbroom Sensor	Pushbroom Sensor
It has wide swath width	It has a narrow swath width
It has the complex mechanical system	It has a simple mechanical system
It has the simple optical system	It has the complex optical system
It consists of filters and sensors	It consists of Dispersion grating and CCDs
Its dwell time is shorter	Its dwell time is longer
It encompasses Pixel distortion	It has no pixel distortion

Table 1: Whiskbroom Vs Pushbroom Sensor

3.3. Resolution

“The ability of an imaging system to record fine details in a distinguishable manner” (Estes and Simonett, 1975)

In general, resolution is defined as the ability of an entire remote-sensing system, including lens, antennae, display, exposure, processing, and other factors, to render a sharply-defined image. Resolution of a remote-sensing system is of different types.

a. Spatial (objects in ground)

b. Spectral (portion of EMR)

c. Radiometric (level of signal)

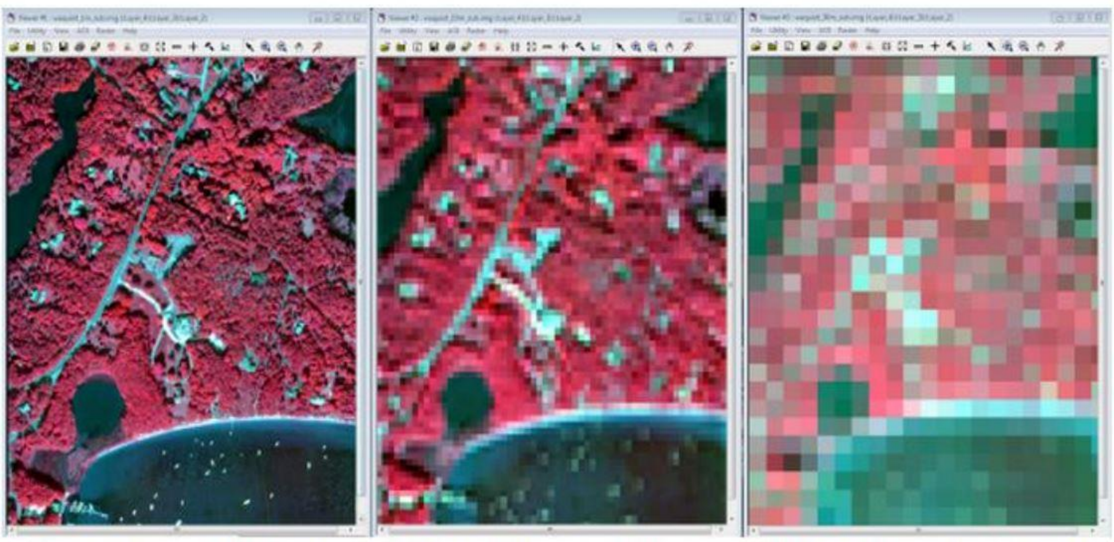
d. Temporal (Sensor Visit)

a. Spatial Resolution

Spatial resolution is a term that refers to the number of pixels utilized in the construction of a digital image. Images having higher spatial resolution are composed with a greater number of pixels than those of lower spatial resolution.

Spatial resolution describes the ability of a sensor to identify the smallest size detail of a pattern on an image. In other words, the distance between distinguishable patterns or objects in an image can be separated from each other and is often expressed in meters. While the distinguishable detail is dependent on the size of the image pixel, the size of an object that can be seen in an image and the size of a single pixel in an image are different. It refers to the size of the smallest possible feature that can be detected.

Detailed mapping of land use practices requires much greater spatial resolution than observing large areas. The same area of the higher spatial resolution contains more pixels than the lower resolution.



Waquiot Bay, MA NAIP aerial imagery in its native 1m format (left) compared to a 10m (middle) and 30m (right) version of the same data. While visual differences are easy to see, the file sizes also change from 2.5MB to 39kB to 23kB.

Figure 7: Appearance of image of Waquiot Bay under Different Spatial Resolution

b. Spectral Resolution

Spectral resolution describes the ability of the sensor to define fine wavelength intervals. It describes the way an optical sensor responds to various wavelengths of light. High spectral resolution means that the sensor distinguishes between very narrow bands of wavelength; low spectral resolution means the sensor records the energy in a wide band of wavelengths as a single measurement. The spectral resolution required by the analyst or researcher depends upon the application involved. Spectral resolution is an important experimental parameter. If the resolution is too low, spectral information will be lost, preventing correct identification and characterization of the sample. If the resolution is too high, total measurement time can be longer than necessary. What makes resolution "too low" or "too high" depends upon the particular application, and what information is desired from the experiment.

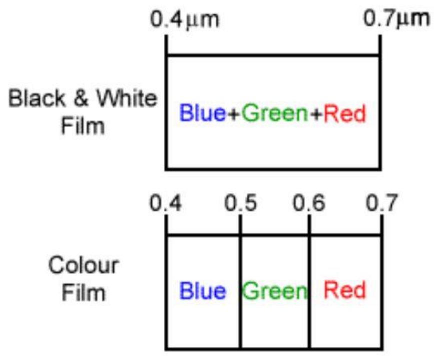


Figure 8: Wavelength Range of Panchromatic and Colour Image)

B/W (Panchromatic) sensor which covers a wide spectral range, the visible portion of EM spectrum has course (lower) spectral resolution because it records entire visible portion not individual bands. But in color image spectral resolution is fine (higher) because it records reflected energy at blue, green and red wavelength of spectrum.

c. Radiometric Resolution

Radiometric Resolution Refers to the ability of a sensor to detect differences in energy magnitude. It is often called contrast. It describes the ability of the sensor to measure the signal strength or brightness of objects. Sensors with low radiometric resolution are able to detect only relatively large differences in the amount of energy received; sensors with high radiometric resolution are able to detect relatively small differences. The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in energy. The more levels, the more detail can be expressed. Most remote sensing imagery is recorded with quantized levels in the 0 – 255 (8-bit) range.

Figure 9: Appearance of Image in different radiometric resolution)

d. Temporal Resolution

Temporal resolution is defined as the amount of time needed to revisit and acquire data for the exact same location. When applied to remote sensing, this amount of time depends on the orbital characteristics of the sensor platform as well as sensor characteristics. The temporal resolution is high when the revisiting delay is low and vice-versa. Temporal resolution is usually expressed in days. The temporal resolution of a satellite sensor may vary from hours to days. It depends on if the platform orbit is geostationary or not.

Moreover, a sun-synchronous orbit follows sun illumination and allows image acquisition at the same time of the day for a location. This characteristic is particularly important for visible-infrared sensors as it makes every image usable (i. e. avoiding image acquisitions during the night) and it, therefore, maximizes the temporal resolution of the sensor.

Some of the satellites and their temporal resolution are as follows.

- Landsat: 16 days
- MODIS: 14 days
- Sentinel: 10 days

3.4. Satellite Orbits

The path followed by a satellite is referred to as its Orbit. It is a circular path described by the satellite in its revolution about the earth.

Orbit selection can vary in terms of altitude (their height above the Earth's surface) and their orientation and rotation relative to the Earth.

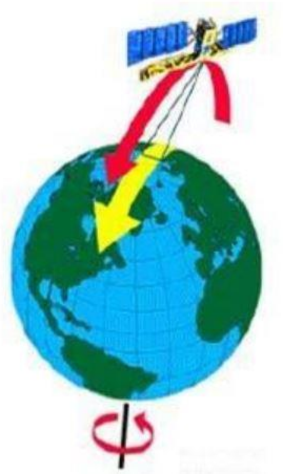
The satellite orbits are always determined by Kepler's law. As time elapses, satellites are always perturbed by gravitational irregularities and friction, so ranging and repositioning are required for satellites to maintain their orbit.

3.6. Types of satellite orbits

Satellite orbit can be classified under two headings, namely, sun-synchronous and Geo-stationary satellite orbit.

a. **Sun-synchronous satellite orbit**

A sun-synchronous orbit is an orbit around the Earth, where the movement of the satellite always looks the same when viewed from the Sun. These orbits are used for satellites that need a constant amount of sunlight. Satellites that take pictures of the Earth would work best with bright sunlight. These satellites orbit at an altitude between 600 to 1000 km with an orbital inclination measured against the equatorial plane i.e., 98 to 99 degrees. The satellites always fly over a particular section always at a specific local time. Most satellites in this orbit cross the equator at mid-morning at around 10:30 am. This orbit allows recording images at 2 fixed times in a day i.e., in the day time and at night time (for thermal or radar). Satellite placed in this orbit is used for earth monitoring (global coverage) and has a good spatial resolution.

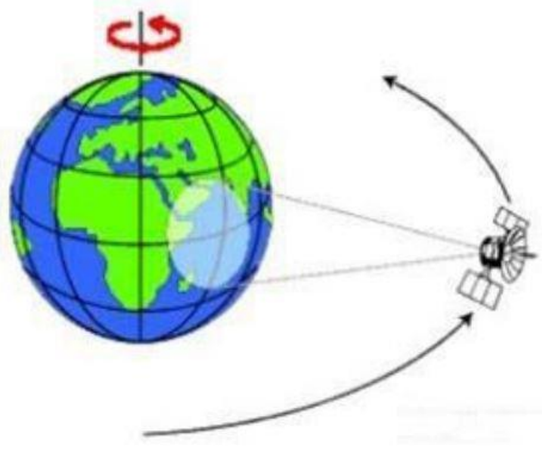


Sun-synchronous satellite orbit

b. **Geostationary satellite orbit**

A satellite in a geostationary orbit appears to remain in the same spot in the sky all the time. Really, it is simply traveling at exactly the same speed as the Earth is rotating below it, but it looks like it is staying still regardless of the direction in which it travels, east or west. A satellite in geostationary orbit is very high up, at 36,000 km above the Earth. Geostationary orbits, therefore, are also known as high orbits. Each satellite can only cover about 25-30%

of the earth's surface. Geostationary satellites are always located directly above the equator with a zero angle of inclination. A geostationary orbit, therefore, is really just a special type of equatorial orbit. This allows the satellite to observe and collect information continuously over specific areas. Due to their high altitude, some satellites can monitor weather and cloud patterns covering the entire hemisphere of the earth. Weather and communication satellites commonly have these types of orbits Such as GMS, GEOS, METEOSAT, INSAT.

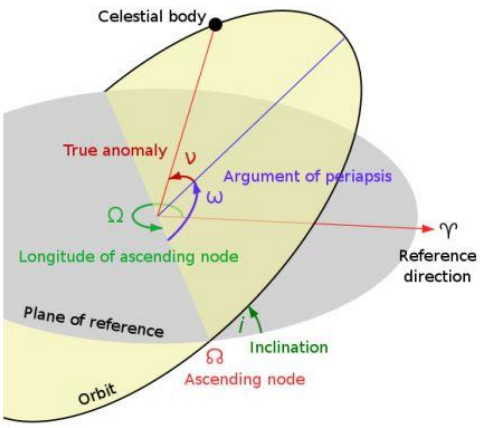


Geostationary satellite orbit

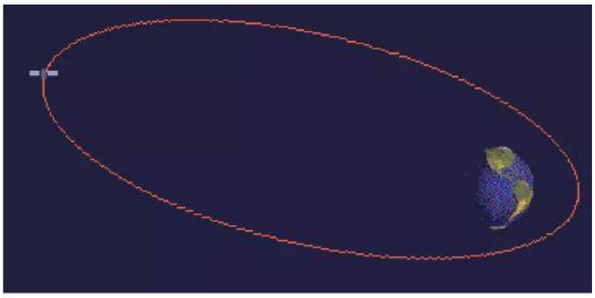
3.5. Orbit Parameters

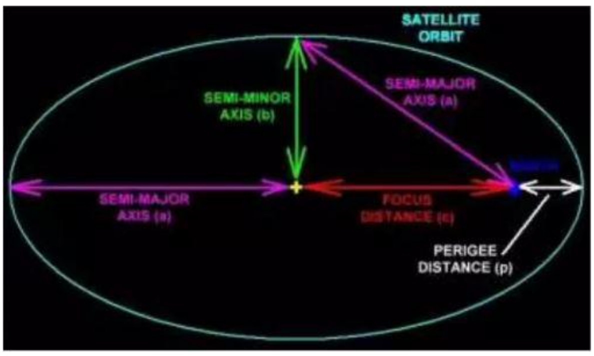
Orbital elements of a satellite required to uniquely identify a specific orbit are called orbital parameters. In astronomy and orbital mechanics, there are overall six parameters used to define an orbit. These are:

i. Semi-major axis (a)
ii. Eccentricity (e)
iii. Inclination or tilt (i)
iv. Longitude of the ascending node (Ω)
v. Argument of periapsis (ω)
vi. Mean anomaly at epoch (ν)



The orbital plane (yellow) intersects a reference plane (grey). The reference plane in the case of earth-orbiting satellites is usually the Earth's *equatorial plane*. The intersection is called the line of the node, as it connects the center of mass with the ascending and descending nodes.

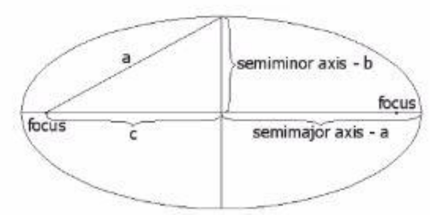




i. **Semi-Major Axis**

Semi-major axis is half of the length of the orbit's major axis. It is denoted by the letter 'a'.

ii. Eccentricity



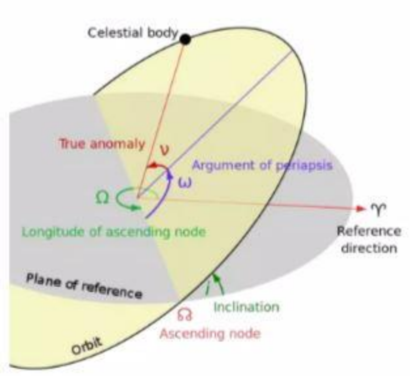
Eccentricity is a measure of the elongation of an orbit. The eccentricity of an orbit is the ratio of the distances from the center of the ellipse to one of the foci and to one of the vertices of the ellipse. It is denoted by ‘e’.

$$e = \sqrt{1 - \left(\frac{b}{a}\right)^2}$$

iii. Inclination or tilt

Inclination or tilt is the angle between the orbital plane and the reference plane. It is always measured counterclockwise from the east. It is measured in degrees (˚). It is denoted by ‘i’.

iv. Longitude of the ascending node (Ω)

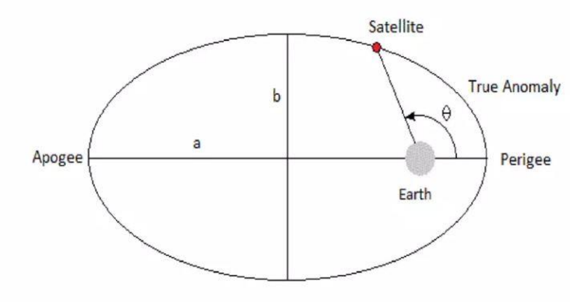


The angle from the origin of the longitude of the reference plane to the orbit’s ascending node is called longitude of the ascending node. It is the point in its orbit where the orbiting body crosses the reference plane going upward. It is denoted by ‘Ω’.

v. Argument of periapsis (ω)

It is the angle from the ascending node to the perigee measured in the orbital plane. It is denoted by ‘ω’.

vi. Mean Anomaly at epoch



A set of orbital elements is a snapshot, at a particular time, of the orbit of a satellite. Epoch is a number simply stating the time at which that snapshot was taken. Mean anomaly simply states the location of the satellite with respect to perigee. It is zero at perigee.

3.7 Some operational multispectral sensors

Different Multispectral scanner platforms scans for different wavelength ranges and named as different bands. Some of sensor platform and their band are shown in figure below.

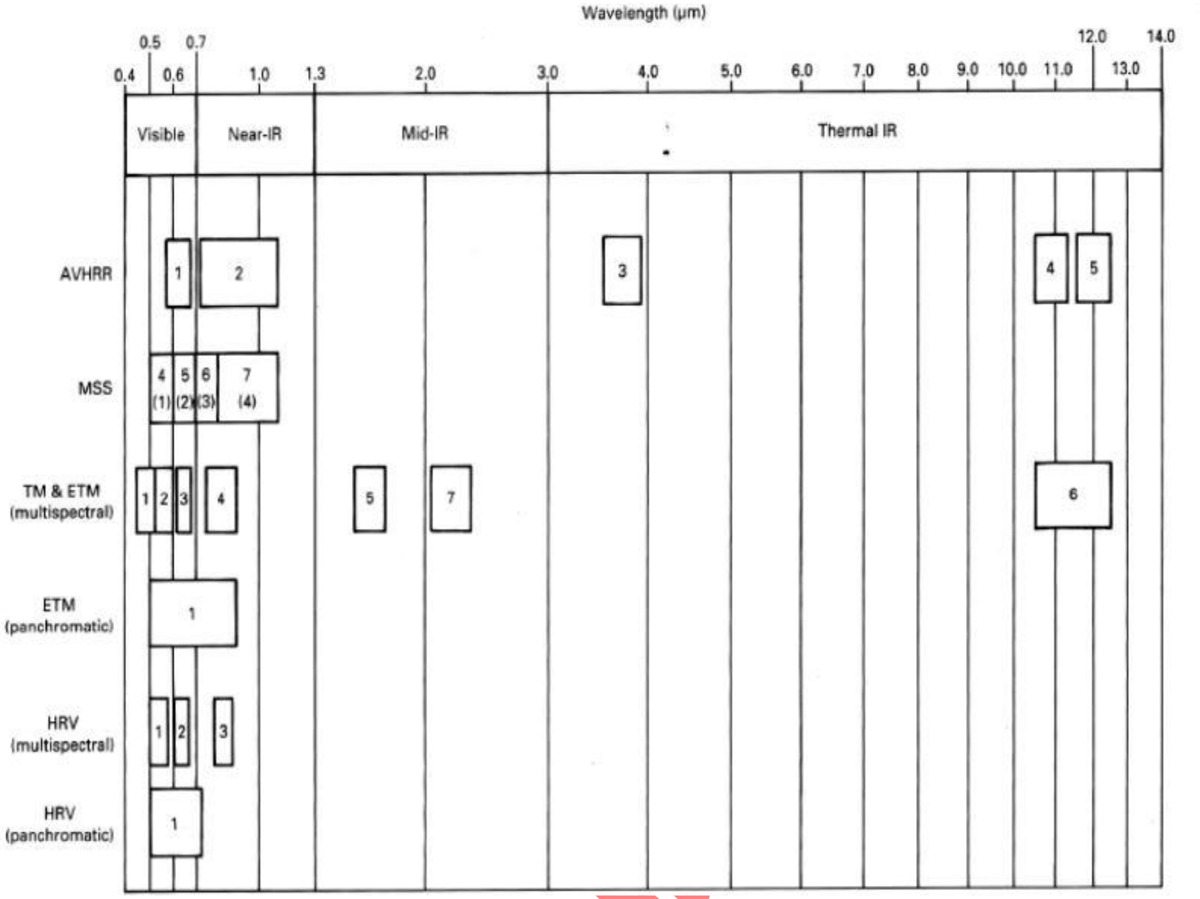


Figure 10: Some operational Multispectral sensors

Platform	Sensor	Resolution	Bands	Swath	Angle	Revisit
Landsat 4 &5	TM	30 m	7	185 km	No	16 days
IRS 1C &1D	LISS-3	24 m	4	142 km	No	24 days
Landsat 7	ETM+	15m (PAN)	8	185 km	No	16 days
Spot 1-3	HRV	10 m (PAN)	3	60 km	±27°	4-6 days
Spot 4	HRVIR	10 m	4	60 km	±27°	4-6 days
		(PAN)				
Terra (EOS AM-1)	ASTER	20 m	14	60 km	±24°	5 days

Table 2: Some Medium Resolution Sensors

Platform	Sensor	Resolution	Bands	Swath	Angle	Revisit
IRS 1C &1D	PAN	5.8 m	1	70 km	±26°	5 days
Cosmos	KVR-1000	2 m	1	160 km	No	N/A
EROS A1	CCD	1 m	1	12.5 km	±45°	3 days
Ikonos	OSA	1 m	4	11 km	±45°	1-3 days
QuickBird*	QBP	1 m	4	27 km	±30°	1-3 Days

Table 3: Some High-Resolution Sensors

* - not operational at 1-10-1999

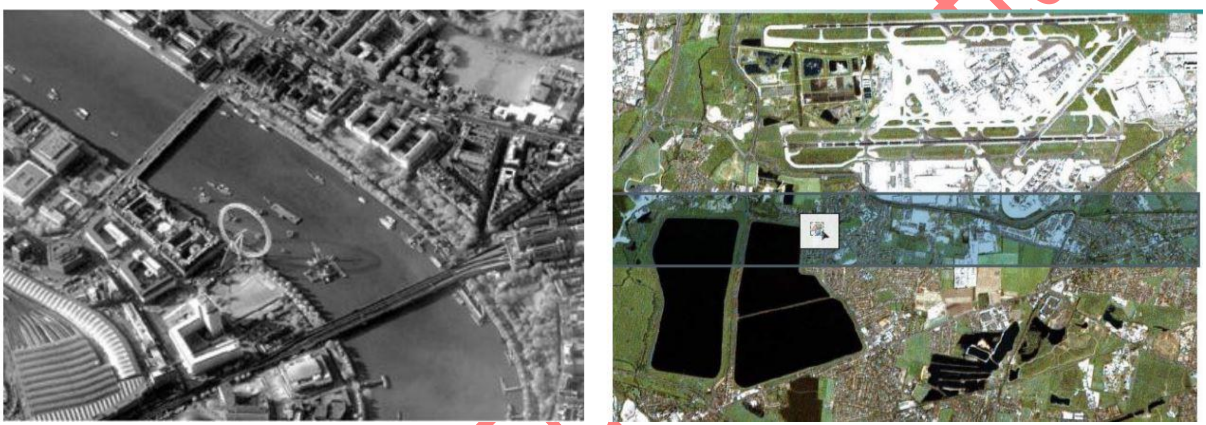


Figure 11: : High Resolution from Space: IKONOS panchromatic 1 m resolution London (figure a) and : IRS, 5.8m resolution (coloured with 24m resolution) (figure b)

(IKONOS satellite is the world‟s first commercial satellite to collect black and white images with 1 meter resolution and multispectral imagery with 4 meter resolution. IKONOS was launched ion September 24, 1999 from Space Launch Complex 6(SLC-6) at Vandenberg Air Force Base in California.

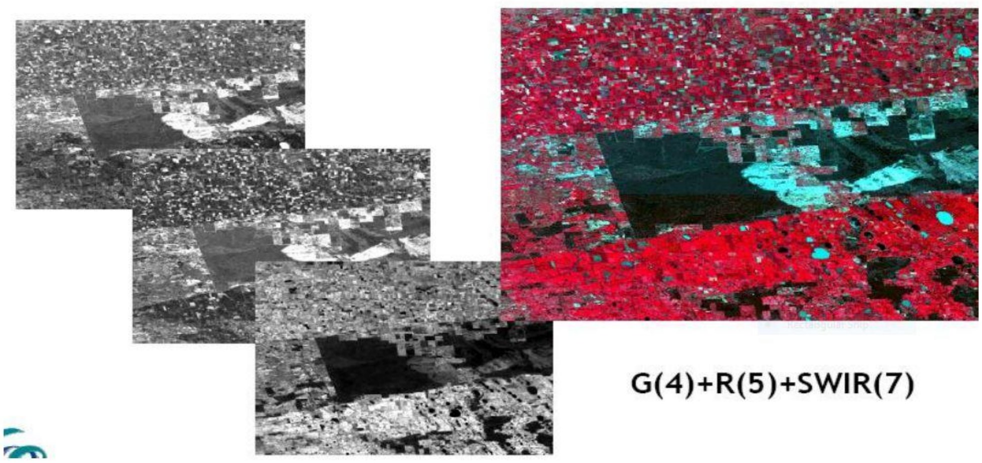


Figure 12: Landsat TM (30 m)

Figure 13: : Landsat ETM+ (30m + 15m combined)

LANDSAT-8
Launch: February 11, 2013
Operational Land Imager (OLI)
Thermal Infrared Sensor (TIRS)

OLI and TIRS band designations.

Spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 1–coastal/aerosol	0.43–0.45	30	Increased coastal zone observations.
Band 2–blue	0.45–0.51	30	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation.
Band 3–green	0.53–0.59	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 4–red	0.64–0.67	30	Emphasizes vegetation slopes.
Band 5–near IR	0.85–0.88	30	Emphasizes vegetation boundary between land and water, and landforms.
Band 6–SWIR 1	1.57–1.65	30	Used in detecting plant drought stress and delineating burnt areas and fire-affected vegetation, and is also sensitive to the thermal radiation emitted by intense fires; can be used to detect active fires, especially during nighttime when the background interference from SWIR in reflected sunlight is absent.
Band 7–SWIR-1	2.11–2.29	30	Used in detecting drought stress, burnt and fire-affected areas, and can be used to detect active fires, especially at nighttime.
Band 8–panchromatic	0.50–0.68	15	Useful in 'sharpening' multispectral images.
Band 9–cirrus	1.36–1.38	30	Useful in detecting cirrus clouds.
Band 10–TIRS 1	10.60–11.19	100	Useful for mapping thermal differences in water currents, monitoring fires and other night studies, and estimating soil moisture.
Band 11–TIRS 2	11.50–12.51	100	Same as band 10.

Instrument-specific relative spectral response functions may be viewed and compared using the Spectral Viewer tool: *http://landsat.usgs.gov/tools_spectralViewer.php*.

Figure 14: Landsat-8 with its different wavelength band and its resolution and use.

Exercises

Q.No. 1 What do you mean by the platform in remote sensing? Briefly explain the types of sensor platforms used in remote sensing.

Q.No. 2 Compare and contrast aerial and satellite surveys.

Q.No 3 Show your acquaintance towards remote sensing sensor and discuss how sensors can be classified based upon the source of energy in a comprehensive fashion.

Q.No 4 Briefly explain across track scanner and along track scanner. Which one is more advantageous and explain the reason, and why? (Hint: Explain the last part question based on the advantages and disadvantages of the across-track scanner and along-track scanner)

Q.No 5 Introduce the term 'resolution' in remote sensing. Explain in brief the different categories of resolution used in remote sensing to describe the satellite imageries.

Q.No. 6 Show the similarities and dissimilarities between the across-track scanner and the along-track scanner.

Q.No 7 Why Whiskbroom Sensor is called Across-track scanning sensor and Pushbroom Sensor, along track scanning sensor?

Q.No 8 Show your familiarity towards satellite orbits and what are the different types of orbits used to describe the movement of the satellites in an orbit. Describe each of them in a comprehensive way.

Q.No 9 Show the distinction between Sun-synchronous satellite orbit and Geostationary satellite orbit.

Q. No 10 There are different elements that uniquely characterize a specific orbit of the remote sensing satellite, what do you call these elements in astronomy and orbital mechanics? List out these elements used to define a satellite orbit and explain each of them with necessary figures and mathematical relationships.

Q. No 11 What do you understand by the multispectral sensor in remote sensing? Tabulate the most popular, operational multispectral sensors used for the acquisition of the imageries, with their key features (e.g platforms where sensor is being used, resolution of imageries being acquired by the sensor, bands, swath, angle, and temporal resolution (revisit time) of the satellite.

Unit 4

Pre-processing

Unit 4: Pre-processing [10 Hrs.]

4.1 Image Enhancement
4.2 Visualization of Image data
4.3 Histogram and histogram operations
4.4 Filtering
4.5 Radiometric distortions and corrections
4.6 Geometric Distortions and correction

Background

Digital image data are usually remotely sensed data, and as such, the data processing in remote sensing is referred as **digital image processing (DIP).** The DIP consists of the application of algorithms on digital images to process, analyze and extract information of interest by manipulation and interpretation of the images. Digital image processing is usually done using a raster data structure—each image is treated as an array of values. The steps involved in digital image processing are presented in the figure.

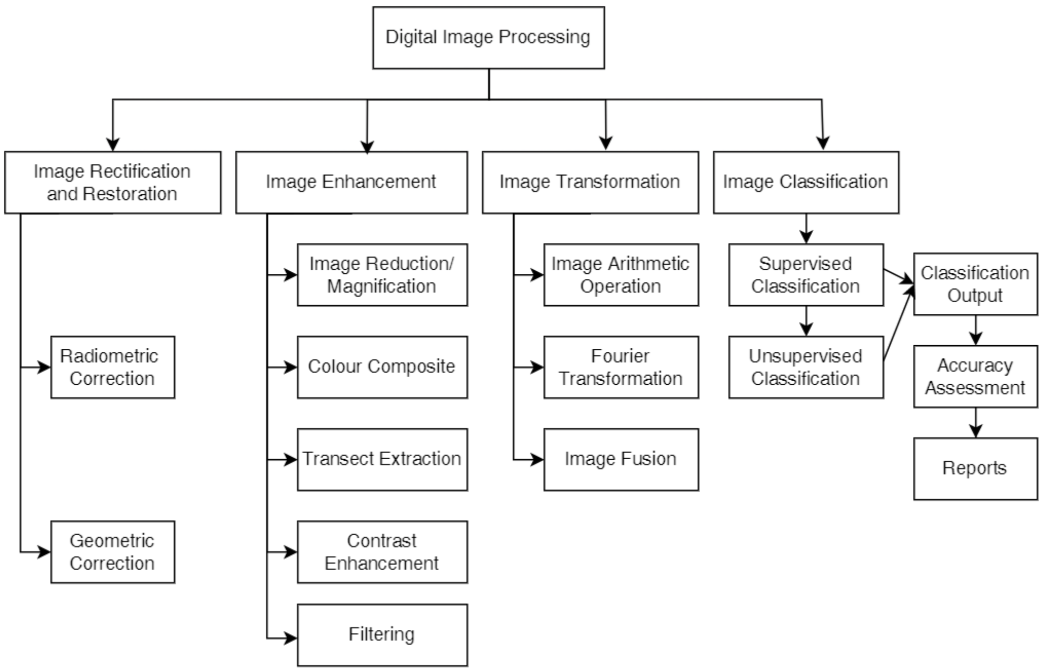


Figure 1: Steps involved in Digital Image Processing

The raw data received from the imaging sensors, on the satellite platforms contain flaws and deficiencies and therefore, need processing, to get the originality of the data. The steps involved may vary from image to image depending on the type of the image format, the initial condition of the image, composition of the image, and the information of the interest. The image analyst examines the images to identify objects and judge their significance through feature extraction, segmentation, and classification.

Digital Image Processing focuses on two major tasks

- Improvement of pictorial information for human interpretation
- Processing of image data for storage, transmission, and representation for autonomous machine perception

When the image processing ends, image analysis and computer vision start.

The geometric correction of image data is an **important prerequisite** that must be performed prior to using images in geographical information systems (GIS) and other image processing programs. To process the data with other data or maps in a GIS, all of the data must have the same reference system. A geographic correction, also called **geo-referencing,** is a procedure where the content of a map will be assigned a spatial coordinate system (e.g. geographic latitude and longitude).

Prior to image analysis, initial processing on the raw data is carried out to correct for any distortion due to the characteristics of the imaging system and imaging condition. Depending on the user's requirement, some standard correction procedures may be carried out by the **ground station operators** before the data is delivered to the end-user. These procedures include **radiometric correction** to correct for uneven sensor response over the whole image and **geometric correction** to correct for the *geometric distortion due to the Earth's rotation and other imaging conditions (such as oblique viewing).*

The image may also be transformed to conform to a specific map projection system. Furthermore, if accurate geographical location of an area on the image needs to be known, ground control points (GCPs) are used to register the image to a precise map (**geo-referencing**).

Digital image processing can be classified into mainly two phases viz. ***image pre-processing and image enhancement.***

In **image pre-processing**, attempts are made to rectify geometric distortions and radiometric characteristics. And in the phase of **image enhancement**, images are manipulated for making them visually pleasant and interpretable.

Digital image processing can thus be categorized as:

- ✓ Preprocessing
    - Radiometric correction
    - Geometric correction
- ✓ Image Enhancement

4.5 Pre-processing

In their raw form, as received from the imaging sensors mounted on satellite/aerial platforms, remotely sensed data generally contains flaws or deficiencies. The correction of deficiencies and the removal of the flaws present in the data are called **pre-processing** (sometimes referred to as image restoration or image correction or image rectification). Pre-processing consists of those operations that prepare data for the subsequent analysis which attempts to correct or compensate for systematic/non-systematic errors.

Among the programs that optimize these values are

- ✓ Atmospheric correction (affecting the DNs of surface materials because if the radiance from the atmosphere itself, involving the attenuation and scattering)
- ✓ Sun-illumination geometry
- ✓ Surface-induced geometric distortions
- ✓ Spacecraft velocity and attitude variations
- ✓ Effects of the earth's rotations
- ✓ Elevation
- ✓ Curvature (including the skew effects)
- ✓ Abnormalities of instrument performance (irregularities of the detector response and scan mode such as variations in mirror oscillations)
- ✓ Loss of specific lines (requires de-striping)

Though it is not necessary to apply all these corrections in every case. These errors are systematic and can be removed or reduced before they reach the user.

On the basis of the nature of the information to be extracted from remotely sensed data, the investigator should decide on the best pre-processing techniques. The entire pre-processing techniques involved in remote sensing may be categorized into two broad categories: **radiometric corrections** and **geometric corrections.** Apart from these, some other pre-processing may be necessary, in which there are absolutely no errors and may be termed as miscellaneous pre-processing.

4.5.1 Radiometric distortions and corrections

Radiometric errors are some errors or inconsistencies in image DN values. Radiometric correction is performed to reduce or remove these errors or inconsistencies. When the emitted or reflected electromagnetic energy is observed by a sensor on-board an aircraft or spacecraft, the observed energy does not coincide with the energy emitted or reflected from the same object observed from a short distance. This is due to the sun's azimuth and elevation, atmospheric conditions such as fog or aerosols, sensor's response, etc., which influence the observed energy. Therefore, in order to obtain real irradiance or reflectance, these radiometric distortions must be corrected.

Radiometric distortion occurs due to variations in scene illumination and viewing geometry, atmospheric conditions, and sensor noise and response. Radiometric correction is performed to correct for distortions and errors introduced in image due to atmospheric conditions, viewing geometry, satellite sensor errors, periodic drift or a temporal failure of a detector, sudden brakes in the data transmission or recording sequence and similar other errors that degrade image quality.

Radiometric correction includes:

- correcting data for sensor irregularities, sensor or atmospheric noise
- converting data to accurately represent reflected/emitted radiation measured by sensor.

Radiometric correction can be classified into the following types;

a. Detector response calibration
    i. De-stripping
    ii. Removal of missing scan lines
    iii. Random noise removal
    iv. Vignetting removal
b. Atmospheric correction

a. Detector response calibration

Detector response calibration consists of de-stripping, removal of missing lines, random noise removal, and vignetting removal.

i. De-stripping

Though each sensor of satellite is well calibrated before their launch, on long term use, some of them may drift significantly from their calibrated condition. Due to this, the DN values recorded by those sensors are either too high or too low compared to those by other sensors on same condition. Due to this, on some images, lines scanned by some particular sensor appear to be either very bright or very dark. This effect of appearance of heterogenous strips is called line striping. It means that data are not absent, rather they need calibration.

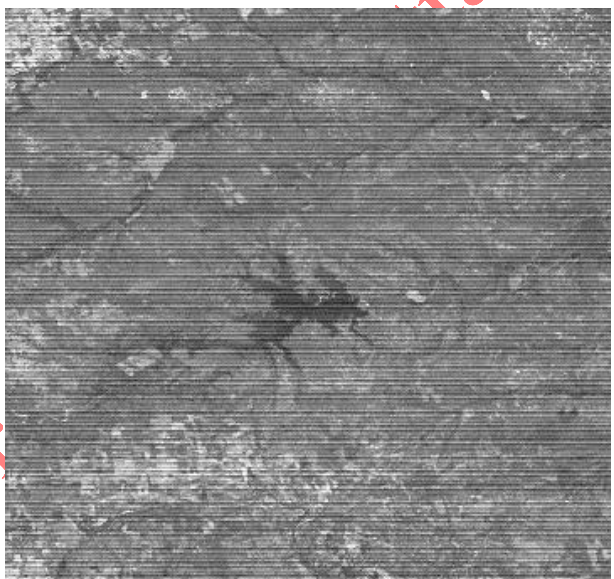


Figure 2: Example of striping in Landsat 4 Multispectral Scanner (MSS) Level-0 data.

This sort of images can be corrected by de-striping. This is implemented by histogram matching. For each detector unit of satellite, a separate histogram is generated. That means, if any satellite has six detector unit, six different histograms are generated. The histogram of erroneous detector unit is then compared to that of correct one in terms of their median and mean. Gain and offset for its correction is then determined and then applied. The initial DNs are now replaced by newly computed DNs. The image is now corrected.

Application of the de-stripping enhances the visual appearance and interpretability of the image.

ii. Removal of Missing Scan Lines

Another common remote sensing device error is line dropout. Line dropout occurs when a detector either completely fails to function, or becomes temporarily saturated during a scan. The result is missing of a line or partial line or defective data along a scan line, creating a horizontal streak.

Line dropout is usually corrected by replacing the bad line with a line of estimated data file values, which is based on the lines above or below it. In case of loss of one line, the lost line is replaced by averaging the two neighboring lines. If the spurious pixel, column x, and line y has a value $DN_{x,y}$ then the algorithms are as follows:

$$DN_{x,y} = (DN_{x, y-1} + DN_{x, y+1})/2$$

If two lines are lost, the first line lost is recovered by repeating the previous line while the second line lost is recovered by repeating the subsequent line. If three consecutive lines are lost, the first lost line is recovered by repeating the previous line and the third lost line is recovered by repeating the subsequent line. The second line is replaced by the average of the first and the third line. The lost line should not be recovered in the case of more than three consecutive line losses.

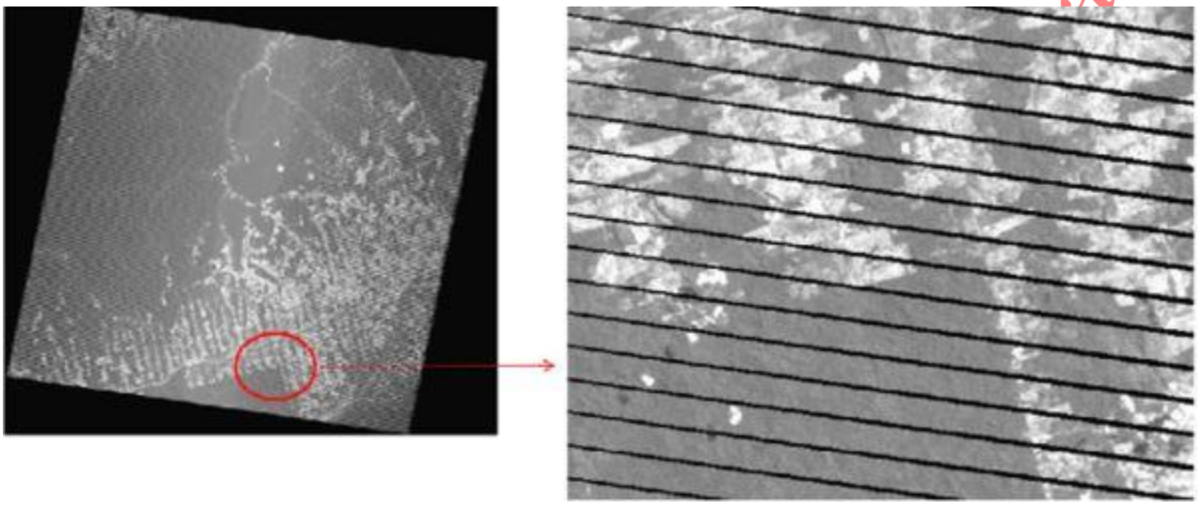


Figure 3: Missing Scan lines in a Landsat 7 Imagery

iii. Random Noise Removal

These errors do not follow any pattern and thus provide salt and pepper effect. It means that the DN value of some pixels change abruptly from those of its adjacent pixels. Due to this reason, these are called shor noises or bit errors. The causes of these noises may be due to errors during transmission of data or some sort of temporarily present obstructions on scene.

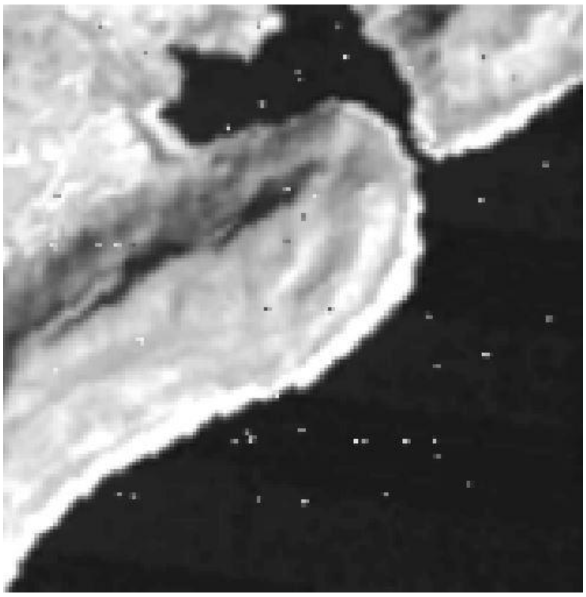


Figure 4: Random noise or spikes, small white dots representing

These errors are corrected by the process of filtering. Generally a low pass filter is used for removal of spikes. It means, value of each pixel is compared with those of adjacent pixels. If the difference is greater than user specified value, it is recognized as noise. A moving window or kernel, generally of 3 x 3 pixels,5x 5 pixels, having specific weight on each box is moved along the image. The value at the central pixel is then substituted with newly calculated DN value representing weighted average within the window.

iv. Vignetting Removal

In case of optical sensors, with the use of a lens, a fringe area in the corners is darker when compared with the central area. This is called vignetting.

The vignetting effect can be experienced in the aerial photo. The most common cause of vignetting is a lens shade that is the wrong size for the focal length being used and using a portable camera lens at an extreme shift, especially with filters. Wide angle lens are often vignetted.

Vignetting can be expressed by cos n, where n is the angle of ray with respect to the optical axis, n is the dependent on the lens characteristics, though n is usually taken as four.

In case of electro-optical sensors, measured calibration data between irradiance and the sensor output signal, can be used for radiometric correction.

b. Atmospheric Correction

All of the images used in remote sensing for particular task may not be acquired at same environmental condition. The images can be acquired at different season, different illumination condition i.e. different time of the day and different solar inclination. The effect of atmosphere depends on the wavelength being used for sensing. All of the images are converted to their equivalent images corresponding to same condition. It refers to atmospheric correction of image. The activities performed in atmospheric correction are haze correction, sun angle correction and skylight correction.

i. Haze Correction

The atmosphere between sensor and scene degraded image quality by several always. First it absorbs some of the radiation and causes the scene appear dim. Secondly it reflects some of the incident radiation on the way, before they actually reach scene, thus adding an extra path radiance. Due to this the total radiance sensed by sensor has an additional haze raised due to path radiance. Haze is subjected to correction before use of image for analysis. That means,

$$L_{tot} = \frac{\rho E T}{\pi} + L_p$$

Where, Ltot = total spectral radiance measured by sensor

ρ = Reflectance of object

E= irradiance on object

T= transmission of atmosphere

Lp = path radiance

The second term in the above equation is the haze to be removed.

The haze correction begins with first identifying some dark on a particular band, that completely absorbs the radiation of that band incident on it. Such an object is called a dark object. Those dark objects are supposed to have zero DN value. If they have some DN value, those are fully due to haze. Commonly we attribute min. DN value of deep water of the image to sky radiance and subtract this value from all DNs in the band. So, from all pixels on the image, the same DN value is subtracted to get the corrected image.

This procedure of haze correction has limitations the assumption is made that all areas on the scene suffer equal haze, which may not be necessarily true on the real scene.

ii. Sun Angle Correction

On different seasons or different times of the same day, the inclination of the sun is not the same, hence resulting in differences in the illumination of objects. In the northern hemisphere, the solar elevation angle is higher in summer than in winter, and hence images of different seasons are at different illumination conditions. Before use for analysis, all images are normalized to their equivalence of the image acquired at the time sun was on zenith. This is obtained by dividing the DN value of the pixel by the sine of solar elevation or cosine of solar zenith angle. Solar zenith angle refers to its angle away from the zenith at the time of image acquisition.

i.e. $DN' = \frac{DN}{\sin(\alpha)} = \frac{DN}{\cos(Z)}$

where,

DN' = normalized DN value

DN = initial DN value

α = solar elevation angle and

Z = solar zenith angle.

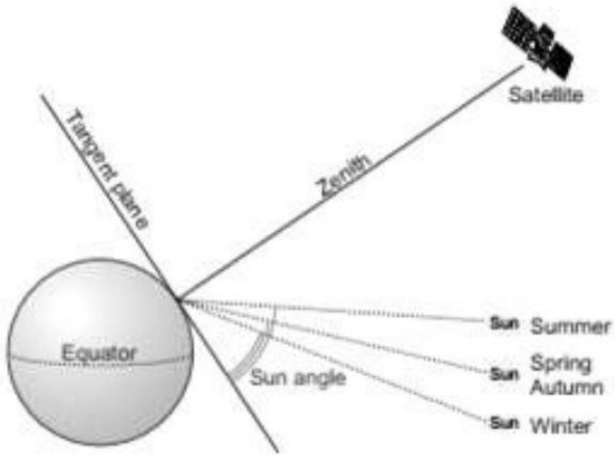


Figure 5: Effect of seasonal change in solar elevation angle

It should be noted that the normalized DN will always be greater than the image DN value since the objects are illuminated more when a light incident is normal to them.

iii. Earth-Sun Distance Correction

The correction is applied to normalize for the seasonal changes in the distance between the earth and the sun. The irradiance from the sun decreases as the square of the earth and the sun distance.

Neglecting the atmospheric effects, the combined influence of the solar zenith angle and the earth-sun distance on the irradiance incident on the surface of the earth can be expressed as

$$E = \frac{E' cos\theta}{d^2}$$

Where,

E = normalized solar irradiance

E' = solar irradiance at mean earth-sun distance

θ = angle of sun from zenith

d = earth-sun distance, in astronomical units

$Note$: 1 $Astronomical\ Unit$ = 149597870700 meters

4.5.2 Geometric Distortions and corrections

Geometric correction is the process of rectification of geometric errors introduced in the image during the process of acquisition. The aim is to transform the remotely sensed image to have the scale and projection properties of a map.

The geometric distortions in the raw digital images arise from the earth's rotation; panoramic distortion, further affected by earth curvature; scan skew; variations of platform's height, velocity, attitude (pitch, roll, and yaw); and aspect ratio distortion.

The distortions may be systematic distortions—the effects that are constant, and can be predicted in advance; or non-systematic—caused due to variations in spacecraft variables, and atmospheric scatter.

The systematic distortions (errors) are corrected by using ephemeris of the platform and the precisely known sensor distortion characteristics. The non-systematic distortions are corrected by matching the image coordinates of the physical features recorded in the image with the geographic coordinates of the same feature from a map or using GPS.

4.5.1 Geometric Distortions

A. Systematic Distortions

B. Non-systematic Distortions

A. Systematic Distortions

The various types of systematic distortions are as follows:

i. Scan Skew

It is caused by the forward motion of the platform during the time required for each mirror sweep. The ground swath is not normal to the ground track but is slightly skewed, producing cross-scan geometric distortion. The scanned lines do not remain exactly perpendicular to the ground track.

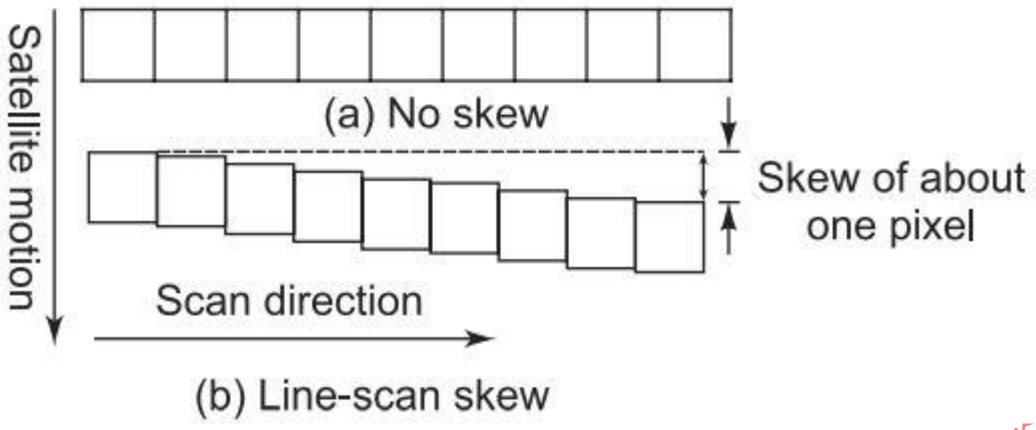


Figure 6: Scan Skew

2. Scanner mirror velocity variance

The mirror scanning rate is usually not constant across a given scan, producing along-scan geometric distortion. An oscillating mirror must stop at the end of each scan and reverse direction.

3. Panoramic/scanner distortion

The ground area imaged is proportional to the scan angle rather than to the angle itself. Because data are sampled at regular intervals, this produces along-scan distortions.

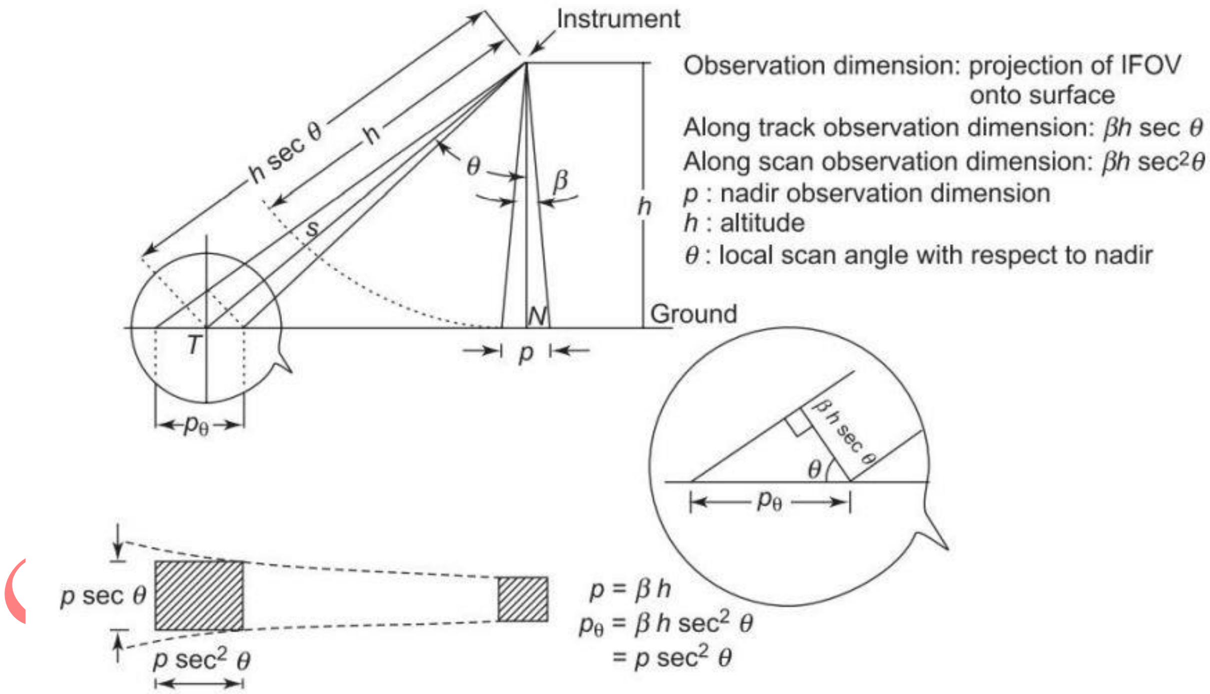


Figure 7: Panoramic Distortion

3. Spacecraft/platform velocity

If the speed of the platform changes, the ground track covered by the successive mirror scan (IFOV) changes, producing along-track distortions in the form of oversampling—when forward platform velocity decreases (higher orbit), or undersampling—when forward platform velocity increases (lower orbit).

Error type	***Source***	***Effects***	***Direction***
Non-systematic			
Altitude	Platform	Deviation from nominal altitude of satellite	Along/across scan
Attitude	Platform	Deviation of sensor axis from normal to earth ellipsoid surface	Along/across scan
Systematic			
Scan skew	Platform	Scanned lines are not exactly perpendicular to ground track	Across scan
Space craft velocity	Platform	Change in along track IFOV (Instantaneous Field of View)	Across scan
Earth rotation	Scene	Westward shift of different scan lines of a scene	Along scan
Map projection	Scene	Geometric error in projecting image on 2D map plane	Along/across scan
Terrain relief	Scene	Relative planimetric error between objects imaged at different heights	Along/across scan
Earth curvature	Scene	Change in image pixel size than actual one	Along/across scan
Optical	Sensor	Barrel and pincushion distortions in image pixels	Along/across scan
Aspect ratio	Sensor	Image pixel size different in horizontal and vertical directions	Along/across scan
Mirror velocity	Sensor	Compression or stretching of image pixels at various points along scan line	Along scan
Detector geometry and scanning sequence	Sensor	Misalignment of different band scan lines of multispectral sensors	Along/across scan
Perspective projection	Scene and sensor	Enlargement and compression of image scene close and far off to nadir point respectively	Along scan
Panoramic	Scene and sensor	Introduces along scan distortions	Along scan

Figure 8: Geometric Errors and their effects

4. Earth rotation

Earth is continuously rotating from West to East. If a satellite is moving from North to South, the earth rotates eastward by some angle between successive image acquisitions. Due to this, each scan sweeps the area that is slightly westward from the previous sweep, but all sweeps are shown in a common line in the image. This is termed **skew distortion**. This type of distortion in remote sensing is systematic.

Skew distortions are corrected by the method of deskewing. It means each successive image is offsetted slightly west from its previous image. This is done because the actual ground covered by any image is slightly west of its previous image.

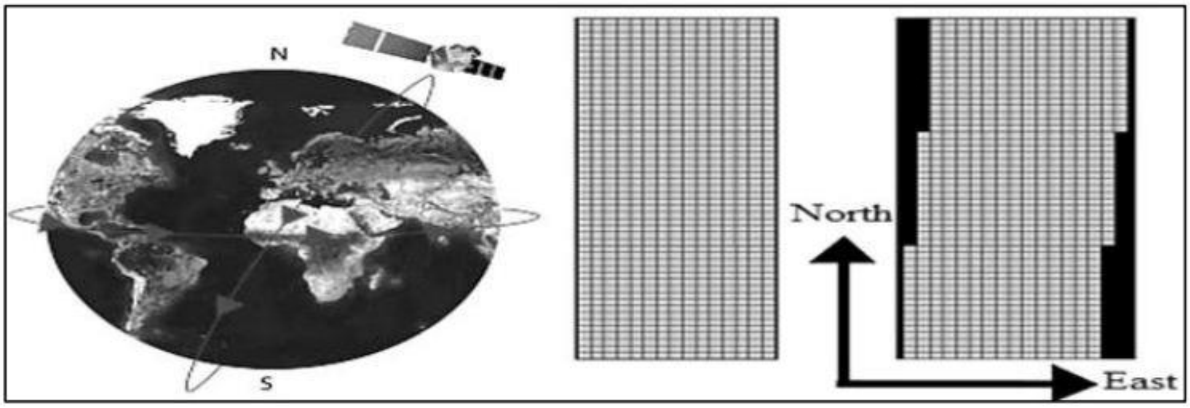


Figure 10: Deskewing: satellite and earth rotation direction, initial image and deskewed image.

Non-systematic Distortions

The non-systematic geometric distortions occur because of following:

1. Altitude variance

If the sensor platform departs from the normal altitude or increases in elevation, a change in scale or pixel size occurs.

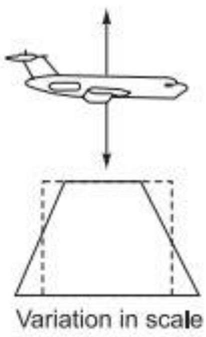


Figure 9: Distortions due to scale variance

2. Platform attitude

One sensor system axis is usually maintained normal to earth ellipsoid surface and other parallel to the spacecraft direction of travel. If the sensor departs from this attitude, the result is geometric distortion. Attitude change implies the change in platform orientation that is significant over the time required to scale a full scene. This is termed as skew motion—motion of aircraft/satellite perpendicular to the intended direction of motion. It may be yaw, pitch, or roll as shown in figure.

- ✓ Pitch is the vertical rotation of a sensor platform, in the direction of motion (noise-up plane), resulting in changes in the spacing of scan lines.
- ✓ Roll is the rotation of sensor platform around the velocity vector, and scale changes in the line direction resulting in lateral shift in scan line positions.

- ✓ Yaw is the rotation of a senor platform in the horizontal plane, or about its vertical axis, hence in a nose-right direction. It causes rotation and skew distortion. Changes in yaw result in scan lines that are not parallel.

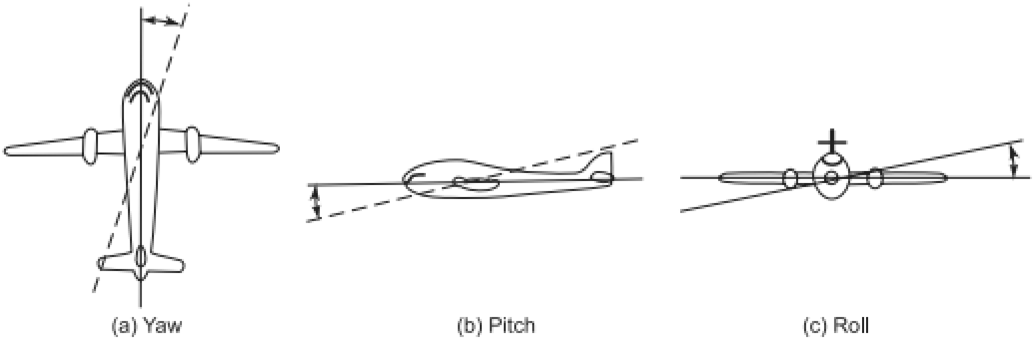


Figure 11: Platform attitude change (Skew Motion)

Non-systematic correction

Computer uses pixel coordinate system to store digital images in it. However, a geospatial analyst requires geographic coordinates (latitude/longitude) for the analysis of the geographical space. Non-systematic geometric correction involves polynomial transformation equations to maintain a relationship among pixel, geographic and projected coordinate systems. Further, for the purpose of overlaying multiple images, they need to be transformed into a common referential system so that the geographical features of an image spatially match with the other images.

There are two types of image non-systematic correction

1. **Image-to-ground geocorrection (or georeferencing)**

It is the correction of digital images to ground coordinates using GCPs collected from maps or collected from ground using GPS (or any GNSS). ***Georeferencing*** is the process of projecting image data onto a plane and making it conform to a map projection system. If the GCPs are collected from ground, the process is known as ***image-to-ground georeferencing***; and if the GCPs are collected from an existing map, then the process is generally referred as ***image-to-image georeferencing.***

2. **Image-to-image correction (or image registration)**

It is fitting of the coordinate system of one image to that of a second image of the same area. Image-to-image correction involves matching the coordinate system of two digital images with one image acting as a reference image and the other as the image to be rectified. It is the process of making one image data conform to another image; a projection or geographical coordinate system is not necessarily involved.

Many applications of remote sensing image data require two or more images of same geographical area, acquired at different dates or by different sensors, to be processed together. Such a situation arises for example when changes are of interest, in which case registered images allow a pixel-by-pixel comparison to be made.

Coordinate Transformation

In this method the input pixels are rearranged on a new grid. The image correction is carried out using polynomial equations converting the source coordinates to rectified coordinates; the order of polynomials is decided depending upon the extent of geometric distortion. Usually, it is carried out with the help of 1st order and 2nd order transformations. For accuracy the number of control points must be more than the number of unknown parameters in polynomial equations.

Resampling

After carrying out the coordinate transformation of the image, a process called resampling, or intensity interpolation is used to determine the pixel values of the transformed image. Image resampling involves the reformation of an image on to a new grid. This is achieved by using features (GCPs) that are common to both the image and the new grid. Suppose that an image with pixel coordinates (x, y) undergoes geometric distortion. The process consists in first defining a geometrically correct geographical grid in terms of latitude and longitude. With computer the latitude and longitude values of each cell of the grid is transformed into x and y coordinates, which becomes the new address of an image pixel. The computer program scans this new address in the image and transfers the appropriate DN based on nearby DN values in original image to this address. The process is repeated until the geographical grid is full at which point the image has been geometrically corrected.

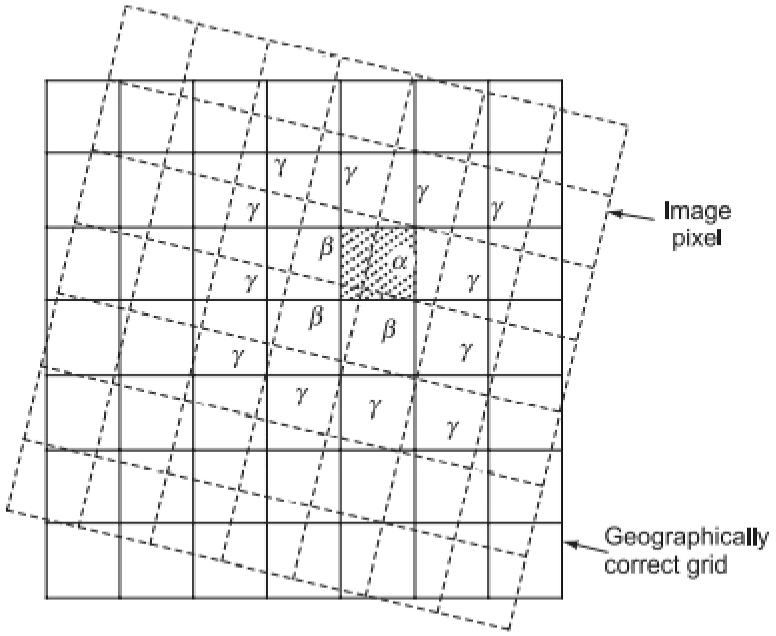
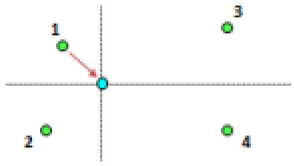


Figure 12: Resampling Procedure

There are generally three types of resampling methods, viz., the nearest neighbor method, the bilinear interpolation method and the cubic convolution method, to assign the appropriate digital number to an output cell or pixel. These methods are described as follows.

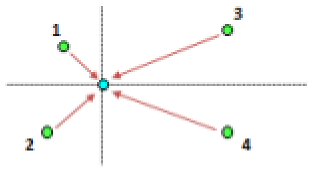
1. **Nearest neighbor method**

The method is also known as zero-order interpolation method. It consists in assigning each corrected pixel, the value of the nearest uncorrected pixel.



The method is simple in application and has the advantage of preserving the original values in the altered scene. However it may introduce noticeable errors, especially in linear features, where the realignment of pixels is obvious. Some of the other disadvantages of the method are blocky picture appearance and spatial shifts.

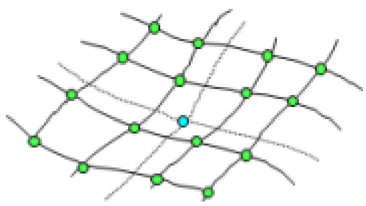
2. **Bilinear interpolation method**



In this method, the calculation of each output pixel value is based on a weighted average of values within a neighborhood of (2 × 2) four adjacent input pixels.

This process is simply the two dimensional equivalent to linear (first-order) interpolation. Since each output value is based on several input values, the output image is much smoother than nearest neighbor method. However, some changes such as loss of brightness values in the input image, a reduction in the spatial resolution of the image, and blurring of sharp boundaries in the picture do occur when bilinear interpolation creates a new pixel value.

3. **Cubic convolution method**



This method is also known as bi-cubic convolution or second-order interpolation method. It is supposed to be the most sophisticated and complex method of resampling. It uses a weighted average of values within a neighborhood of (4 × 4) 16 adjacent input pixels. Though, the images produced are noticeably sharper than the previous two methods, but get drastically altered. This method, however, introduces some loss of high frequency information.

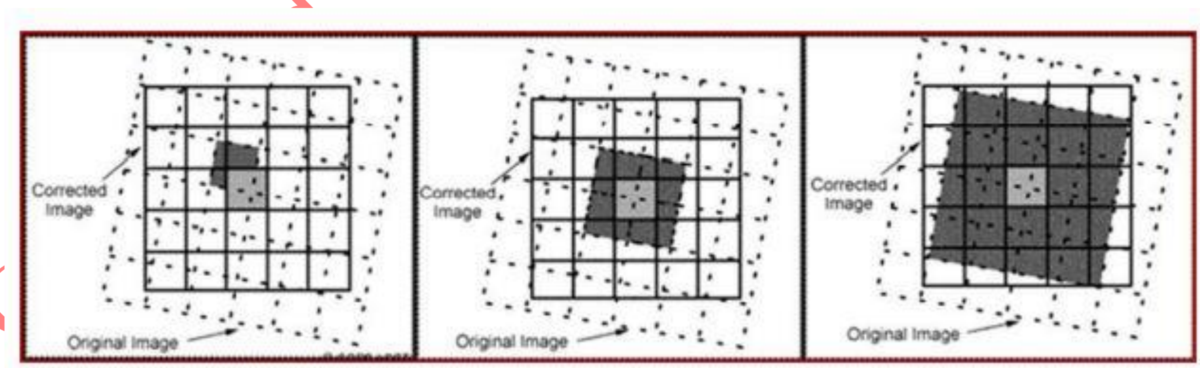


Figure 13: Resampling methods: Nearest neighborhood, bilinear and bicubic interpolation.

Why Geometric Correction?

i. To transform an image to match a selected map projection.
ii. To be able to locate points and features of interest on the image.
iii. To be able to merge two or more remote sensing images to make a single image.

iv. To be able to overlay two or more images of the same area collected at different times (images may have been collected by different sensors).

v. To be able to merge the remote sensing image with other geographic data with a similar projection (e.g., to use the satellite image as an information layer within a GIS).

4.1 Image Enhancement

Image Enhancement can be defined as the conversion of the image quality to a better and more understandable level for feature extraction or image interpretation. Though image has been corrected for geometric errors and radiometric errors so far, some analysis needs the image to be clearly identifiable and visually pleasant, even in compromise on change on DN values. Visually pleasant images are obtained by image enhancement.

The principal objective of image enhancement is to process an image so that the result is more suitable than the original image for a specific application. This objective is achieved by following image enhancement types:

i. radiometric enhancement (point operations) — modification of the brightness values of each pixel in an image dataset independently.
  - It brings out the contrast in the image.
  - It is applied separately to each band of data.
  - In radiometric enhancement, enhancement applied to one band may not be appropriate to other bands.
  - Contrast enhancement falls under radiometric enhancement.

ii. spectral enhancement — enhancing images by transforming the values of each pixel on a multiband basis

iii. spatial enhancement (local operations) — modification of the pixel values based on the values of surrounding pixels

Image enhancement improves the interpretability of the image by increasing apparent contrast among various features.

Image enhancement images can be classified into the following categories:

i. Contrast manipulation: level slicing, contrast stretching

ii. Spatial feature manipulation: spatial filtering, edge enhancement, and Fourier analysis

iii. Multi-image and multi-band manipulation: band rationing, principal components, vegetation indices

Procedures of image enhancement

i. Image Reduction

ii. Image Magnification

iii. Color Compositing

iv. Transect Extraction

v. Contrast Enhancement

vi. Filtering

Contrast Enhancement

A sensor might record a considerable amount of energy from any material in a certain wavelength, whereas another material is recorded at a much less energy on the same wavelength. The ranges of brightness values present on an image are referred as contrast.

Contrast enhancement is a process that makes the image features more clearly by making optimal use of the colors available on the display or output device. It involves changing the range of values in an image in order to increase the contrast. For example, an image having a range of brightness value between 35 and 80 when stretched to a range of 0 to 255 enhances the differences between the features.

In this method, contrast between pixels representing different features is attempted to enhance or make them differentiable.

Types of contrast enhancement methods

i. level slicing
ii. contrast stretching ***(Note: syllabus*— Histogram & Histogram Operations**)

i. Level slicing

In this method of contrast enhancement, the whole distribution of DN values is divided into a no. of categories as determined by analyst, depending on varieties of features existing on image. Each category contains a defined range of DN values. Then all DN values falling on a category are assigned some unique value and color. It means that if an 8 bit image has been classified into four different categories, image can be represented with just four colors. As an example the analyst may ask to assign a new value of 100 to all old DN values between 56 and 92, and so on. This sort of enhancement method is applicable in activities like land use zoning.

So, level sliced image appears somehow like choropleth map.

ii. Contrast stretching

Most commonly used satellite images use 8 bit image to represent features in image. But the features may not occupy the whole range of DNs values supported by that image. For an example, a 8 bit image contains 256 visual ranges, ranging from 0 to 255. But the image may not necessarily contain all 255 DN values. Due to this, while some DN values are blank, some others having higher no. of pixels falling on them are limited to a narrower range. Due to this, readability of image decreases. Contrast stretching aim at stretching the narrower range of DN values to the full extent supported by image.

Mainly two methods are common in contrast stretching:

a. Linear stretch
b. Histogram equalization (or histogram stretch)

a. Linear Stretch

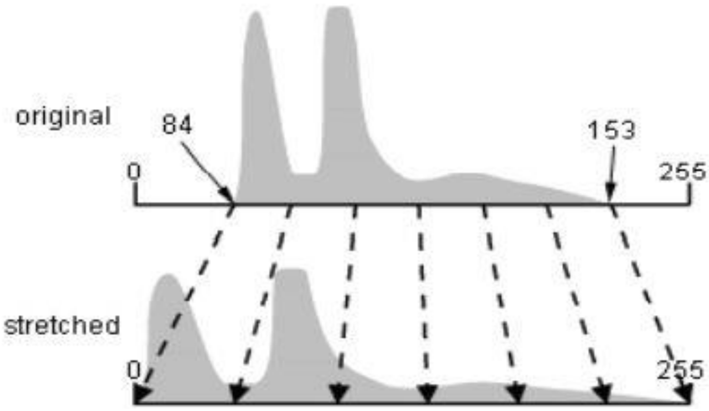


Figure 14: Contrast stretch by linear stretch

This method of contrast stretching expands the initial range of DN value into new full range linearly. That means it doesnot consider the frequency of occurrence of particular DN value on image.So, dark pixels appear darker while bright pixels turn brighter after linear stretch. In an 8 bit image, new DN value for each pixel is calculated using relation:

$$DN' = \frac{DN - DN_{min}}{DN_{max} - DN_{min}} * 255$$

Where,

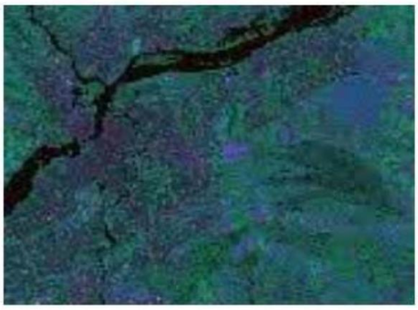
DN' = newly calculated DN value

DNmax = maximum DN value in initial image

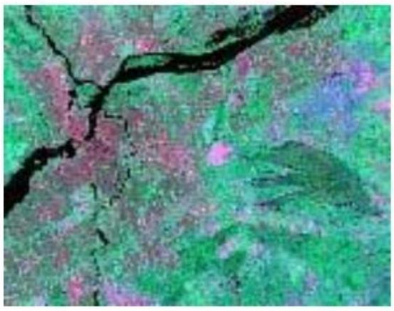
DNmin = minimum DN value in initial image

DN = original DN value of pixel

Creating new DN value individually for each pixel is not possible. So before actual calculation of new DN value, a lookup table (LUT) is creates that calculates new DN value for all possible DN values. Now, for each pixel, new DN value is taken from its corresponding value on LUT. That means, new DN value for each old DN value is calculated only once, independent of no. of pixels having that DN value. It makes the stretching method efficient and fast. But this method has a limitation that even after stretching, the new range assigned for frequently occurring pixel values is same as that for very less frequently occurring pixel values.



Before linear stretch



After linear stretch

b. Histogram Equalization

In this method of contrast stretching, the new pixel value range are determined based on the frequency of occurrence of pixels having that value. It means that DN values covering equal interval on initial image may not cover equal range on stretched image. While the most occurring DN values cover the larger range, one with lower frequency will cover a smaller range even if the range was equal in original image.

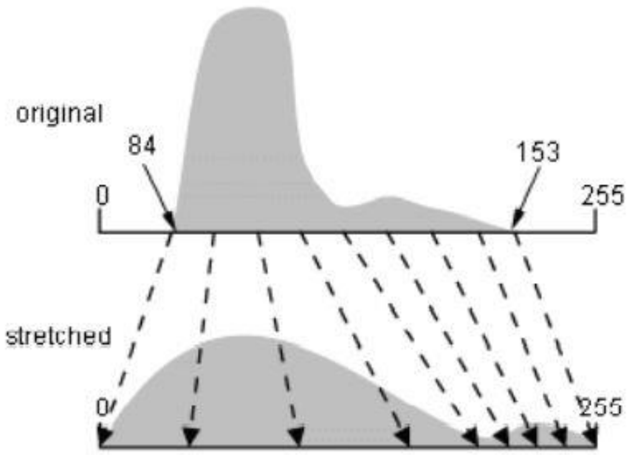
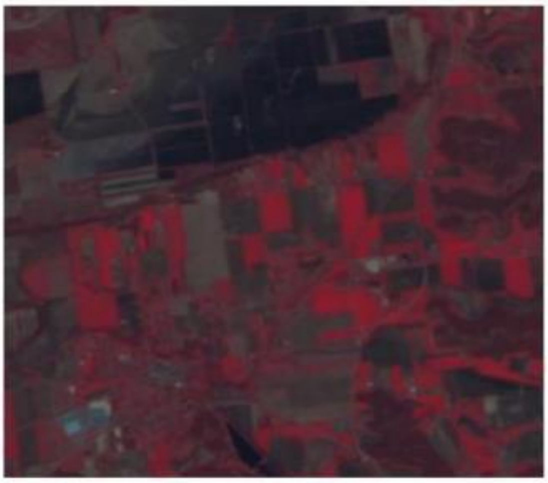


Figure 15: Contrast stretch by histogram equalization



Before Histogram equalization

After Histogram equalization

Let us make a comparison between these two methods of contrast stretching. consider an 8 bit image whose details contain DN value ranging between 58 and 158 while no pixels lie on range of 0-57 and 159-255. Even among the DN value between 58 and 158, very less pixels lie on range of 58-108. Whereas it has very high pixels having their DN value between 58 and 108.

From figure 16, it can be seen that linear stretch does not consider the frequency. Even if the no. of pixels is higher on range between 58-158, the initial range of 58-108 occupies equal portion as that of initial range of 108-158 in new image. Now the image is stretched such that DN value of 58 stretches to zero and that of 158 to 255.It apparently seems that even if the image has been stretched, the region between 108 and 158 of image is still limited to half of the range on new image even though it contains almost 90 percent of pixels on it.

The second method has now addressed the above issue. Referring to figure 16, it can be seen the original visual range of 58-108 of initial image covers just 38 visual range of stretched image, due to its lower frequency whereas the visual range of 108-158 is stretched to cover a larger range of 38-255 due to its higher occurrence. It means that even the small difference is highly exaggerated in the zone of maximum occurrence while it is less exaggerated in range with less occurrence.

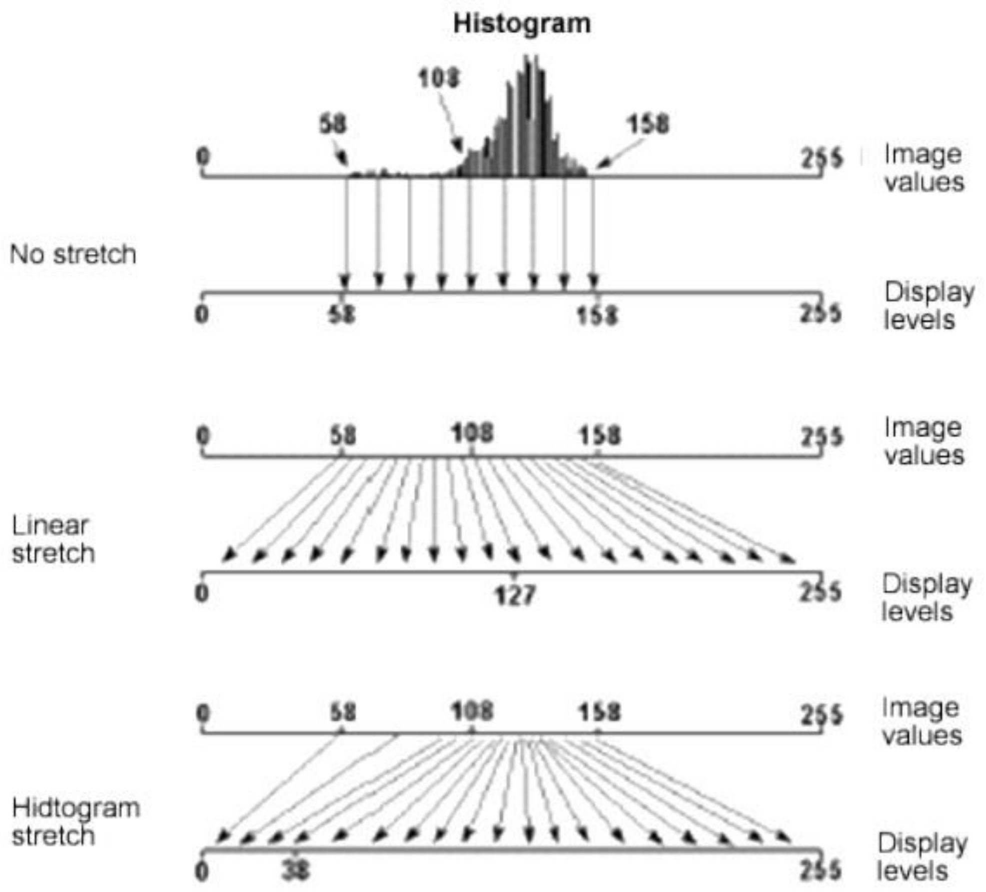
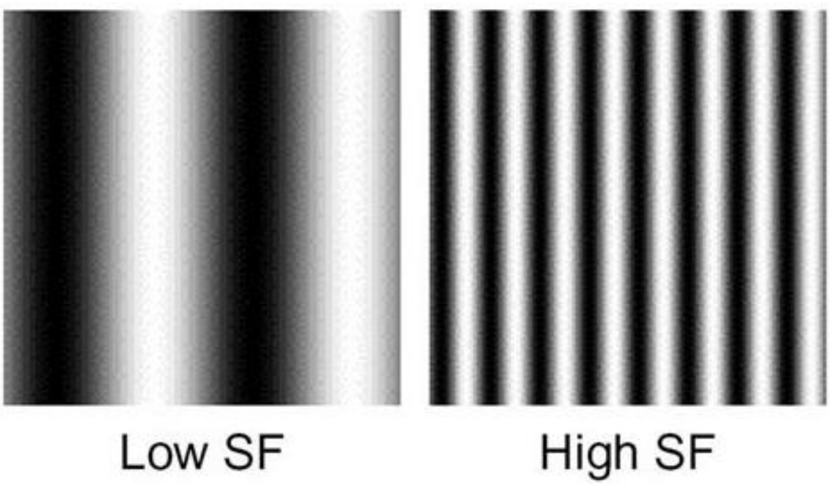


Figure 16: Comparison between contrast stretching techniques

4.4 Filtering

Contrast enhancement only amplifies small differences between DN values so we can visually differentiate between features more easily. But it does not increase the information content of the data and it does not consider a pixel neighborhood. That's why filter operations are applied.

Filtering encompasses another set of digital image processing functions, which are used to enhance the appearance of an image. Spatial filters are designed to highlight or suppress specific features in an image based on their spatial frequency.



Spatial frequency is related to the concept of image texture, the manner in which in which grayscale values change relative to their neighbors within an image. It refers to the the frequency of the variations in tone that appears in an image. Rough textured areas of an image, where the changes in tone are abrupt over a small area, having high spatial frequencies, while smooth areas with little variations in tone over several pixels have high spatial frequency.

Filtering techniques can be implemented through Fourier transform in

i. Frequency domain by reconstruction with reconstruction filters
ii. Spatial domain by convolution (enhancement) filters

Note:

- The coordinates of the 2D space in which frequency components are represented are given in terms of frequency, called frequency domain.

- The normal row/column coordinate system in which images are normally expressed in spatial location, called spatial domain.

- The Fourier transform is used to convert a single-band image from its spatial domain representation to the equivalent frequency domain representation, and vice-versa.

Types of Filters

A. Spatial filters (convolution filters)
B. Reconstruction filters (frequency domain filtering)
C. Statistical Filters
D. Crisp Filter

A. Spatial filters

✓ Re-calculate the grey value of each pixel based on its local environment. That is, they take the grey values of neighbor pixels into account, apply them in a dedicated algorithm in order to re-calculate the grey value of the pixel itself.
✓ Filters are usually applied on single band, to extract features from images, eg. Edges and lines.

The new DN value of a pixel is defined by considering the values of its neighboring pixels lying inside the kernel of defined dimension.

The kernel is a moving window of certain dimension with weight assigned to each box.

The central pixel takes the value of weighted average taken inside the kernel.

The selection of kernel size and weight depends on the scene and type of output desired.

The convolution filters are classed as

a. low pass
b. high pass filters

a. Low Pass Filter

A low-pass filter, also called smoothing filter, is designed to emphasize larger, homogeneous areas of similar tone and reduce the smaller detail in an image. Thus, low-pass filter generally serve to smooth the appearance of the image. It enhances low spatial frequencies.

Low pass filters may be of average, or median, or mode type depending upon the respective statistical parameter used.

i. **Averaging filter:** A typical low pass averaging kernel is shown in Figure 17(a) and Figure 17(b) shows the original data of a digital image. The output DN is found by the sum of the products of corresponding convolution kernel and image elements. The smoothening effect of averaging filter ((1/9) (4 + 12 + 10 + 10 + 3 + 9 + 7 + 6 + 13) = 8.22 $\approx$ 8) is as shown in Figure 17(c).
Averaging filter is most widely used to reduce the effect of speckle in the radar image. It is used to reduce the random noise in the image.

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

(a) Typical low pass kernel

4	12	10
10	3	9
7	6	13

(b) The original data

4	12	10
10	**8**	9
7	6	13

(c) Smoothening effect of low pass filter

4	5	10
11	3	8
9	7	12

(d) The original data

4	5	10
11	**8**	8
9	7	12

(e) The enhanced image (the central pixel value 8 is the median of the original data)

11	9	9
9	11	8
8	9	11

(f) The original data

11	9	9
9	**9**	8
8	9	11

(g) The enhanced image(the central pixel 9 is the mode of original data)

–1	–1	–1
–1	5	–1
–1	–1	–1

(h) Typical high pass kernel

4	12	10
10	22	9
7	6	13

(i) The original data

4	12	10
10	**39**	9
7	6	13

(j) Smoothening effect high pass filter

Figure 17: Convolution filtering

i. **Median filter:** This filter operates by rearranging all DN values in sequential order within the defined window. The pixel of interest is replaced by the value in the center of this distribution, the median. This filter is used for removing pulse or spike noise. When the values of digital image data of Figure 17(d) are arranged in ascending order (3, 4, 5, 7, 8, 9, 10, 11, 12) the median will be 8 and the smoothening effect is as shown in Figure. 17(e).

ii. **Mode filter:** This filter computes the mode of the grey level values (the most frequently occurring grey level value) within the filter window surrounding each pixel.

As an example, the original digital data of an image is given in Figure 17(f). When arranged as 8, 8, 9, 9, 9, 9, 11, 11, 11 the data results in a value nine that occurs maximum four times. It is the mode value and will replace the central value (11) of Figure 17(f) as shown in Figure 17(g).

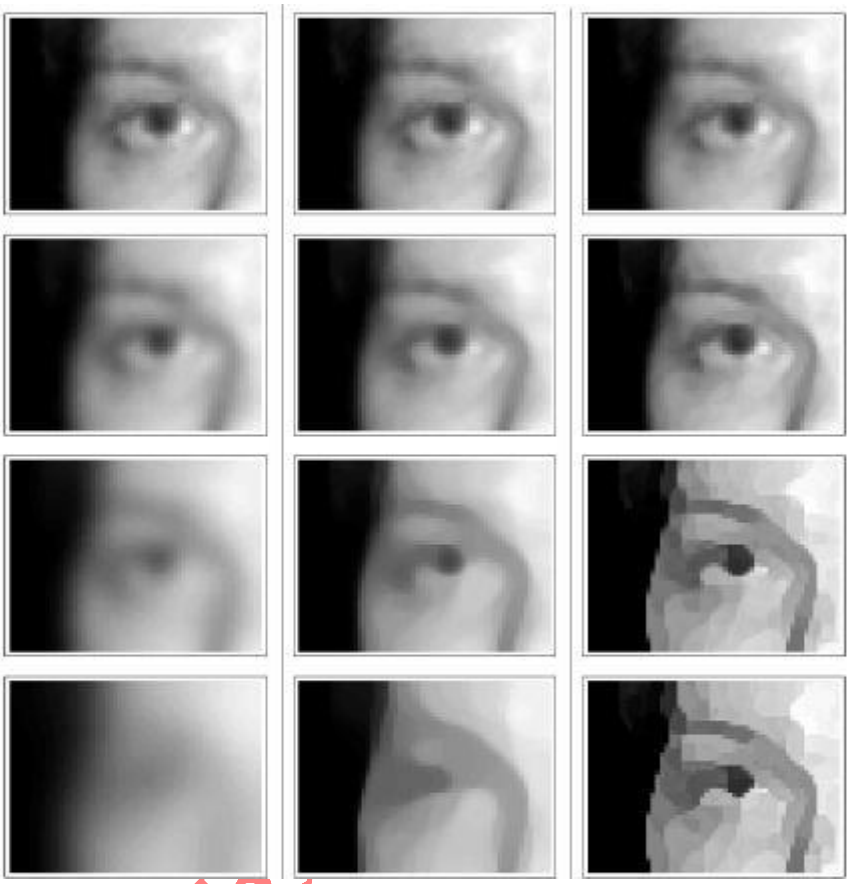


Figure 18: The effect of the mean (left column), median (center), and mode (right) filtering. The first row shows the original image; the other rows reading downwards show the progressive effect of repeated filtering after 4, 16, and 64 iterations. The mode-filtered image at the bottom right is the final state for this image; further mode filtering has no effect.

b. High-Pass Filter

These filters serve to sharpen the appearance of fine detail in an image by enhancing high spatial frequencies. It increases the spatial frequency by subtracting the low frequency image (resulting from a low pass filter) from the original image.

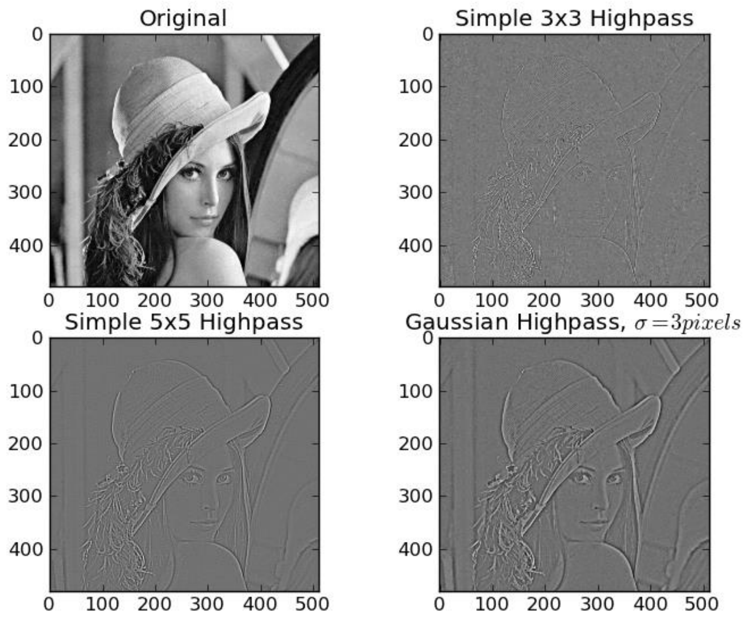
i.e., original image – low pass filter = high pass filter.

Figure 17 (h, i and j) shows the enhancement effect of a high pass filter. A typical high pass filter is shown in Figure 17(h). The sharpening effect of high pass filter is achieved by replacing the original middle pixel value (22) by (39).

High pass filter are design to emphasize the high spatial frequency and suppress the low frequencies.A high-pass filter does the opposite, and serves to sharpen the appearance of the image.

Types of High-Pass Filter:

1. Gradient (directional) filters
2. Laplacian or Non-directional filters



1. **Gradient (directional) filters**
   Gradient filters are used to enhance the linear trends. They are designed in such way that edge running in a certain direction (e.g. horizontal, vertical, diagonal) are enhanced.

1	1	1	1	0	-1	1	1	0
0	0	0	1	0	-1	1	0	-1
-1	-1	-1	1	0	-1	0	-1	-1
horizontal			vertical			diagonal		

z

2. **Laplacian or Non-directional filters**

Laplacian filters are non-directional filters because they enhance the linear features having almost any direction in the image. The filter highlights the points, lines, edges in the images and suppresses smooth regions (low frequencies)

B. Reconstruction filters (Frequency Domain Filtering)

Filtering in the frequency domain consists of the following three steps:

i. Fourier transform the original image and compute the Fourier Spectrum
ii. Select an appropriate filter function and multiply by the elements of the Fourier Spectrum
iii. Perform an inverse Fourier transform to return to the spatial domain for display purposes.

Note:

- After an image is transformed into discrete component spatial frequencies, it is possible to display these values in a two-dimensional scatter plot known as a Fourier spectrum.

C. Statistical Filters

Statistical filters output a local statistical property of an image. These filters are very useful for filtering classified imageries and radar images.

i. Maximum filter: the resulting grey value is the maximum of its n x n environment. Its effect is smoothing and enlargement of bright values.
ii. Minimum filter: the resulting grey value is the minimum of its n x n environment. Its effect is smoothing and enlargement of dark areas (lower DN values).
iii. Mean filter: the resulting grey value is the mean of its n x n environment. Its effect is smoothing.
iv. Median filter: the resulting grey value is the median of its n x n environment. Its effect is smoothing and disappear of grey value transitions.
v. Gaussian filter: calculates the resulting grey value by the weighted mean of its n x n environment. The weights are distributed according to a 3D Gaussian normal distribution function.

D. Crisp Filter

The crisp filter sharpens the overall scene luminance without distorting the inter-band variance content of the image. This is useful enhancement if the image is blurred due to atmospheric haze, rapid sensor motion, etc.

Exercises

1. What is spatial filtering? Briefly explain the basic principles and types of spatial filter. [2078]
2. Write short notes on: [2078]
   i. Image Enhancement
   ii. Geometric distortions and Correction
3. How are the image-preprocessing performed in remote sensing images? [2078]
4. What is line striping in RS image? How can you remove line striping? Why geometric correction is required in RS image? [2077]
5. Write short notes on: [2077]
   i. Haze correction
   ii. High-pass filter

Unit 5

Image Analysis

Unit 5: Image analysis **(14 hrs.)**

5.1 Visual Image Interpretation of Satellite Images

The examination and analysis of images for the purpose of identifying objects and features and judging their importance is known as **image interpretation/photo interpretation.**

Analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features, which consist of points, lines, or areas.

Targets may be defined in terms of the way they reflect or emit radiation. This radiation is measured and recorded by a sensor, and ultimately is depicted as an image product such as an Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of **tone, shape, size, pattern, texture, shadow, and association.**

When we look at satellite imagery, we see various objects of different sizes and shapes. Some of these objects may be readily identifying while others may not, depending on our individual perceptions and experience. When we can identify certain objects or areas and communicates the information identified to others, we are then practicing **image interpretation.**

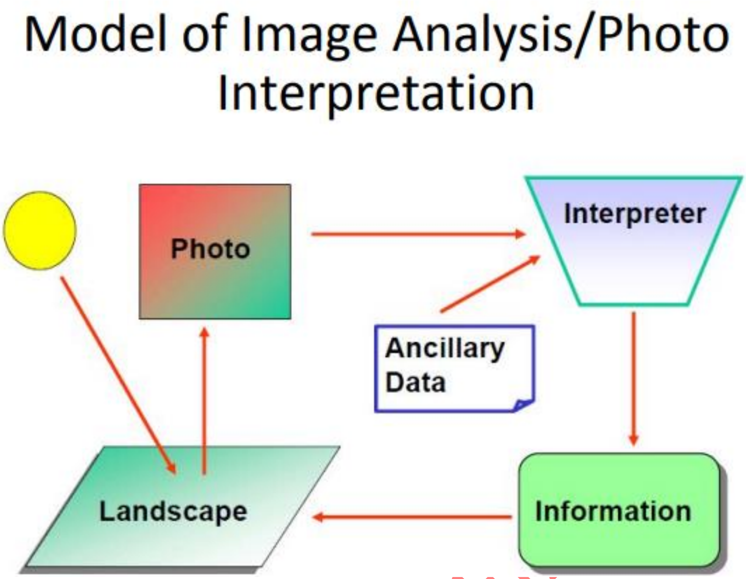
An image interpreter systematically examines the satellite imagery in conjunction with maps, field observations, and other information, and makes an interpretation of the physical nature of features and phenomena appearing in the imagery.

The **success of image interpretation of satellite images depends on**

- training and experience of the interpreter
- nature of the objects or phenomena being interpreted

- quality of the satellite images

The most skilled interpreters generally have keen powers of observation, coupled with an ability to assimilate and analyze information. Knowledge of the subject, the geographic region and the sensor are critical.



Information

A. Metric – Measurements of
    - Distance
    - Area
    - Location (X, Y) and height (Z) of objects
    - Size and shape

B. Interpretive – Identification of
    - Feature or cover type
    - Condition

5.1.1 Image (Photo) Interpretation Elements

i. Size
ii. Shape
iii. Tone or Color
iv. Texture
v. Pattern
vi. Shadow
vii. Site
viii. Association

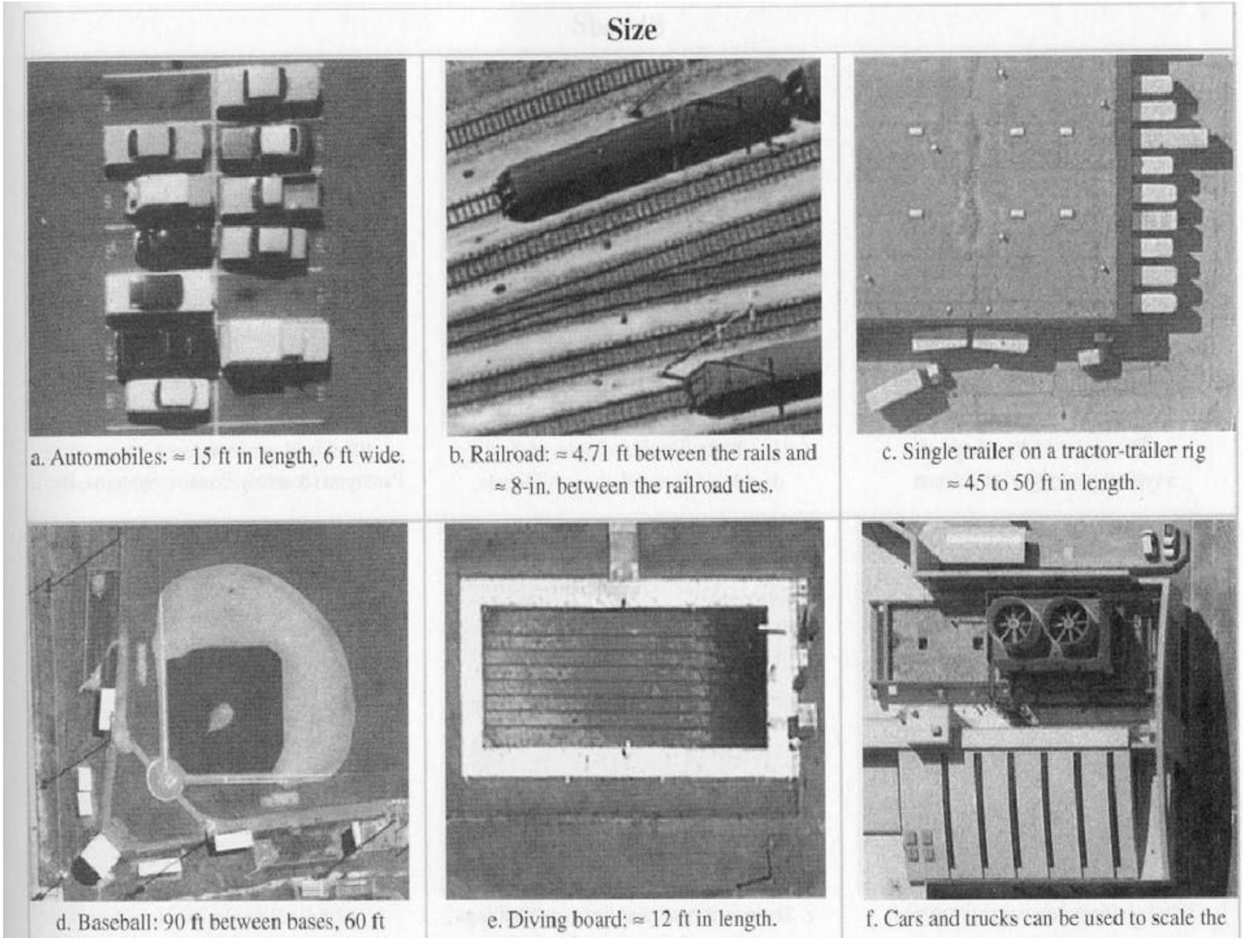
i. Size

Size is the measure of surface dimensions of objects, including height, length-width, and slope.

Size of an object is a function of photo scale. The sizes of objects can be estimated by comparing them with objects whose sizes are known. It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target.

A quick approximation of target size can direct interpretation to an appropriate result more quickly.

For example, if an interpreter had to distinguish zones of land use, and had identified an area with a number of buildings in it, large buildings such as factories or warehouses would suggest a commercial property, whereas small buildings would indicate residential use.



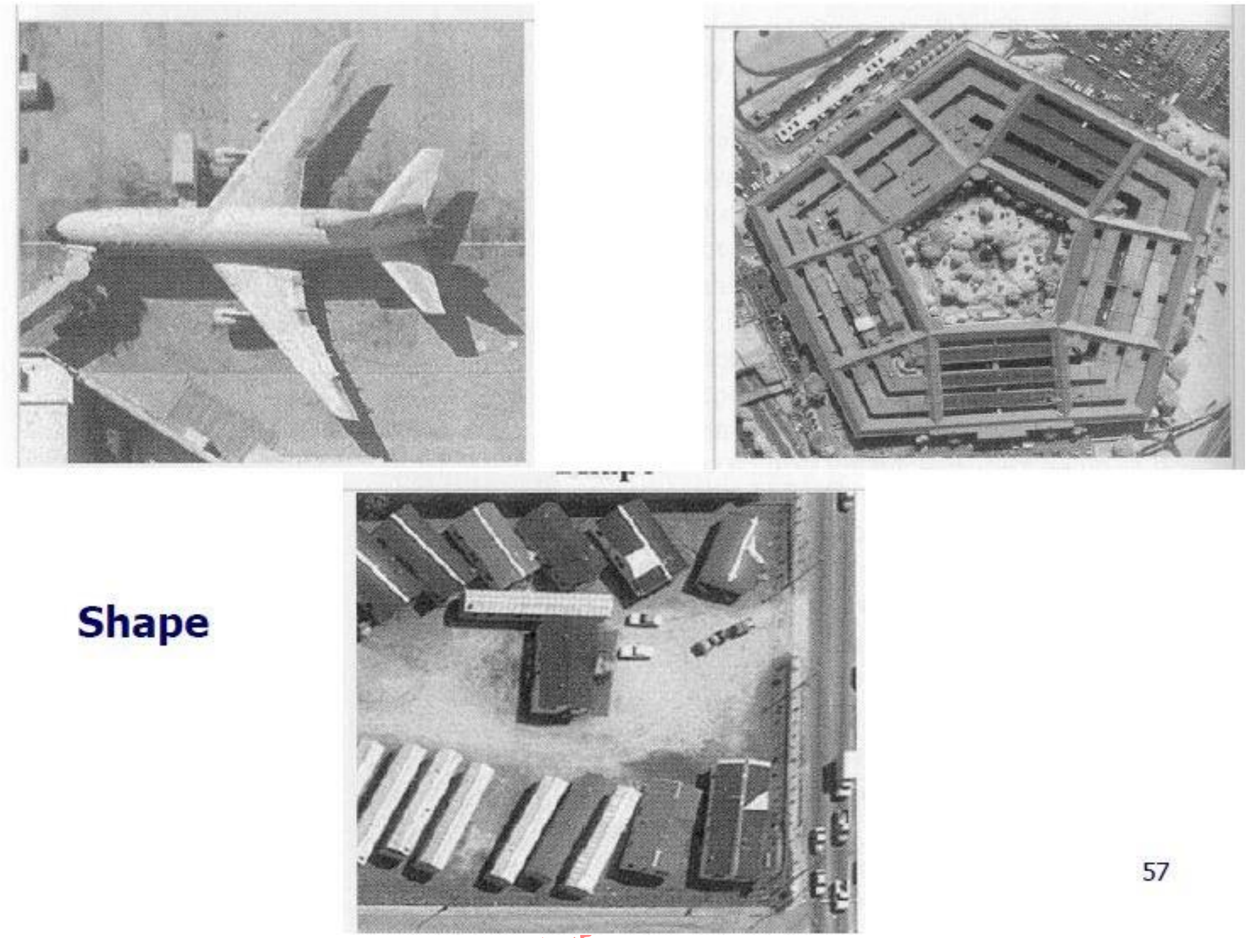
a. Automobiles: ≈ 15 ft in length, 6 ft wide.
b. Railroad: ≈ 4.71 ft between the rails and ≈ 8-in. between the railroad ties.
c. Single trailer on a tractor-trailer rig ≈ 45 to 50 ft in length.
d. Baseball: 90 ft between bases, 60 ft
e. Diving board: ≈ 12 ft in length.
f. Cars and trucks can be used to scale the

ii. Shape

Shape describes the form or configuration of an object.

Shape is a qualitative statement referring to the general form, configuration or outline of an object (e.g. 'V'shaped valleys indicative of deeply incised river).

Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape, except where man has created a road or clear cuts. Farm or crop land irrigated by rotating sprinkler systems would appear as circular shapes. Airports, harbors, factories and so on can be identified by their shape.



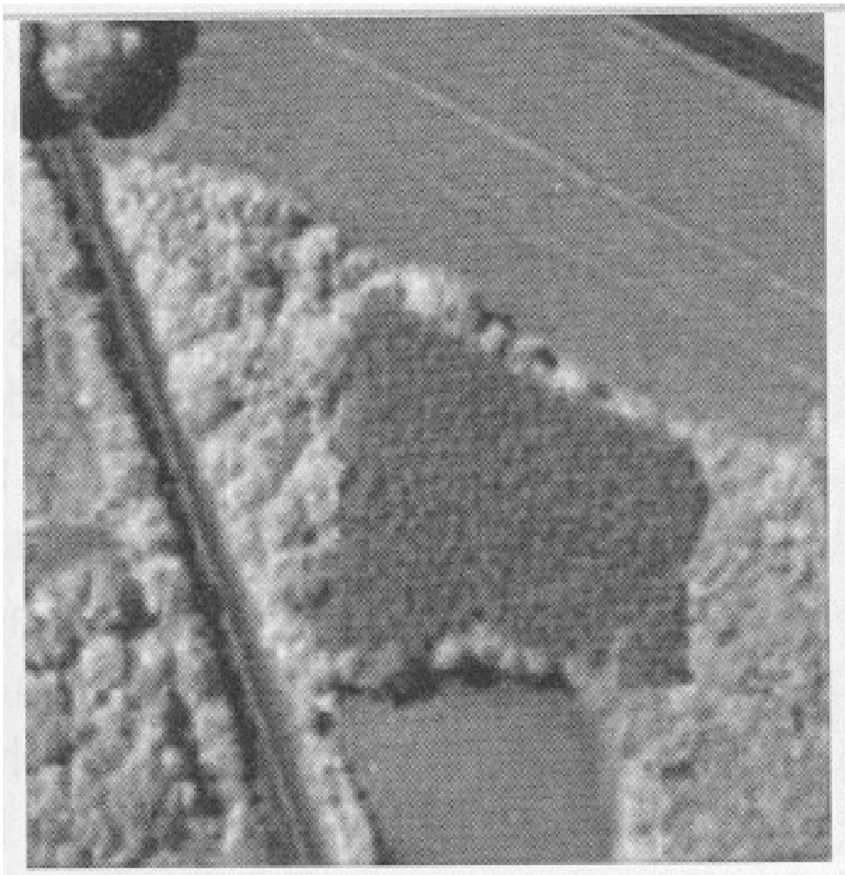
iii. Tone or Color

Tone or color relates to the spectral reflectance characteristics of objects.

Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone also allow the elements of shape, texture, and pattern of objects to be distinguished.

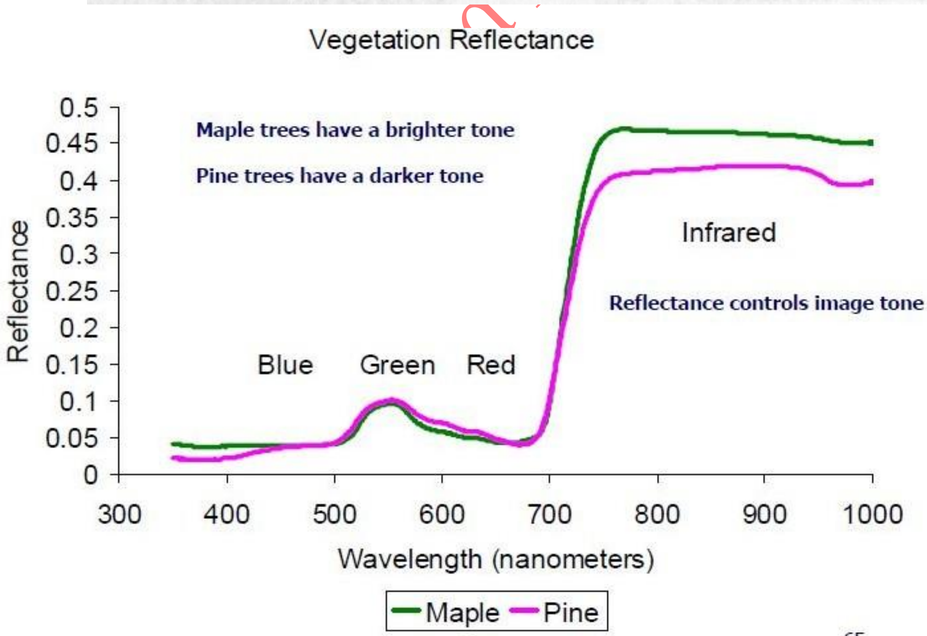
Tone or hue refers to the relative brightness or colour of objects on an image. It is the most important characteristics of the photo. It represents a record of the radiation that has been reflected from the Earth's surface onto the film.

Light tone represents areas with a high reflectance/radiance and dark tone represents areas with low radiance. The nature of the materials on the Earth's surface affects the amount of light reflecte



e. Stand of pine (evergreen) surrounded by hardwoods (courtesy Litton Emerge, Inc.).

- Collected with Near-infrared film.
- Image tone – variations in image tone (e.g., the grey scale from white to black) allow for discrimination of different forest cover types
- Dark area is a pine stand and the light-colored forests are deciduous trees.



iv. Texture

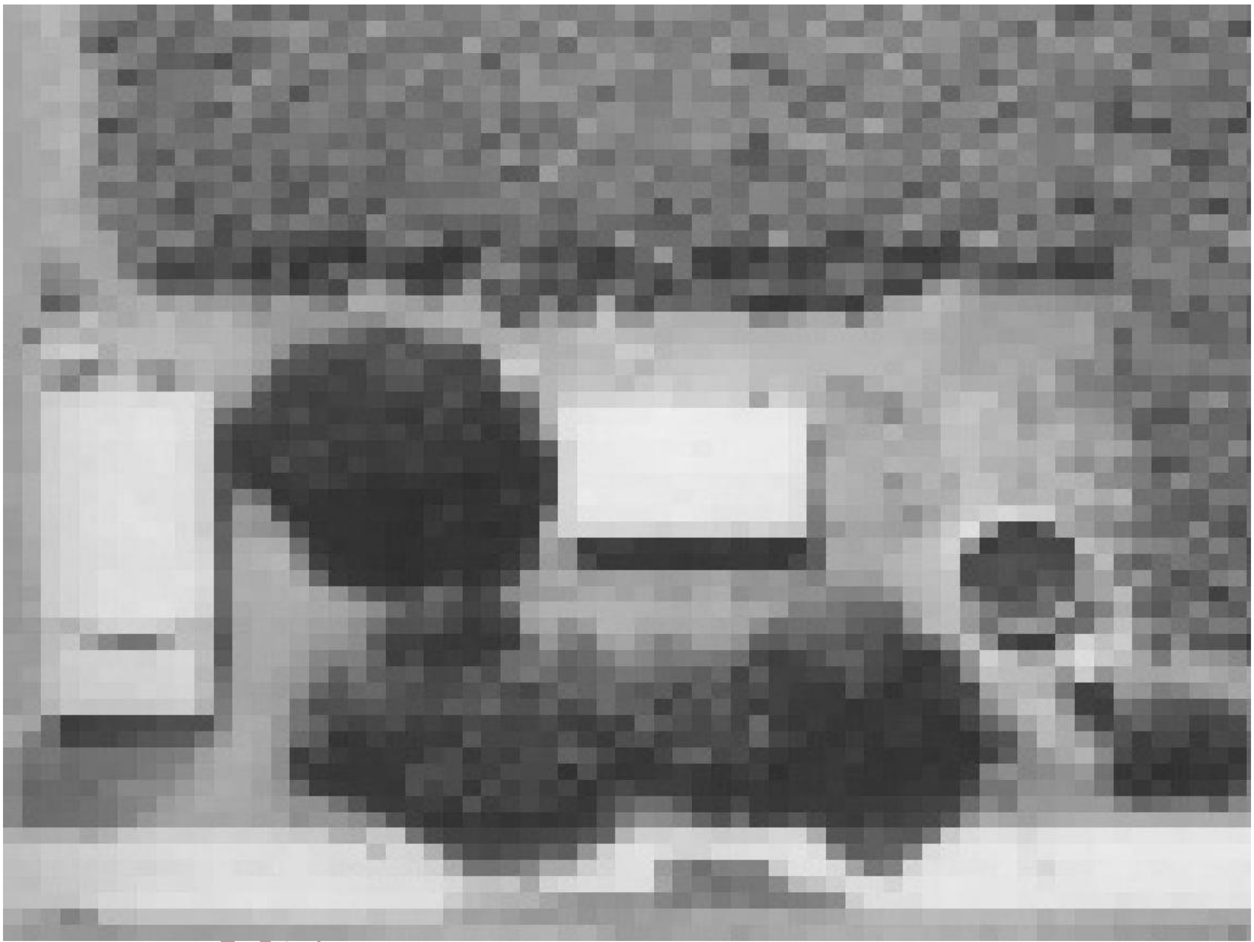
Texture refers to the arrangement and frequency of tonal variation in particular areas of an image.

Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas some of the textures would have very little tonal variation. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance.

Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands.

Texture is one of the most important elements for distinguishing features in radar imagery.

Texture is dependent on the scale of aerial photographs. As the scale is reduced the texture progressively becomes finer and ultimately disappears.

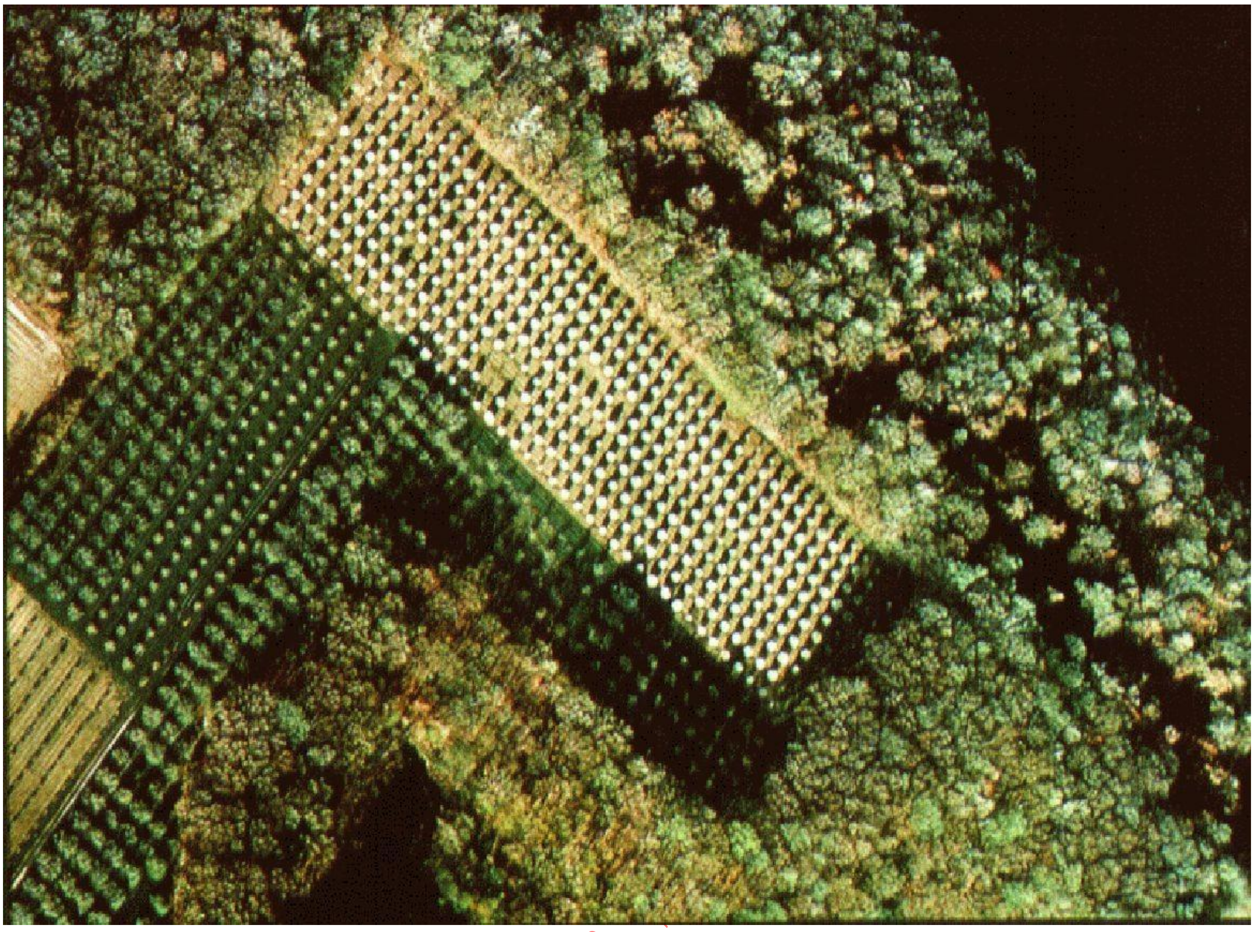


v. Pattern

Pattern is the spatial arrangement of objects. The repetition of certain general forms or relationships is characteristic of many objects. For examples road patterns or drainage pattern, crop disease pattern and lithological pattern.

Pattern refers to the spatial arrangement of visibly discernible objects.

Typically an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees and urban streets with regularly spaced houses are good examples of pattern.



vi. Shadow

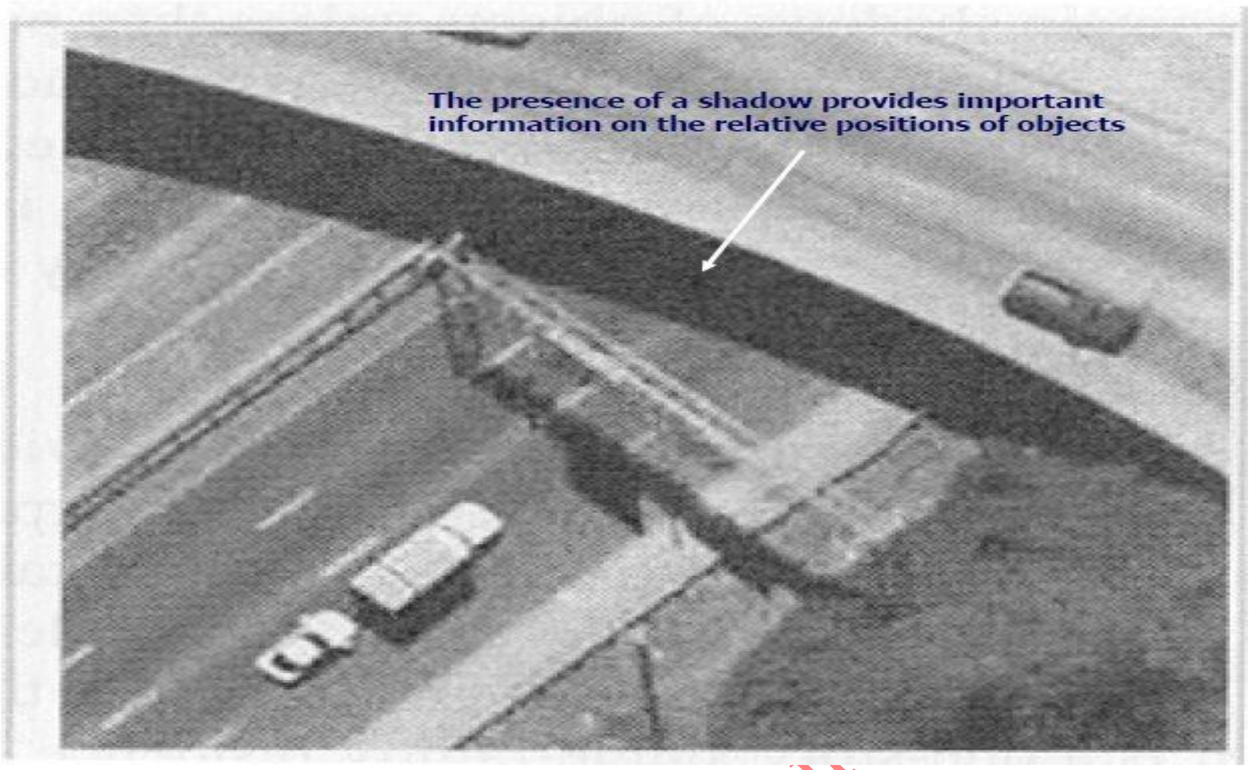
Shadows may reveal details about size and shape not apparent from an overhead view.

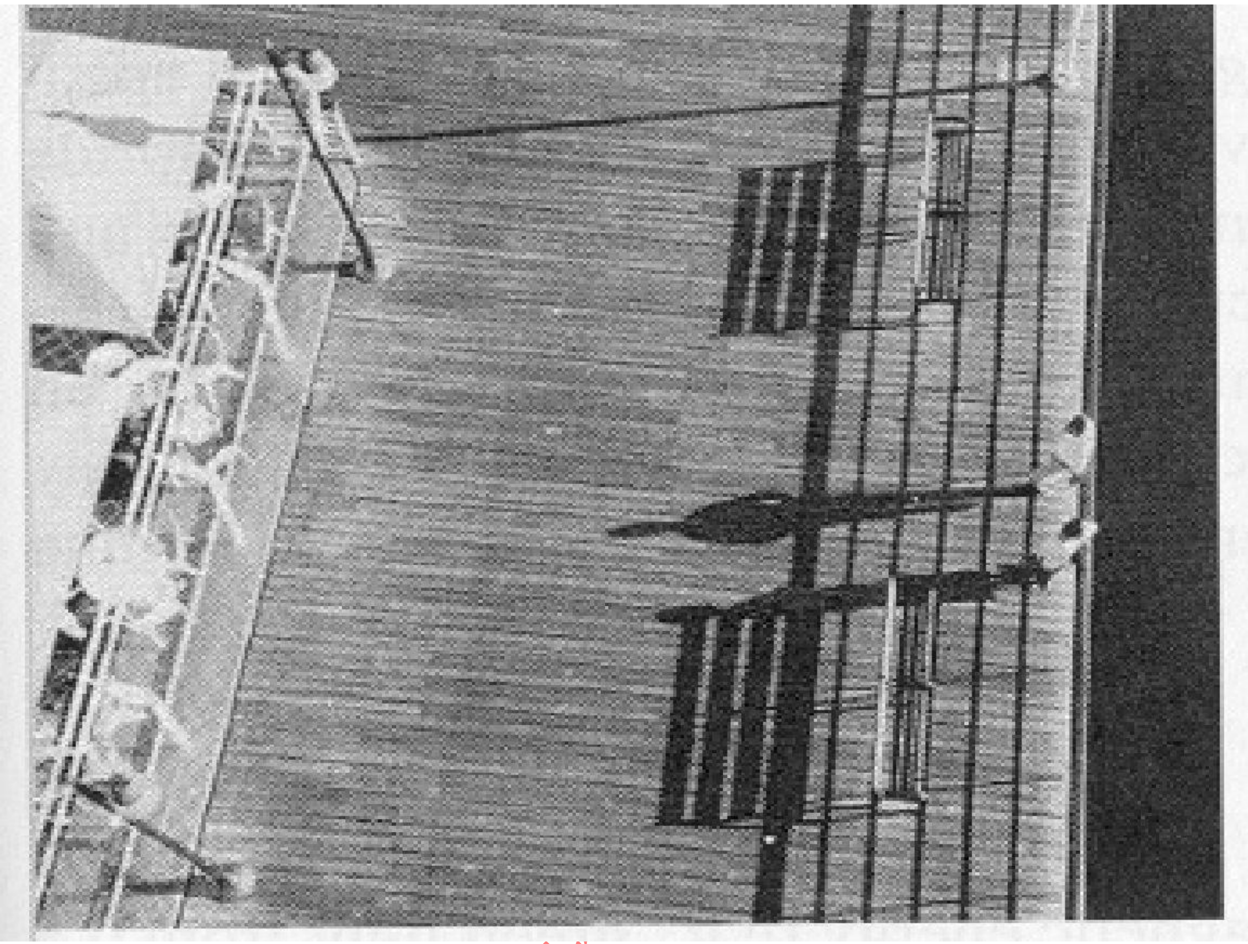
Shadow is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings.

Shadow is also useful for enhancing or identifying topography and landforms, particularly in radar imagery. Shadows of objects aid in their identification.

Shadows are important in two opposing respects:

- the shape or outline of shadow affords an impression of the profile view of objects (which aids in interpretation)
- objects with shadows reflect little light and are difficult to discern on a photo


The presence of a shadow provides important
information on the relative positions of objects



vii. Site

Site refers to the location of the object in relation to its geographic or topographic setting.

Place/site is a statement of an object's position in relation to others in its vicinity and usually aids in its identification (e.g., certain vegetation or tree species are expected to occur on well drained uplands or in certain countries).

viii. Association

Association refers to the occurrence of certain features in relation to others. For example, a merry-go-round wheel might be difficult to identify if standing in a field near a barn, but would be easy to identify if stand in an area identified as amusement park.

Association takes into account the relationship between other recognizable objects or features in proximity to the target of interest.

The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given above, commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated with schools, playgrounds, and sports fields. A lake is associated with boats, a marina, and adjacent recreational land.

5.1.2 Why is image interpretation such an important tool? (Significance of image interpretation)

i. Image interpretation represents the fundamental process for human (visual) analysis of remote sensing imagery.
ii. It provides a unique spatial observation perspective.
iii. It provides information that cannot easily be obtained in other ways.
iv. It provides the ability to do accurate mapping, including 3-D information.
v. It can provide information beyond our visual perception range.
vi. It allows for change detection analyses of specific regions where satellite data are not available.

5.1.3 Steps in Image Interpretation

During the process of interpretation of satellite images, image interpreters usually make use of seven tasks, which form a chain of events. They are:

1. **Detection:** It involves selectively picking out objects that are directly visible (e.g. water bodies, rivers, rock faces etc.) or areas that are indirectly visible (e.g. areas of wet soils or paleochannels) on the photographs.
2. **Identification and Recognition:** It involve naming objects or areas (the most important task in this chain of events).
3. **Analysis:** It involves trying to detect the spatial order of the objects or areas.
4. **Deduction:** It is rather complex and involves the principle of convergence of evidence to predict the occurrence of certain relationships on the photo.

5. **Classification:** helps or comes in to arrange the objects and elements identified into an orderly system.
6. **Idealization:** The interpretation is idealized using guidelines/directions which are drawn to summarize the spatial distribution of objects (e.g., land use/land cover).
7. **Accuracy determination:** It involves visiting random points in the field to confirm or refute the interpretation.

5.1.4 Photo (Image) Interpretation Strategies

i. Direct recognition

It involves the application of experience, skill, and judgment to associate image patterns and responses with information classes. It needs to be a disciplined process with a careful, systematic examination of the image.

ii. Field observations

If cannot recognize an object or pattern in an image, go to the field and identify it.

iii. Inference

It involves the use of a visible response or pattern to infer one that is not visible.

Soils are defined by vertical profile (subsurface characteristics) which cannot be seen, but soils are also closely related to patterns of landforms that can be seen on an image. Therefore, the landform becomes a surrogate.

Example—use of landform and vegetation information to infer soil information Inference requires knowledge of the links between proxy and mapped patterns.

iv. Probabilistic

It attempts to narrow the range of possibilities by integrating non-image information into the interpretation process.

For example, phenology, crop calendar, or topography.

v. Deterministic

It is the most rigorous and precise approach; more information is derived from the image.

For example, the use of a stereo model to estimate height or topographic elevation

vi. Collateral Information

It refers to ancillary, non-image information used in interpretation, which can come from books, maps, or field observations. But it often includes the implicit (frequently intuitive) knowledge that the interpreter brings to the task in the form of training and experience.

5.2 Digital Image Classification

Image classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their spectral response (the measured brightness of a pixel across the image bands, as reflected by the pixel's spectral signature).

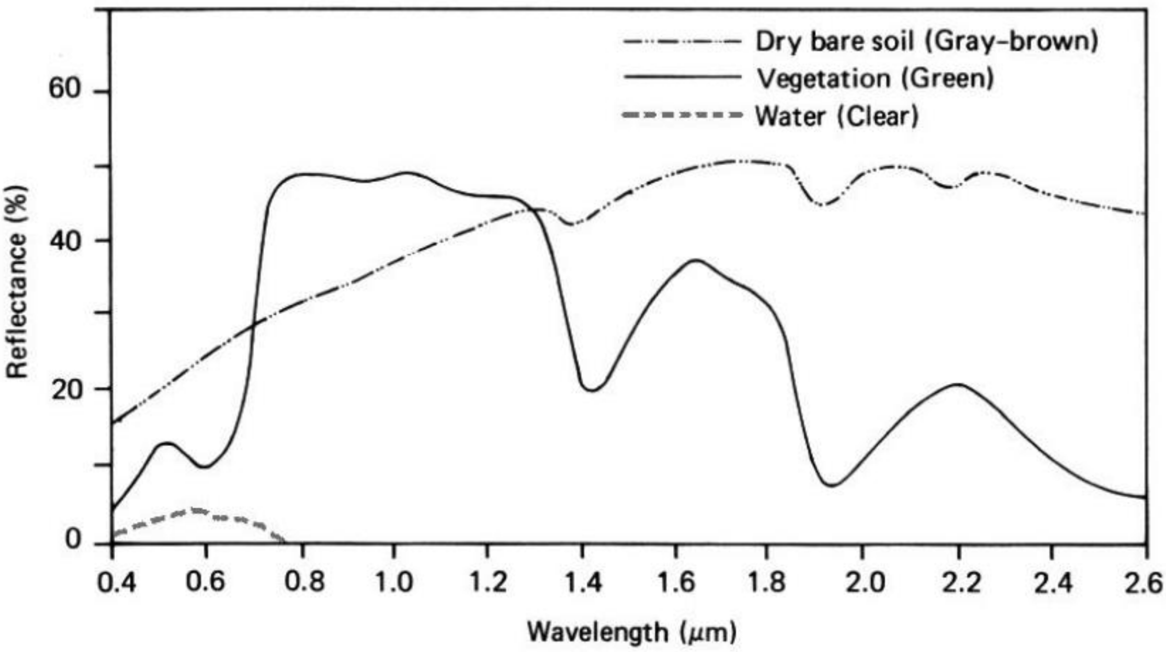


Figure 1: Typical spectral reflectance curve for vegetation, soil, and water.

Digital image classification involves

- grouping of similar features
- separation of dissimilar ones
- assigning class label to pixels
- resulting in manageable size of classes

Image classification is to automatically categorize all pixels in an image into land cover classes or themes. Normally, multispectral data are used to perform the classification, and the spectral pattern present within the data for each pixel is used as a numerical basis for categorization. That is, different feature types manifest a different combination of DNs based on their inherent spectral reflectance and emittance properties. The final output of the classification process is a type of digital image, specifically a map of the classified pixels. For display, the class at each pixel may be coded by character or graphic symbols or by color. The classification process compresses the image data by reducing a large number of gray levels in each of several spectral bands into a few numbers of classes in a single Image.

In conclusion,

Image classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their DN (pixel) values. Classification of remotely sensed data is used to assign corresponding levels with respect to groups with homogeneous characteristics, with the aim of discriminating multiple objects from each other within the image. The level is called ***class.*** Classification is the most popularly used information extraction technique in digital remote sensing.

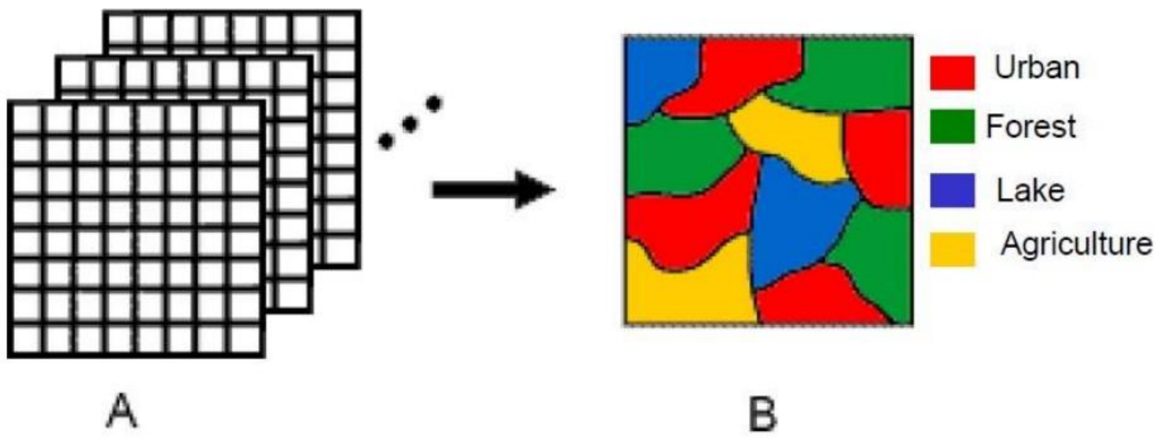


Figure 2: Assigning each pixel in a remotely sensed image a level describing a real-world object.

5.2.1 Advantages of Image Classification.

i. Cost efficient in the analyses of large data sets.
ii. Results can be reproduced.
iii. More objective than visual interpretation.
iv. Effective analysis of complex multi-band (spectral) interrelationships.
v. Classification achieves data size reduction.
vi. To analyze thematic characteristics of object based on brightness values in image.
vii. To translate continuous variability of image data into map patterns that provide meaning to the user.
viii. To obtain insight in the data with respect to ground cover and surface characteristics.
ix. To find anomalous patterns in the image data set.

5.2.2 Principles (Assumptions) of Image Classification

The underlying assumption of image classification is that ***the spectral response of a particular feature (i.e., land-cover class) will be relatively consistent throughout the image*.**

5.2.2.1 Image Space

A digital image is a 2D array of elements. In each element, the energy reflected or emitted from the corresponding area on the Earth's surface is stored. The spatial arrangement of the measurements defines the **image or image space.** Depending on the sensor, data are recorded in n bands. Digital image elements are usually stored as 8-bit DN-values (range: 0–255).

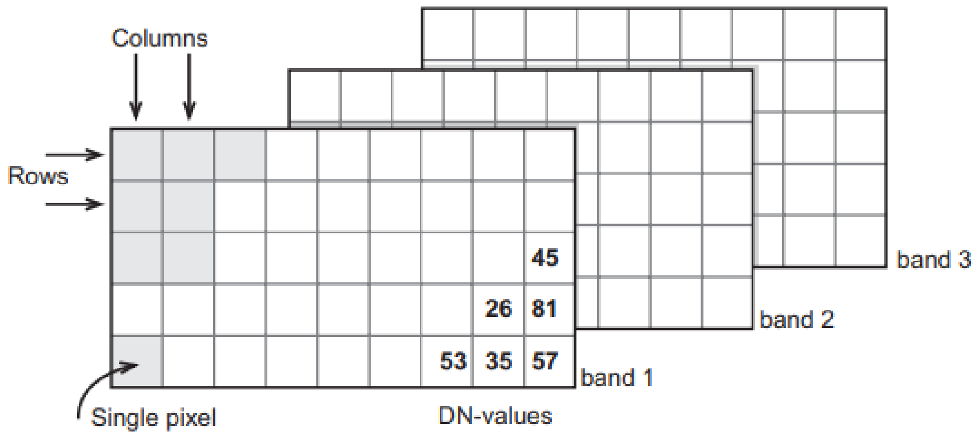


Figure 3: The structure of a multi-band image.

5.2.2.2 Feature Space

In one pixel, the values in (for example) two bands can be regarded as components of a two-dimensional vector, the feature vector. An example of a feature vector is (13, 55), which tells that 13 DN and 55 DN are stored for band 1 and band 2 respectively. This vector can be plotted in a two-dimensional graph.

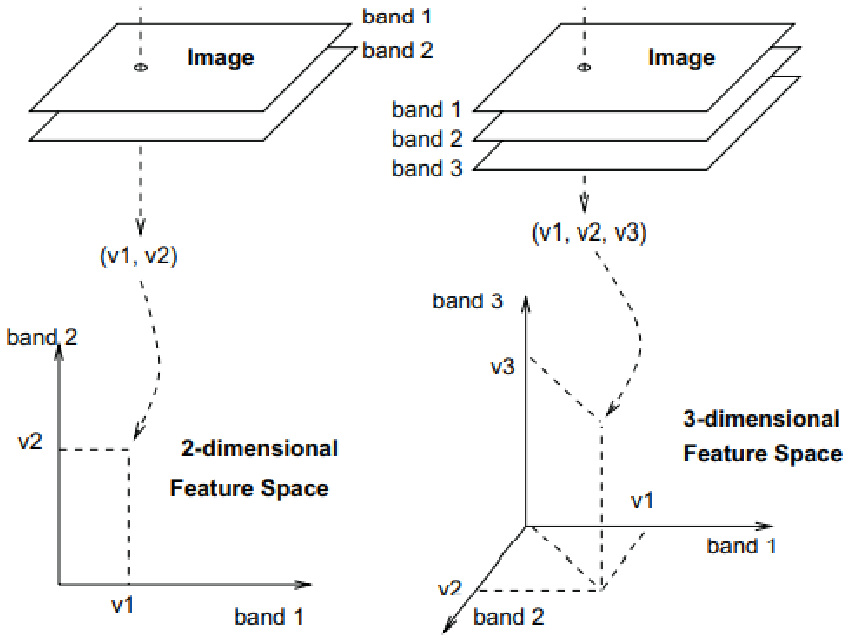


Fig 4: Plotting of the values of a pixel in the feature space for a two and three band image.

Similarly, this approach can be visualized for a three-band situation in a three-dimensional graph. A graph that shows the values of the feature vectors is called **a feature space, or also a feature space plot or scatter plot**. Fig 4 illustrates how a feature vector (related to one pixel) is plotted for two and three bands, respectively. Two-dimensional feature space plots are the most common.

Note that plotting values is difficult for a four- or more-dimensional case, even though the concept remains the same. A practical solution when dealing with four or more bands is that all the possible combinations of two bands are plotted separately. For four bands, this already yields six combinations: bands 1 and 2, 1 and 3, 1 and 4, bands 2 and 3, 2 and 4, and bands 3 and 4.

Plotting the combinations of the values of all the pixels of one image yields a large cluster of points. Such a plot is referred to as a scatterplot (Fig 5). A scatterplot provides information about the combinations of pixel values that occur within the image. Note that some combinations will occur more frequently and can be visualized by using intensity or color.

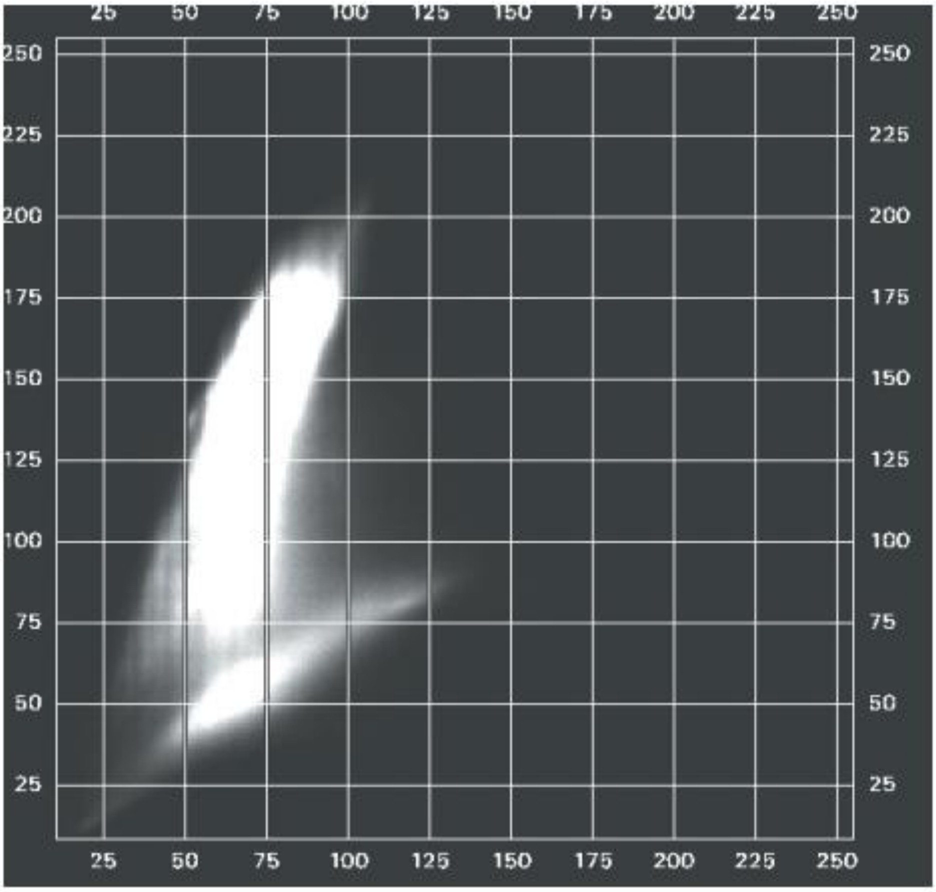


Fig 5: Scatterplot of two bands of a digital image. Note the units (DN-values) along the x and y-axes. The intensity at a point in the feature space is related to the number of pixels at that point.

5.2.2.3 Distances and clusters in the feature space

We use distance in the feature space to accomplish classification. Distance in the feature space is measured as 'Euclidian distance' in the same unit as the DNs (the unit of the axes). In two-dimensional feature space the distance can be calculated according to Pythagoras' theorem.

In the situation of Fig 6, the distance between [10,10] and [40,30] equals the square root of $(40-10)^2 + (30-10)^2$.

For the three or more dimensions, the distance is calculated in a similar way.

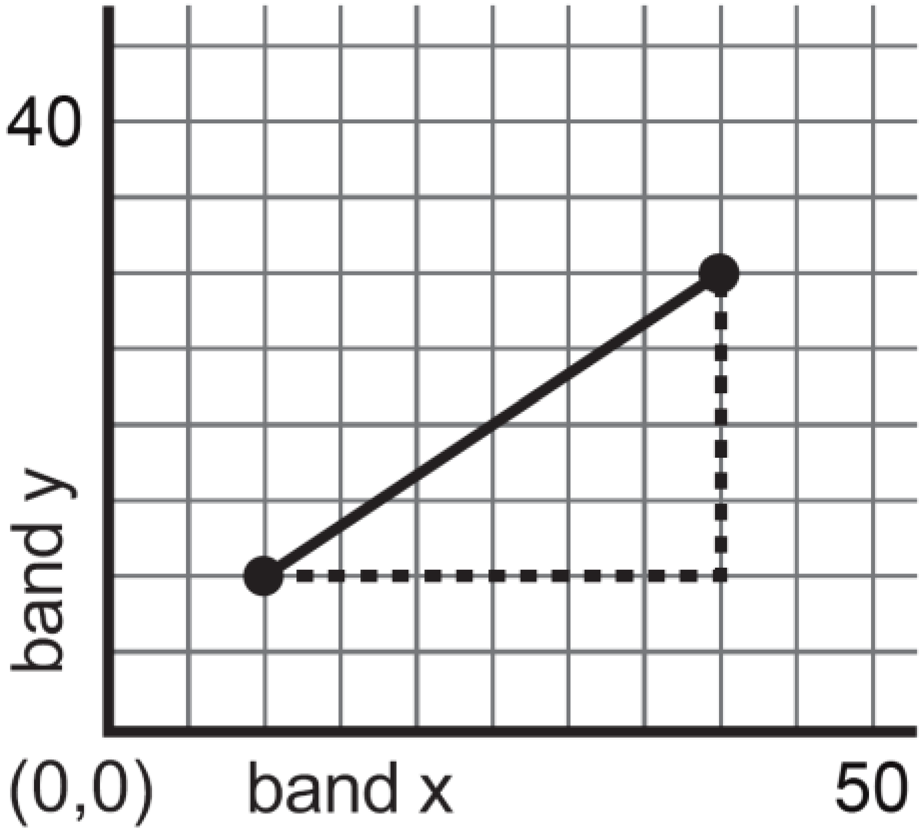


Figure 6: Euclidian distance between the two points using Pythagoras' theorem.

5.2.3 Image Classification

Classes to be distinguished in an image classification need to have different spectral characteristics. This can, for example, be analyzed by comparing spectral reflectance curves.

Figure 7 also illustrates the **limitation of image classification**: *if classes do not have distinct clusters in the feature space, image classification can only give results to a certain level of reliability*.

The principle of image classification is that a pixel is assigned to a class based on its feature vector, by comparing it to predefined clusters in the feature space. Doing so for all image pixels results in a classified image.

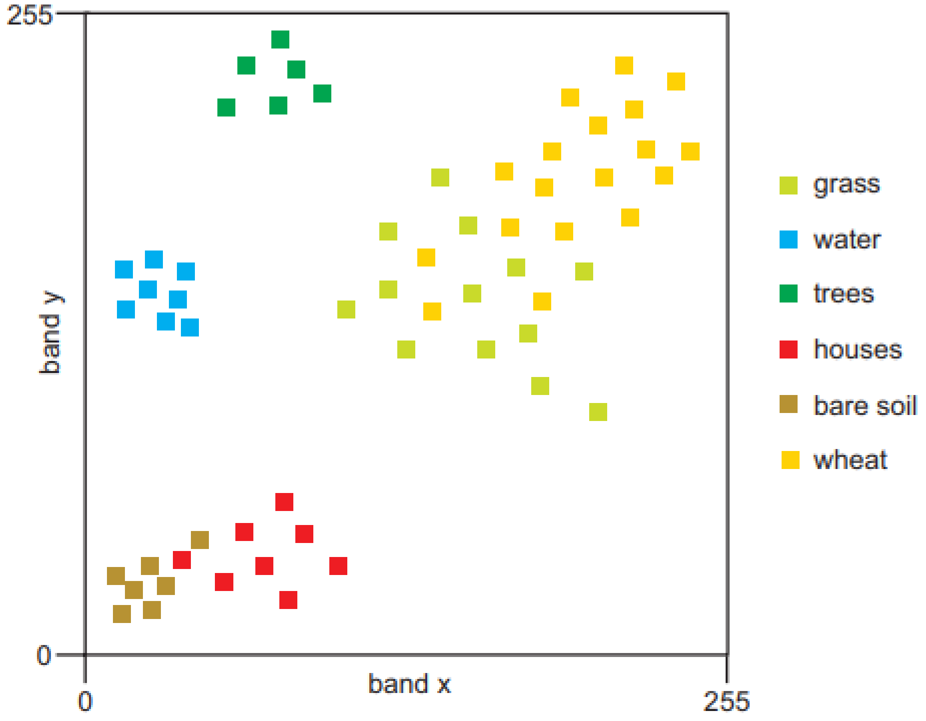


Figure 7: Feature space showing the respective clusters of six classes; note that each class occupies a limited area in the feature space.

The crux of image classification is in comparing it to predefined clusters, which requires

- definition of the clusters and
- methods for comparison.

Definition of the clusters is an interactive process and is carried out during the training process. Comparison of the individual pixels with the clusters takes place using ***classifier algorithms***.

Information Class and Spectral Class

Information Class

Information class is a class specified by the image analyst. It refers to the information to be extracted. These classes are those categories of interest that the analyst actually tries to identify in the imagery, such as water, vegetation, urban, etc.

Spectral Class

Spectral class is a class which includes similar gray-level vectors in the multi-spectral space. Spectral classes are groups of pixels that are uniform (or near similar) with respect to their brightness values in the different spectral channels of the data. These classes are created as Class-1, Class-2,…...…………………etc. which class represents what land-cover feature (e.g., water, vegetation) has not identified. The objective is then to match the spectral classes in the data to the information classes of interest.

5.2.3.1 Image Classification Process

The process of image classification typically involves five steps:

1. Selection and preparation of the image data

Depending on the cover types to be classified, the most appropriate sensor, the most appropriate date(s) of acquisition, and the most appropriate wavelength bands should be selected.

2. Definition of the clusters in the feature space

Here two approaches are possible: ***supervised classification and unsupervised classification***. In supervised classification, the operator defines the clusters during the training process; in unsupervised classification, a clustering algorithm automatically finds and defines a number of clusters in the feature space.

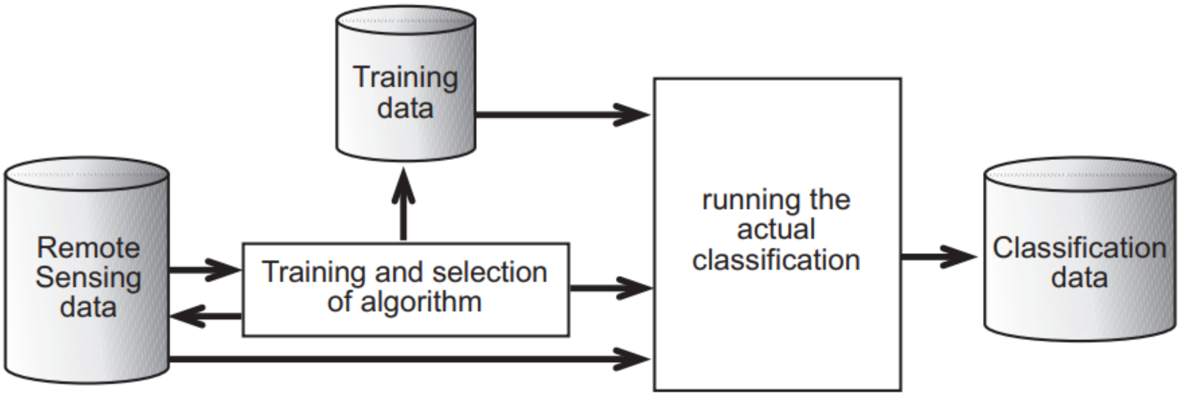


Figure 8: The classification process; the most important component is the training in combination with a selection of the algorithm.

3. Selection of classification algorithm

Once the spectral classes have been defined in the feature space, the operator needs to decide how the pixels (based on their DN-values) are assigned to the classes. The assignment can be based on different criteria.

4. Running the actual classification

Once the training data have been established and the classifier algorithm selected, the actual classification can be carried out. This means that, based on its DN values, each individual pixel in the image is assigned to one of the predefined classes.

5. Validation of the result

Once the classified image has been produced its quality is assessed by comparing it to reference data (ground truth). This requires the selection of a sampling technique, the generation of an error matrix, and the calculation of error parameters.

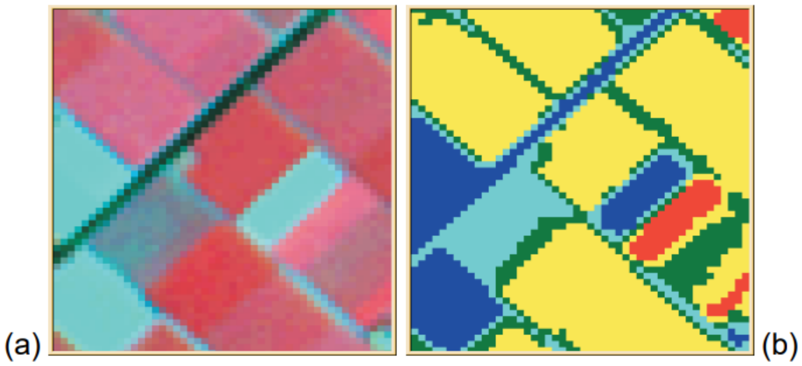


Figure 9: The result of classification of a multi-spectral image (a) is a raster in which each cell is assigned to some thematic class (b).

Note:

- In principle, however, image classification can be carried out on any n-dimensional data set. Visual image interpretation, however, limits itself to an image that is composed of a maximum of three bands.

5.2.3.2 Image Classification Methods

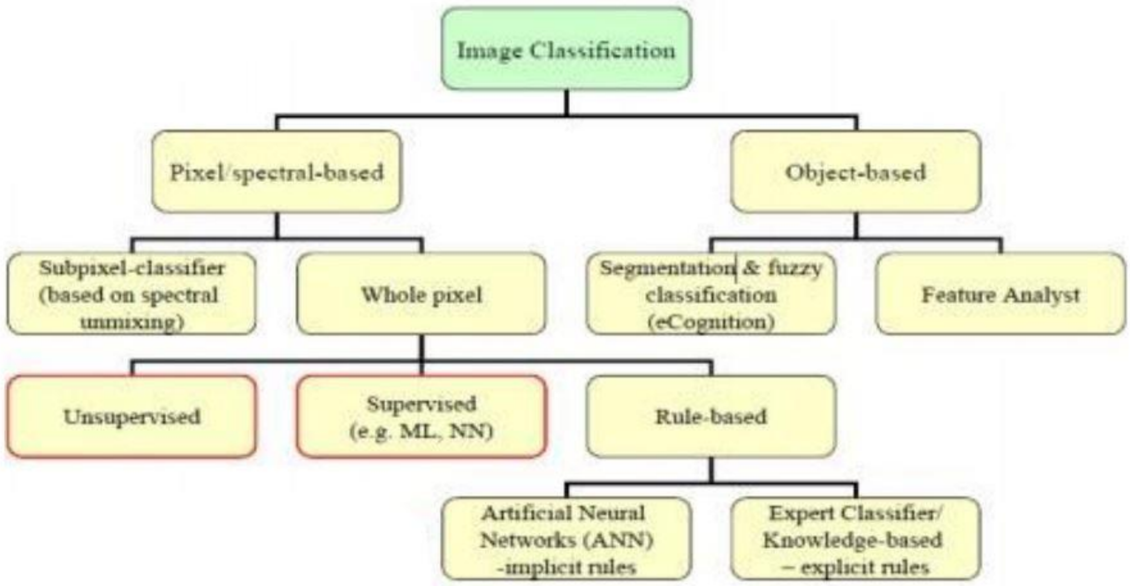


Figure 10: Methods of Image Classification.

5.2.3.2.1 Pixel-Based Classification

In pixel-based classification, individual image pixels are analyzed by the spectral information that they contain. **Supervised and unsupervised image classification** are examples of pixel-based image classification (also called per-pixel classification)

This is the traditional approach to classification since the pixel is the fundamental (spatial) unit of a satellite image.

Limitations of Pixel-Based Classification

i. **Information from surrounding pixels, which may help in correctly identifying the target's pixel class, is not used.**
Consequently, a class that displays high spectral heterogeneity may have its pixels labeled as different classes. For example, when farm fields exhibit high within-field spectral variability due to variations in soil fertility, soil moisture content, pests, and diseases, or erratic farm practices, this approach could lead to a high rate of misclassification, where parts of a field in some class is incorrectly classified as another class.

ii. **Misclassifications are pronounced when the pixel-based image classification approach is applied to highly heterogeneous landscapes.**
The use of high spatial resolution imagery to capture heterogeneity leads to increased errors when per-pixel approaches are adopted.

iii. **In pixel-based image classification, signal from the multiple land covers is present in a single pixel.**
A per-pixel classification attempts at geospatial segmentation of earth-surface features based on the pixels and their digital values. The point-based image classification approach overlooks the existence of mixed pixel.
One of the approaches developed to overcome this challenge of the mixed signal is sub-pixel classification, through which the proportion of different land covers with a pixel is determined.

Sub-pixel Classification

Sub-pixel classification considers the geographic space as a continuous phenomenon (field).

It tries to quantify the amount of feature or material within a pixel. Therefore, it calculates the percentage or amount of that material within a pixel. For example, pixels under class-1 contain 90-100% built-up, pixels under class-2 contains 80-90% built-up, and so on.

This concept handles the problem of mixed pixel well, but ignores the identification of other surface materials.

One classified image layer contains information about one earth's surface materials only; and it appears like a gradient map. Therefore, there is no spatial segmentation among the features.

This method of classification works better with high spectral-resolution images.

Sub-pixel classification is useful when coarse spatial resolution images are used or heterogeneous landscapes are under analysis. They do so by determining the fractional proportion of different land-cover types in a pixel on the basis of an appropriate training data set.

Object-based Classification

Both per-pixel and sub-pixel classification are actually pixel-based; they rely on the pixel value. Per-pixel classification creates square pixels and each pixel has a class. Sub-pixel approach also creates a square pixel and each pixel has a percentage of material. Object-based image classification (also called object-oriented classification or object-based image analysis) is one of the approaches developed to overcome the limitations of pixel-based approaches.

The object-oriented approach aggregates the pixels by means of image segmentation, i.e., it divides the image into groups of pixels (called objects) aggregating them according to criteria linked not only to the spectrum (spectral bands) but also to the shape and homogeneity. Then for the classification, the characteristics of the whole object are used, including not only the mean vector of pixels, contained within the signature, but also statistical, shape, texture, and contextual information.

It also allows defining rules based on the position of the objects with respect to each other. It generates objects with different scales in an image simultaneously. These objects are more meaningful because they represent features in the image.

In object-based classification, one can use multiple data sources to create objects and then classify them. For example, one can take NIR band, thermal band, elevation or shapefile to classify each object.

The first step in this classification is to segment the image into homogeneous objects. The term object here stands for a contiguous cluster of pixels. Segmentation is based on pre-defined parameters like compactness, shape, and scale, derived from real-world knowledge of the features that one wants to identify.

In the second step, each object (segment) is classified on the basis of one or more statistical properties of the contained pixels. This means that all pixels within a segment are assigned to one class, eliminating the within-field spectral variability and mixed pixel problems associated with pixel-based approaches.

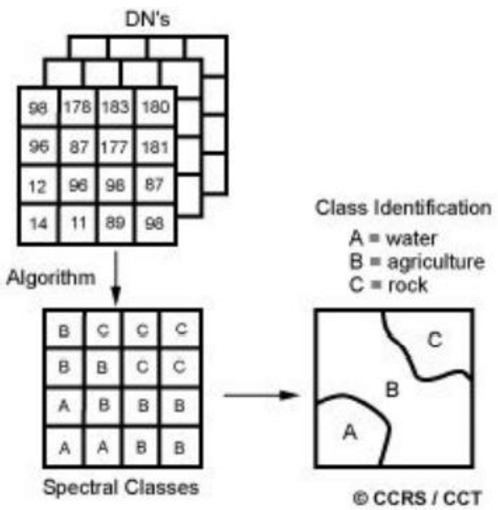
5.2.3.2.1.1 Classification Types ((Pixel Based)Image Classification Techniques)

Common classification procedures can be broken down into two broad subdivisions based on the method.

i. **Unsupervised Image Classification**
ii. **Supervised Image Classification**

5.2.3.2.1.1.1 Unsupervised Image Classification

The computer or algorithm automatically group pixels with similar spectral characteristics (means, standard deviations, covariance matrices, correlation matrices, etc.) into unique clusters according to some statistically determined criteria. The analyst then re-labels and combines the spectral clusters into information classes.



Unsupervised classification (a.k.a., "clustering") identifies groups of pixels that exhibit a similar spectral response. These spectral classes are then assigned "meaning" by the analyst (e.g., assigned to land-cover categories).

Unsupervised classification is the process where numerical operations are performed that search for natural groupings of the spectral properties of pixels, as examined in multispectral feature space. The clustering process results in a classification map consisting of m spectral classes. The analyst then attempts to assign or transform the spectral classes into thematic information classes of interest (e.g., forest, agriculture).

This may be difficult some spectral clusters may be meaningless because they represent mixed classes of Earth surface materials. Therefore, the analyst must understand the spectral characteristics of the terrain well enough to be able to label certain clusters as specific information classes.

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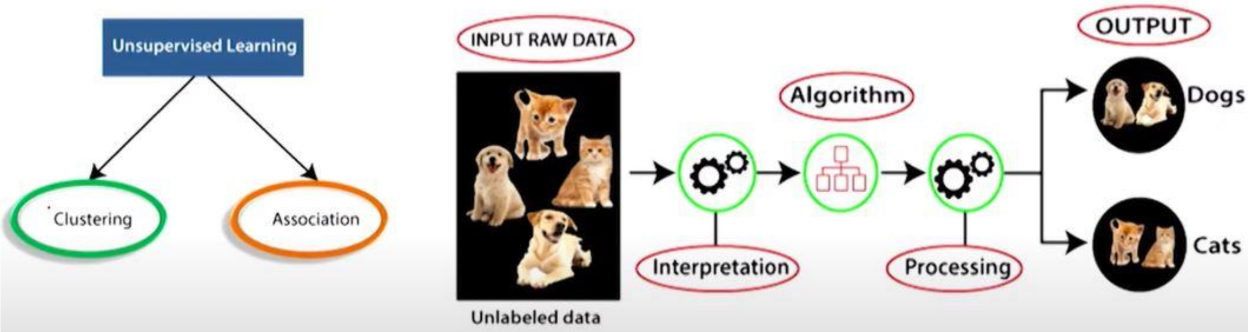


Figure 11: An illustration of unsupervised learning

Advantages and Disadvantages of Unsupervised Image classification

Advantages

- No prior knowledge of the image area is required.
- Human error is minimized.
- Unique spectral classes are produced.
- Relatively fast and easy to perform.

Disadvantages

- Spectral classes do not represent features on the ground.
- Does not consider spatial relationships in the data.
- Can be very time-consuming to interpret spectral classes.
- Spectral properties vary over time, across images.

Process (Steps/Workflow) of Unsupervised Classification

1. Determine a general classification scheme
2. Assign pixels to spectral classes (ISODATA)
3. Assign spectral classes to informational classes

1. Determine a general classification scheme

- Depends upon the purpose of the classification

- With unsupervised classification, the scheme does not need to be very specific

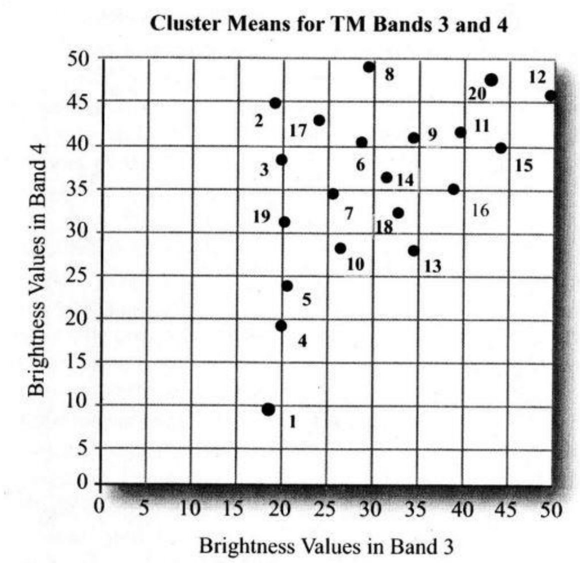
2. **Assign pixels to spectral classes (ISODATA)**

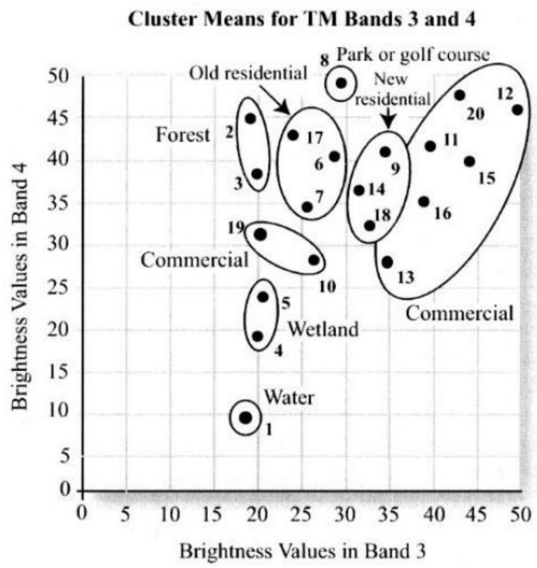
- Group pixels into groups of similar values based on pixel value relationships in multi-dimensional **feature space (clustering)**
- Iterative **ISODATA** technique is the most common
- Assign spectral classes to informational classes

3. **Assign spectral classes to informational classes**

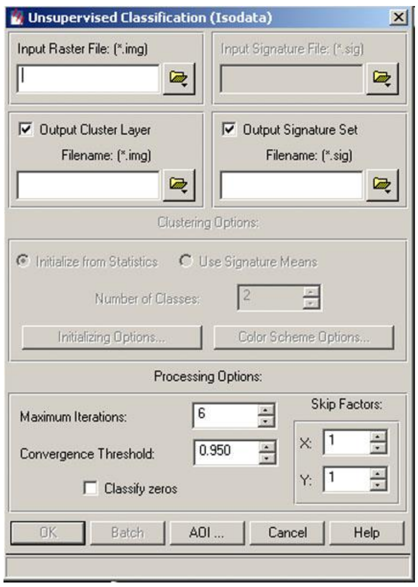
- Once the spectral clusters in the image are identified, the analyst must assign them to the "informational" classes of the classification scheme (i.e., land cover)

Spectral to Informational Classes





ISODATA



• Iterative Self-Organizing Data (ISODATA) Analysis Technique is a popular clustering algorithm for unsupervised image classification technique, which uses the <u>**spectral distance**</u> between image pixels in feature space to classify pixels into a specified number of unique spectral groups (or **clusters**).

ISODATA Parameters & Guidelines

i. **Number of clusters:** should be 10 to 15 per desired land cover class

ii. **Convergence threshold:** refers to the percentage of pixels whose class values should not change between iterations; generally, set to 95%.

- ✓ A convergence threshold of 95% indicates that processing will cease as soon as 95% or more of the pixels stay the same from one iteration to the next (or 5% or fewer pixels change)
- ✓ Processing stops when the of iterations or convergence threshold is reached (whichever comes first)
- ✓ Maximum number of iterations: ideally, the convergence threshold should be reached
- ✓ Should set reasonable parameters so that convergence is reached before iterations run out.

Several Algorithms for clustering in Unsupervised image Classification

i. One-pass clustering
ii. Sequential Clustering
iii. Statistical Clustering
iv. K-means Clustering
v. ISODATA Clustering

i. K-means Clustering

The K-means (also known as C-means) method uses an iterative (repetitive) approach to determining classes.

The K means algorithm analyzes a sample of the input to determine a specified number of initial class centers. Cells are assigned to classes by determining the closest class center (e.g. using minimum Euclidian distance). After each classification iteration, the process calculates a new center for each class by finding the point which minimizes the sum of the squared spectral distance from each pixel in the class to the class center. The process repeats until the shift in class centers falls below a specified threshold value, or a specified maximum number of iterations is reached.

Advantage

- It has simplicity and, speed which allows it to run on large datasets.

Disadvantages

- It does not yield the same result with each run, since the resulting clusters depend on the initial random assignments
- It is sensitive to outliers, so, for such datasets k-medians clustering is used
- One must specify the number of clusters as an input to algorithm.

ii. ISODATA (Iterative Self-Organising Data Analysis Technique) clustering

This clustering method is an extension of k-means clustering method. It represents an iterative classification algorithm and is useful when one is not sure of the number of clusters present in an image. It is iterative because it makes a large number of passes through the remote sensing dataset until specified results are obtained. Good results are obtained if all bands in remote sensing image have similar data ranges. It includes automated merging of similar clusters and splitting of heterogeneous clusters.

The clustering method requires us to input maximum number of clusters that you want, a convergence threshold and maximum number of iterations to be performed. ISODATA clustering takes place in the following steps:

- k arbitrary cluster means are established
- All pixels are relocated into the closest clusters by computing distance between pixel and cluster
- Centroids of all clusters are recalculated and above step is repeated until the threshold convergence
- If the number of clusters are within the specified number and distances between the clusters meet a prescribed threshold, then only clustering is considered complete.

Advantages

- It is good at finding “true” clusters within the data
- It is not biased to the top pixels in the image
- Does not require image data to be normally distributed
- Cluster signatures can be saved, which can be easily incorporated and manipulated along with supervised spectral signatures.

Disadvantages

- It is time consuming
- It requires maximum number of clusters, convergence threshold and maximum number of iterations as an input to algorithm

LULC (Land Use Land Cover) map from unsupervised image classification technique

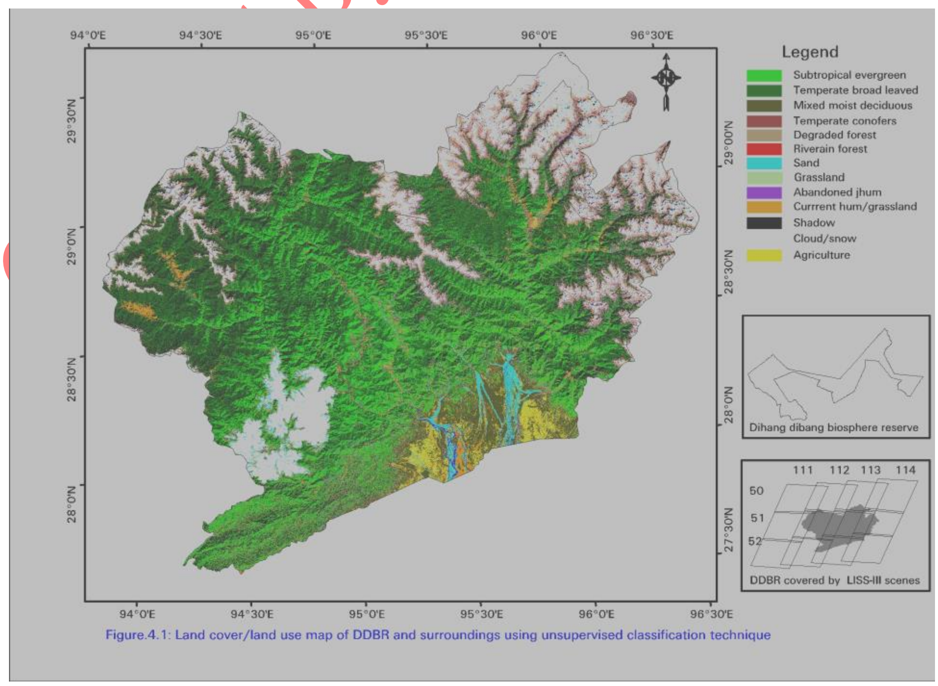


Figure 12: LULC map created from unsupervised image classification approach (technique)

Summary of Unsupervised Image Classification

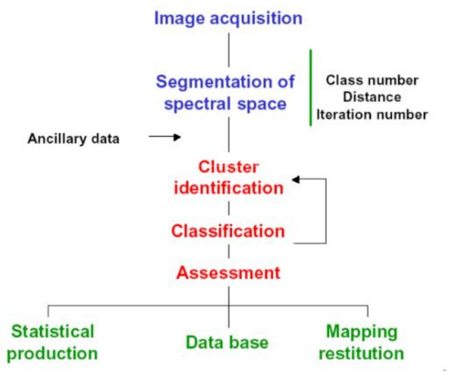
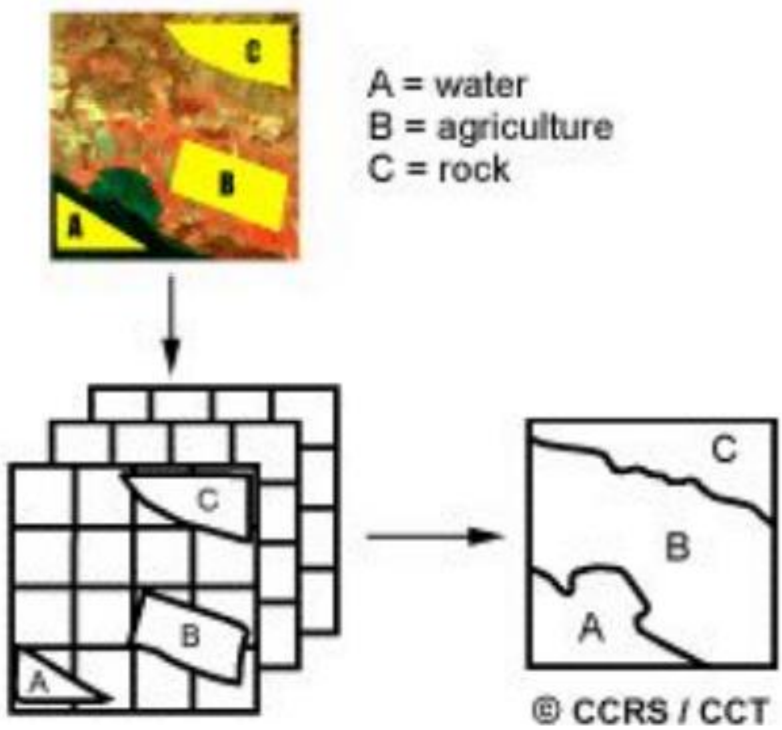


Figure 13: Summary of the image classification from unsupervised image classification approach/technique.

1.2.3.2.1.1.2 Supervised Image Classification

In supervised image classification, training sites are identified prior to (through a combination of fieldwork, map analysis, and personal experience) and spectral characteristics of these sites are used to train the classification algorithm for eventual land-cover mapping of the remainder of the image. Every pixel both within and outside the training sites is then evaluated and assigned to the class of which it has the highest likelihood of being a member.



Supervised classification uses image pixels representing regions of known, homogenous surface composition—training (sites)areas to classify unknown pixels.

For supervised image classification,

i. The analyst uses prior knowledge derived from field surveys, photo-interpretation, and other sources, about small regions of the image to be classified to identify those pixels that belong to the classes of interest.

ii. The feature signatures of these analysts identified pixels are then calculated and used to recognize pixels with similar signatures throughout the image.

In a supervised classification, the identify and the location of some of the land cover types, such as urban, agriculture, wetland, and forest, are known a priori though a combination of field work, analysis of aerial photography, maps, and personal experience. These areas are commonly referred to as **training sites** because the spectral characteristics of these known areas are used to **"train"** the classification algorithm for eventual land cover mapping of the remainder of the image.

Multi-variate statistical parameters (means, standard deviations, covariance matrices, correlation matrices, etc.) are calculated for each training site. Every pixel both within and outside these training sites is then evaluated and assigned to the class of which it has be highest likelihood of being a member.

Considerations for Supervised Image Classification

The following **important aspects must be considered for conducting a rigorous and useful supervised classification of remote sensor data:**

- An appropriate classification scheme must be adopted.
- Representative training sites must be selected, including an appreciation for signature extension factors, if possible.
- Statistics must be extracted from the training site spectral data.
- The statistics are analyzed to select the appropriate features (bands) to be used in the classification process.
- Select the appropriate classification algorithm.
- Classify the imagery into m classes.
- Statistically evaluate the classification accuracy

The classification performance depends on using suitable algorithms to label the pixels in an image as representing particular ground cover types, or classes. A wide variety of **algorithms** are available for supervised classification.

Advantages and Disadvantages of Supervised Image Classification

Advantages

- Generates informational classes representing features on the ground
- Training areas are reusable (assuming they do not change; e.g. roads)

Disadvantages

- Information classes may not match spectral classes (e.g., a supervised classification of "forest" may mask the unique spectral properties of pine and oak stands that comprise that forest)
- Homogeneity of information classes varies
- Difficulty and cost of selecting training sites
- Training areas may not encompass unique spectral classes

Process (Steps/Workflow) of Supervised Classification

1. Determine a classification scheme
2. Create training areas

3. Generate training area signatures
4. Evaluate and refine signatures
5. Assign pixels to classes using a classifier (a.k.a., "decision rule")

1. Determine a classification scheme

- Depends upon the purpose of the classification
- Make the scheme as specific as resources and available reference data allow
  The classification scheme is generalized to make it less specific, making it more specific involves starting over

Classification Scheme—Example

I. Vegetated
   A. Forest
      1. Evergreen
         a. Spruce-fir Forest
            i. Spruce-fir with winterberry understory
         b. Lodgepole pine forest
      2. Deciduous
   B. Shrubland
II. Non-vegetated

2. **Create training areas**

Training areas can be created by following methods:

i. Digitizing: drawing polygons around areas in the image
ii. Seeding: "grows" areas based on spectral similarity to seed pixel
iii. existing data: existing maps, field data (GPS, etc.), high-resolution imagery

Training data (fields/areas/samples)

Training fields are areas of known identity delineated on the digital image, usually by specifying the corner points of a rectangular or polygonal area using line and column numbers within the coordinate system of the digital image.

The analyst must, of course, know the correct class for each area. Usually, the analyst begins by assembling maps and aerial photographs of the area to be classified.

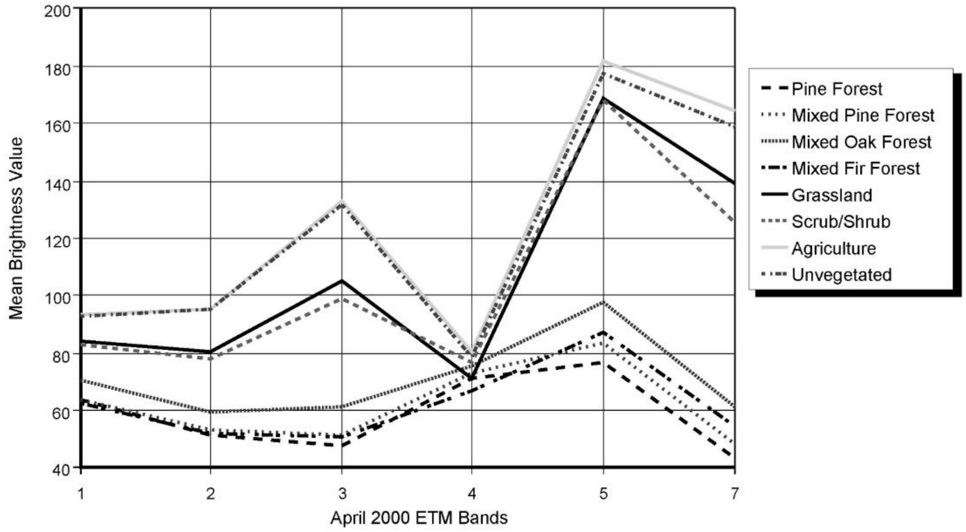
Specific training areas are identified for each informational category, the objective is to identify a set of pixels that accurately represents spectral variation present within each information region.

3. **Generate training area signatures**

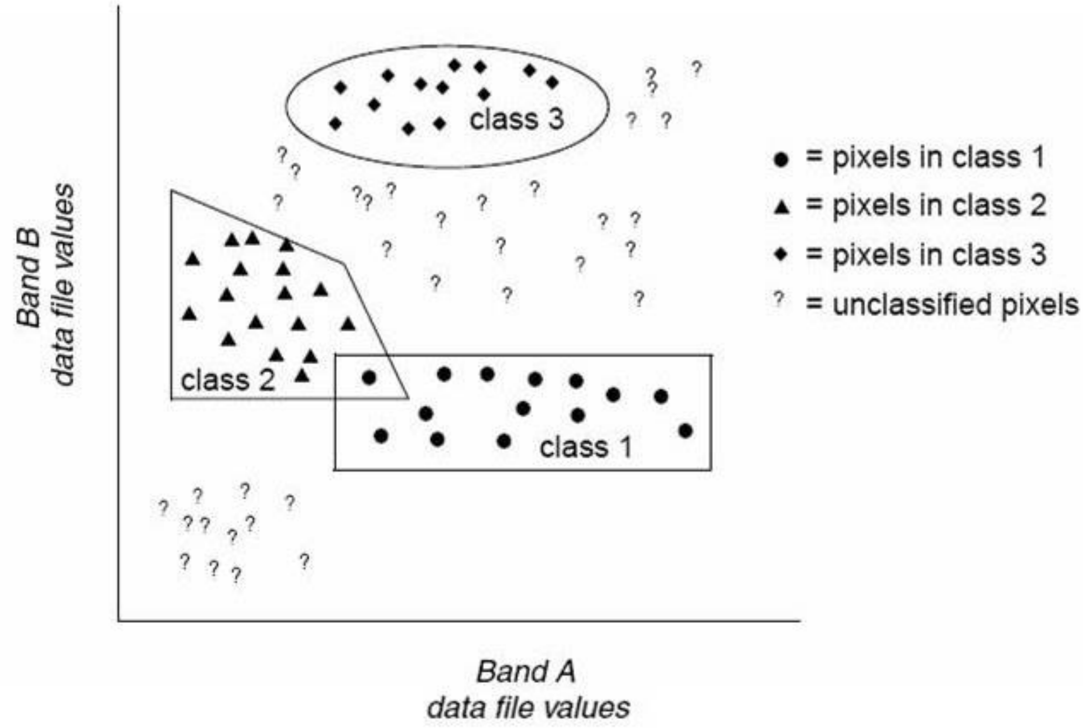
- Signatures represent the collective spectral properties of all the training areas defined for a particular class
- It is the **most important step in supervised classification**

Types of Signatures

i. **Parametric Signature**: Signature that is based on statistical parameters (e.g., mean) of the pixels that are in the training area (normal distribution assumption).



ii. **Non-parametric Signature**: signature that is not based on statistics, but on discrete objects (polygons or rectangles) in a feature space image.



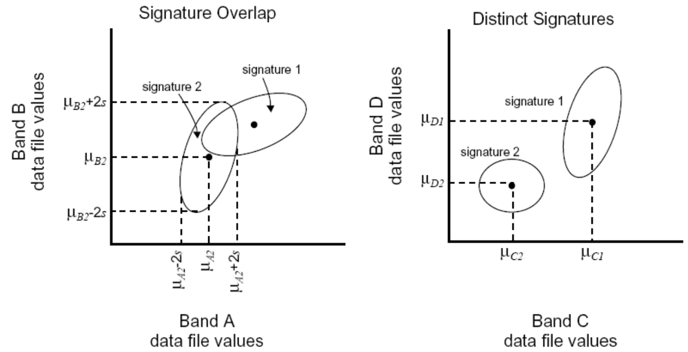
4. **Evaluate and refine signatures**

- Attempt to reduce or eliminate overlapping, non-homogeneous, non-representative signatures
- Signatures should be as "spectrally distinct" as possible

Some Signature Evaluation Methods

i. Ellipse evaluation (feature space)

Figure 99: Ellipse Evaluation of Signatures



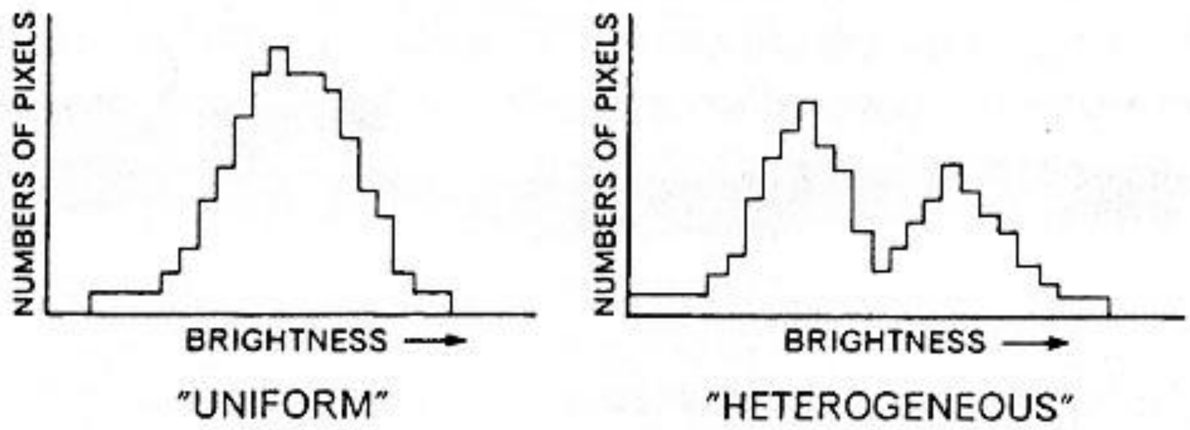
ii. Contingency matrices

Contingency analysis produces a matrix showing the percentage of pixels that are classified correctly in a preliminary image classification of **only the training areas.**

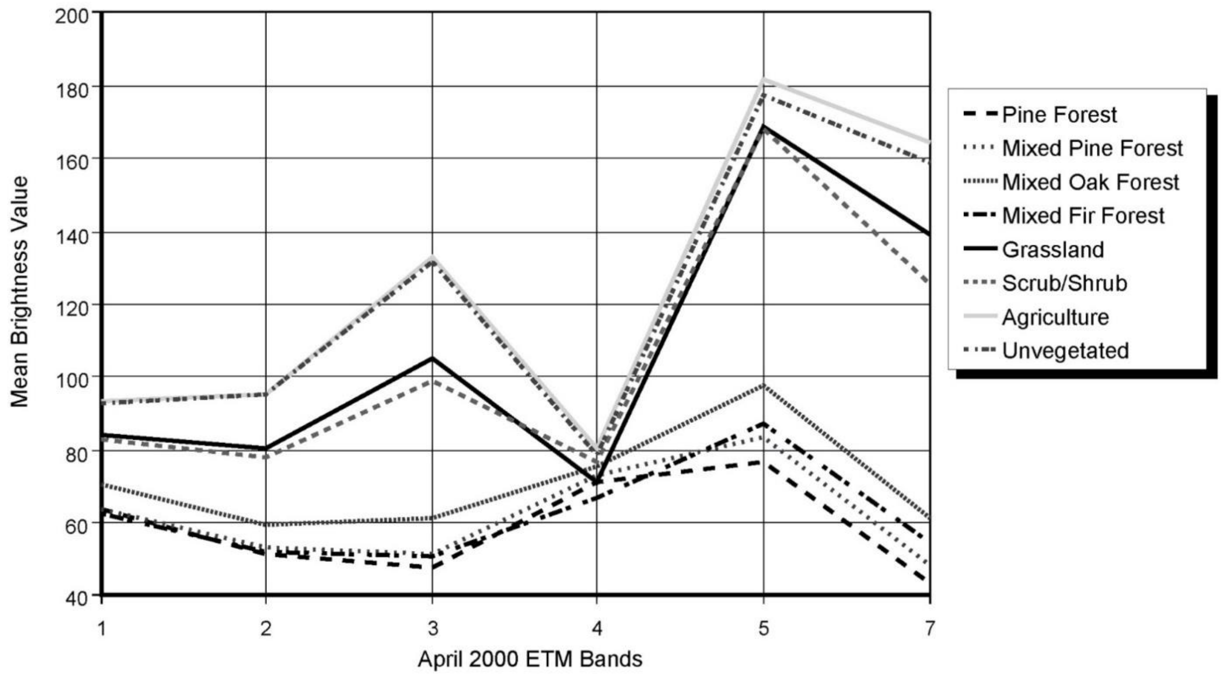
- It assumes that most of the training area pixels should be assigned to their respective land-cover class.
- If a significant percentage of training pixels are classified as another land-cover, it indicates that the spectral signatures are not distinct enough to produce an accurate classification of the entire image.

			Actual Land-cover					
Classified Land-cover	Pine	Mixed Pine	Mixed Oak	Mixed Fir	Grass	Scrub	Agricult	UnVeg
Pine	101	96	1	2	0	0	0	0
Mixed Pine	24	213	3	2	0	0	0	0
Mixed Oak	4	23	19	0	0	0	0	0
Mixed Fir	7	25	0	64	0	0	0	0
Grass	0	0	0	0	90	1	9	55
Scrub	0	0	0	0	2	31	0	0
Agricult.	0	0	0	0	2	0	213	57
UnVeg	0	0	0	0	5	0	14	997
Column Total	136	357	23	68	99	32	236	1109
% Correct	74.3%	59.7%	82.6%	94.1%	90.9%	96.9%	90.3%	89.9%

iii. Training area histograms



iv. Signature plots

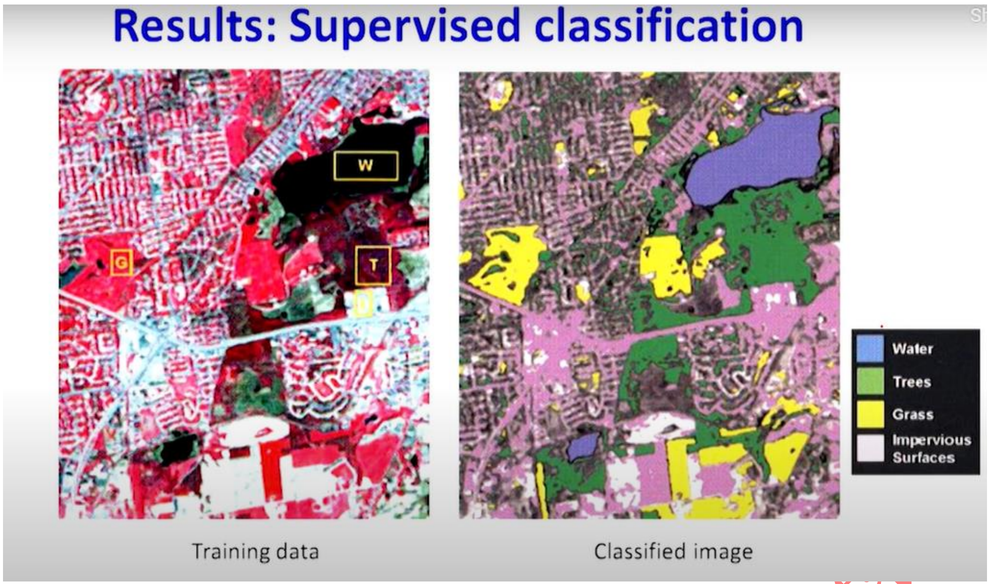


Signature Refinement Methods

i. Refine training area boundaries
ii. Add/delete training areas
iii. Modify classification scheme/merge signatures

5. Assign pixels to classes using a classifier (a.k.a., "decision rule")

- Each pixel is independently compared to each signature relative to the selected classification criteria, or "decision rule".
- Pixels that satisfy the criteria for a class signature are assigned to that class



Some

Popular Supervised Image Classification Rules

Various supervised classification algorithms may be used to assign an unknown pixel to one of a number of classes.

The choice of a particular classifier or decision rule depends on the nature of the input data and the desired output.

Parametric classification algorithms assume that the observed measurement vectors Xc for each class in each spectral band during the training phase of the supervised classification are Gaussian in nature; that is, they are normally distributed.

Nonparametric classification algorithms make no such assumption. It is instructive to review the logic of several of the classifiers.

Among the most frequently used classification algorithms are

1. Parametric
   a. Minimum distance to mean
   b. Maximum Likelihood
2. Non-Parametric
   a. Parallelepiped
   b. Feature Space

a. Minimum distance to mean

- Minimum Distance Classification is an automatic option for classification when sufficient ground truth data is not available for different cover types in a given area.
- This is a classifier, which does not make use of variance-covariance matrices while classifying different cover types.
- With this classifier, training data is used only to determine class means; classification is then performed by placing the pixel in the class of the nearest mean.

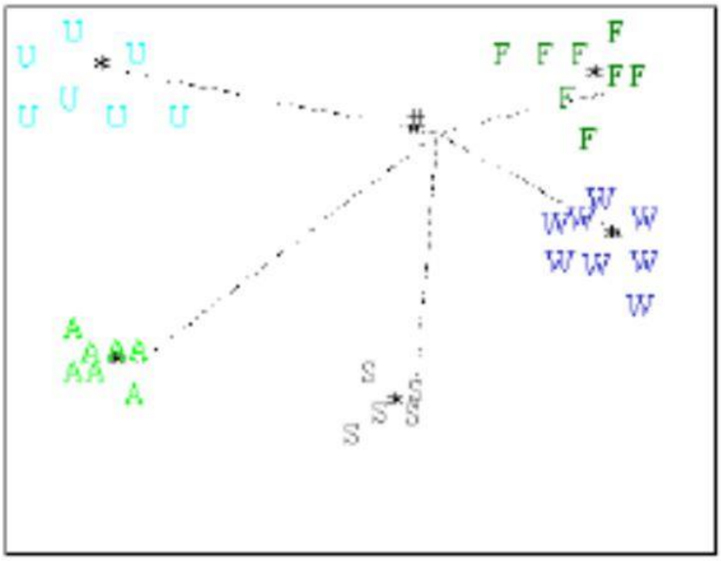
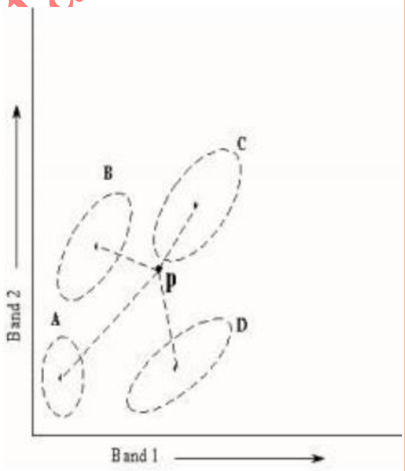


Figure 14: Minimum distance classification



Characteristics (Advantages)

- Emphasis on the location of cluster center
- Class labeling by considering minimum distance to the cluster centers

Disadvantages

- Avoids the presence of variability within a class
- Shape and size of the clusters are not important

b. Maximum likelihood classification

- Maximum likelihood classification is the most common method used with remote sensing image data.
- The decision rules are based on Baye's principle.
- To derive the a priori probabilities sufficient amount of training data should be available in the form of ground referenced data for various cover types.
- From this information training set spectral statistics and a priori probabilities are calculated for each pixel before categorizing to respective likelihood class (as shown in figure below).

Characteristics (Advantages)

- Considers variability within a cluster
- Considers the shape, the size and the orientation of clusters.

Figure 15: Maximum Likelihood Classification

Disadvantages

- Takes more computing time
- Based on the assumption that probability density function (*pdf*) is normally distributed.

Parallelepiped Classification

- Also called Box Classification
- Parallelepiped Classification is a very simple supervised classifier that is, in principle, trained by inspecting histograms of the individual spectral components of the available training data.
- The Upper and lower significant bounds on the histograms are identified and used to describe the brightness value range for each component characteristic of that class.
- Together, the range in all components describes a multidimensional box or parallelepiped
- A two-dimensional pattern space might therefore be segmented.
- If there is a considerable gap between two parallelepipeds, pixels in those regions will not be classified.
- Whereas in the case of maximum likelihood and minimum distance algorithms, the pixels are labeled as belonging to one of the available classes depending on the pre-set threshold.

Characteristics

- Considers only the lower and the upper limits of the cluster
- Computation is simple and fast

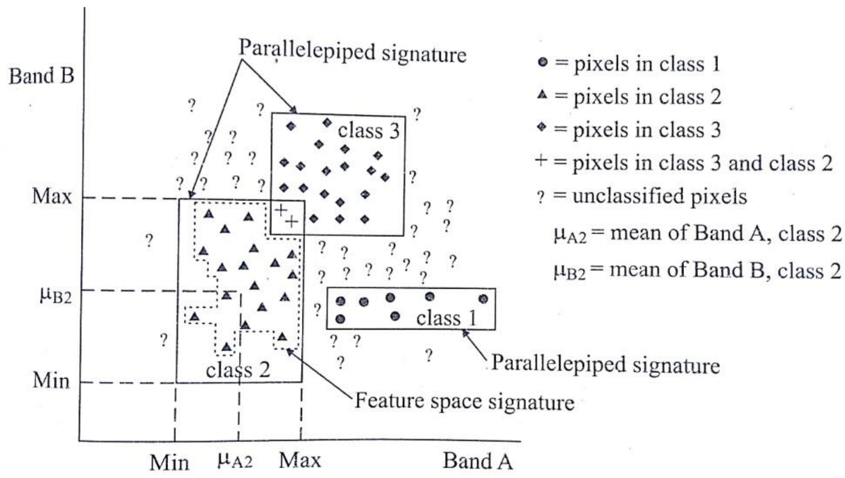


Figure 16: Graphical Representations of parallelepiped and feature space classifier

Advantages

- it is a simple and computationally inexpensive method
- it does not assume a class statistical distribution and includes class variance

Disadvantages

- it is least accurate method
- it does not adapt well to elongated (high-covariance) clusters
- it often produces overlapping classes, requiring a second classification step
- it also becomes more cumbersome with increasing number of channels
- pixels falling outside the defined parallelepiped remain unclassified.

Summary of Supervised Image classification

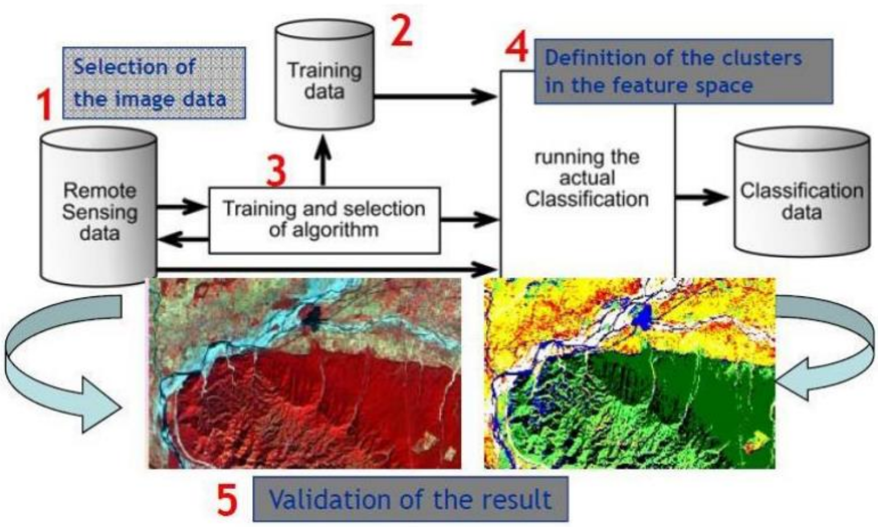


Figure 17: Summary illustrating the workflow for Supervised Image Classification.

Comparison between Unsupervised and Supervised Image Classification

Parameters to differentiate	**Supervised Image Classification**	**Unsupervised Image Classification**
Association of spectral class to an information class	An information class on the image is first specified, then an algorithm is used to form class signatures and is used with a decision rule to assign the pixels in the image file to a class.	An algorithm is first applied on the image and some spectral classes (also called clusters) are formed, where the image analyst tries to assign a spectral class to a desired information class.
Controlling of image classification	Supervised image classification is *closely controlled (supervised) by the analyst*, thus the name Supervised Image classification.	Unsupervised image classification is *more computer-automated.*
Knowledge of the image area	For image classification, *prior knowledge of the image area is required* which is gained through the combinations of fieldworks, map analysis, and personal experiences.	For image classification, *no prior knowledge of the image area is required*, where the computer identifies the group of pixels that exhibits similar spectral response.
Time for analyzing	Bulk of analyst's work comes *before* the classification process.	Bulk of analyst's work comes *after* the classification process.
Dependency of the training	Supervised training largely depends on the cognition and skills of the image analyst for the specification of the classes.	Unsupervised training is dependent on the data itself for the definition of the classes.
Consideration for the features on the ground	Generates information class *representing features* on the ground.	Spectral classes *do not represent features* on the ground.
Uniqueness of the spectral classes	Training areas *may not encompass unique spectral classes.*	*Unique spectral classes* are produced.
Need for training sites	There may be difficulty and cost in *selecting training sites*.	*No training samples* have to be selected, only the spectral classes have to be appropriately interpreted and identified.

Map Accuracy

Map accuracy is defined as the process of assessing the accuracy of maps generated from remotely sensed data.

Map accuracy requires evaluating both **positional accuracy and thematic accuracy.** While these two accuracies can be assessed separately, they are very much interrelated, and failure to consider both of them is a serious mistake.

Positional Accuracy

Positional accuracy is a measure of how closely the imagery fits the ground. It is the most common measure of map accuracy.

In other words, positional accuracy is the accuracy of the location of a point in the imagery with reference to its physical location on the ground.

The major factor influencing positional accuracy is topography, while sensor characteristics and viewing angles can also have some effect.

It is commonly accepted that a positional accuracy of half a pixel is sufficient for sensors such as Landsat Thematic Mapper and SPOT.

As sensors increase in spatial resolution, such as the 4-rn multispectral IKONOS data, positional accuracy increases in importance and new standards need to be established.

These standards need to be based on the current ability to locate the chosen location (sample site) on both the image and the ground.

Thematic Accuracy

Thematic accuracy refers to the accuracy of a mapped land cover category at a particular time compared to what was actually on the ground at that time.

Clearly, to perform a meaningful assessment of accuracy, land cover classifications must be assessed using data that are believed to be correct.

Thus, it is vital to have at least some knowledge of the accuracy of the reference data before using it for comparison against the remotely sensed map.

Although no reference data set may be completely accurate, it is important that the reference data have high accuracy or else it is not a fair assessment. Therefore, it is critical that the ground or reference data collection be carefully considered in any accuracy assessment.

5.2.3 Accuracy Assessment and Validation of the Result

Accuracy Assessment of the remote sensing product is a feedback system for checking and evaluating the objectives and the results.

Accuracy assessment determines the correctness of the classified image.

Accuracy is the measure of the agreement between a standard that is assumed to be correct and a classified image of unknown quality. If the image classification corresponds closely with the standard, it is said to be accurate.

There are several different ways in which the accuracy assessment can be done:

i. Compare the classified image to a reference image:
A random set of points is generated and classified results are compared with the true information classes in the reference image.

ii. Using a GPS:
A random set of points is generated over the classified image. Ground-truthing would be performed by going to the field at the location of each randomly generated point. The classification results would then be compared to the actual land-cover at each point's location.

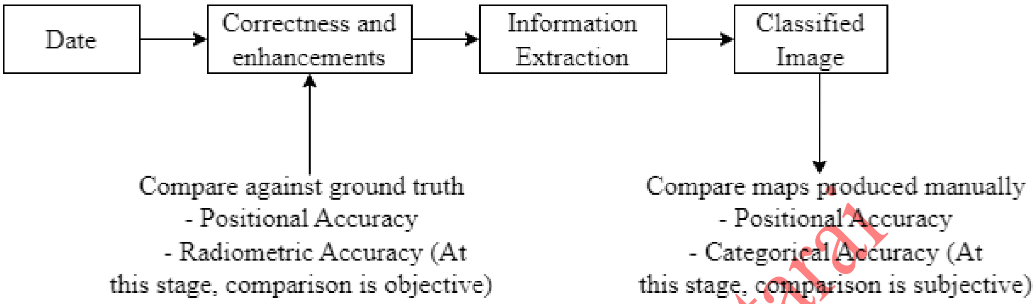


Figure 18: Involvement of accuracy assessment in the processes of remote sensing data to cartographic products

Why Accuracy Assessment? (Importance/Significance of Accuracy Assessment)

i. To assess the accuracy of maps generated from remotely sensed data.
ii. To evaluate both **positional accuracy and thematic** accuracy of the cartographic products from remote sensing data.
iii. Accuracy assessment increases map quality by identifying and correcting sources of error.
iv. Accuracy assessment provides a comparison to two sources of information – Remote Sensing derived classification map and Reference Test information.
v. Accuracy assessment provides a comparison for the accuracy of various data, processing techniques, classification schemes, and interpreters.
vi. Accuracy assessment provides validation to our result of remote sensing image classification.
vii. Accuracy assessment allows self-evaluation and to learn from mistakes in the classification process
viii. It also ensures greater reliability of the resulting maps/spatial information to use in decision-making process.

Error matrix/ Confusion (or contingency) matrix (or table)

Accuracy assessment begins with the generation of a matrix, a square array of numbers or cells set out in rows and columns, which expresses the number of sample units assigned to each land cover type as compared to the reference data. Such a matrix is called an error matrix or **Confusion (or contingency) matrix (or table).** The columns in the matrix represent the reference data (actual land cover) and the rows represent assigned (mapped) land cover types. The major diagonal of the matrix indicates agreement between the reference data and the interpreted land cover types.

Significance of Error Matrix

i. The error matrix is useful for both visualizing image classification results and for statistically measuring the results.

ii. The error matrix is the only way to effectively compare two maps quantitatively.
iii. A measure of **overall accuracy** can be calculated from the error matrix.
iv. The error matrix also provides accuracies, both **producer's accuracy, and user's accuracy**, for each land cover category present in the image classification.
v. Both **errors of exclusion (omission errors)** and **errors of inclusion (commission errors)**, for each land cover category, present in the image classification can be deduced from error matrix.

Table 1 is the example of Confusion Table. The diagonal elements (shown in grey shade) in the matrix indicate number of the sample for which the classification results agree with the reference data.

		Reference/Ground					
		Forest	Water	Urban	Row Total	Commission Error	User's Accuracy
Classified Image	Forest	56	28	30	114	51%	49%
	Water	2	30	10	42	29%	71%
	Urban	2	2	40	44	9%	91%
	Column Total	60	60	80	200		
	Omission Error	7%	50%	50%			
	Producer's Accuracy	93%	50%	50%			

Table 1: Example of a confusion Table

Commission Error

The error matrix contains the complete information on the categorical accuracy. Off-diagonal elements in each row present the numbers of sample that has been misclassified by the classifier, i.e., the classifier is committing a label to those samples that actually belong to other labels. This misclassification error is called **commission error**.

For the given confusing matrix, User's accuracy for each category can be computed as,

$$Commission\ Error = \frac{Total\ number\ of\ miscorrectly\ classified\ sample\ units\ for\ a\ category}{Total\ number\ of\ samaple\ units\ that\ were\ classified\ in\ that\ category}$$

Therefore,

$$Commission\ Error\ for\ Forest\ = \frac{28+30}{114} * 100\% = 51\%$$

i.e., 49% of the Forest class has been misclassified by the classifier.

Similarly,

$$Commission\ Error\ for\ Water\ = \frac{2+10}{42} * 100\% = 29\%$$

i.e., 71% of the Water class has been misclassified by the classifier.

And,

$$Commission\ Error\ for\ Urban\ = \frac{2+2}{44} * 100\% = 9\%$$

i.e., 91% of the Urban class has been misclassified by the classifier.

Omission Error

The off-diagonal elements in each column are those samples being omitted by the classifier. Therefore, this misclassification error is called **omission error.**

For the given confusing matrix, producer's accuracy for each category can be computed as,

$$Omission\ Error = \frac{Total\ number\ of\ misclassified\ sample\ units\ in\ a\ category}{Total\ number\ of\ samaple\ units\ in\ that\ category\ from\ the\ referenced\ data}$$

Therefore,

$$Omission\ Error\ for\ Forest\ = \frac{2+2}{60} * 100\% = 7\%$$

i.e., 93% of reference Forest samples are misclassified by the classifier.

Similarly,

$$Omission\ Error\ for\ Water\ = \frac{28+2}{60} * 100\% = 50\%$$

i.e., 50% of reference Water samples are misclassified by the classifier.

And,

$$Omission\ Error\ for\ Urban\ = \frac{30+10}{80} * 100\% = 50\%$$

i.e., 50% of reference Urban samples are misclassified by the classifier.

In order to summarize the classification results, the most commonly used accuracy measure is overall accuracy.

Overall Accuracy

A measure that is calculated by dividing the sum of all the entries in the major diagonal of the confusing (error) matrix by the total number of sample units in the same matrix is called the overall accuracy of that confusing matrix.

For the given confusing matrix,

We can obtain overall accuracy as,

$$Overall\ Accuracy = \frac{\text{sum of all the entries in the major diagonal of the confusing matrix}}{\text{total number of sample units in the same matrix}}$$

or, Overall Accuracy = $\frac{56+30+40}{200}$ * 100% = 63%

In the ideal situation, all the non-major diagonal elements of the error matrix would be zero, indicating that no area had been misclassified and that the map was 100 percent correct.

For individual category accuracy assessment tasks, more specific measures are needed than overall accuracy because overall accuracy does not indicate how the accuracy is distributed across the individual categories. The categories could, and frequently exhibit drastically different accuracies, but the overall accuracy method considers these categories as having equivalent or similar accuracies.

Producer's Accuracy

A measure that is obtained by dividing the total number of correctly classified sample units in a category by the total number of sample units in that category from the reference data is called the producer's accuracy of that category.

From this measurement, the producer of the classification will know how well a certain area was classified, so called producer's accuracy.

For example, the producer may be interested in knowing how many times forest was in fact classified as forest (and not, say, water or urban). To determine this, the 56 correctly classified forest samples (Table 1) would be divided by the total 60 units of forest from the reference data, for a producer's accuracy of 93%.

In other words, forest was correctly identified as forest 93% of the time.

For the given confusing matrix, producer's accuracy for each category can be computed as,

$$Producer's\ Accuracy = \frac{Total\ number\ of\ correctly\ classified\ sample\ units\ in\ a\ category}{Total\ number\ of\ samaple\ units\ in\ that\ category\ from\ the\ referenced\ data}$$

Therefore,

$$Producer's\ accuracy\ for\ Forest = \frac{56}{60} * 100\% = 93\%$$

i.e., 93% of reference Forest samples are correctly classified.

Similarly,

$$Producer's\ accuracy\ for\ Water\ = \frac{30}{60} * 100\% = 50\%$$

i.e., 50% of reference Water samples are correctly classified.

And,

$$Producer's\ accuracy\ for\ Urban\ = \frac{40}{80} * 100\% = 50\%$$

i.e., 50% of reference Urban samples are correctly classified.

User's Accuracy

The measure which is calculated by dividing the number of correctly classified sample units for a category by the total number of sample units that were classified in that category is called user's accuracy for that category.

This measure is also called "user's accuracy," indicating for the user of the map the probability that a sample unit classified on the map actually represents that category on the ground.

In the given table, while the producer's accuracy for the forest category is 93%, the user's accuracy is only 49%. That is, only 49% of the areas mapped as vegetation are actually vegetation on the ground.

For the given confusing matrix, User's accuracy for each category can be computed as,

$$User's\ Accuracy = \frac{Total\ number\ of\ correctly\ classified\ sample\ units\ for\ a\ category}{Total\ number\ of\ samaple\ units\ that\ were\ classified\ in\ that\ category}$$

Therefore,

$$User's\ accuracy\ for\ Forest\ = \frac{56}{114} * 100\% = 49\%$$

i.e., 49% of the Forest class has been correctly classified.

Similarly,

$$User's\ accuracy\ for\ Water\ = \frac{30}{42} * 100\% = 71\%$$

i.e., 71% of the Water class has been correctly classified.

And,

$$User's\ accuracy\ for\ Urban\ = \frac{40}{44} * 100\% = 91\%$$

i.e., 91% of the Urban class has been correctly classified.

Other than the User's and Producer's accuracies, a popular and more accurate method of accuracy assessment is ***Kappa coefficient of agreement*** (commonly referred as ***Kappa Statistics***).

Kappa coefficient of agreement

The Kappa Coefficient (κ) is generated from a statistical test to evaluate the accuracy of the classification. Kappa essentially evaluates how well the classification performed as compared to just randomly assigning values.

It is calculated as

$$\kappa = \frac{(Total\ number\ \ of\ samples * (Sum\ of\ all\ entries\ in\ the\ major\ diagonal)) - Chance\ agreement}{(Total\ numbber\ of\ samples)^2 - Chance\ agreement}$$

Chance agreement = Σ (Product of row and column marginal for each class)

Therefore, Kappa coefficient of the given error matrix can be calculated as:

$$\kappa = \frac{(200*(56+30+40) - (114*60) + (42*60) + (44*80))}{(200)^2 - ((114*60) + (42*60) + (44*80))} = 0.454\ (\approx 45\ \%)$$

i.e., 18% classification accuracy could be due to chance agreement.

Note:

The Kappa Coefficient ranges from -1 to 1.

Analysis:

If κ = 0, then there is no agreement between the classified image and the reference

If κ = 1, then the classified image and the reference are totally identical

So, the higher the κ, value, the more accurate the image classification.

If the Kappa coefficient is

- ✓ greater than 0.80, it represents the strong agreement and good accuracy,
- ✓ lies between 0.40 – 0.80, it represents moderate accuracy,
- ✓ less than 0.40, represents poor accuracy

One can notice that the overall accuracy was 63% (see above), but the Kappa Coefficient is only 45% (see above for the values). That means that (63% - 45% = 18% classification accuracy could be due to chance agreement. The basic idea behind Kappa is that some of the apparent classification accuracy given by the overall accuracy measures could be due to the chance.

It is vital that the error matrix generated for the accuracy assessment be valid.

An improperly generated error matrix may not be truly representative of the thematic map and, therefore, meaningless.

The following factors must be considered to generate a valid error matrix

i. Reference data collection
ii. Classification scheme
iii. Sampling scheme
iv. Spatial autocorrelation
v. Sample size and sample unit

i. Reference Data Collection

- Reference data collection is the first step in any assessment procedure, and may be the single most important factor in accuracy assessment, since an assessment will be meaningless if the reference data cannot be trusted.
- Reference data can be collected in many ways, including photo interpretation, aerial reconnaissance with a helicopter or airplane, video, drive-by surveys, and visiting the area of interest on the ground.
- Not all of these approaches are valid in every situation but great care needs to be taken to make sure that the reference data are accurate.

ii. Classification scheme

- A classification scheme categorizes remotely sensed map information into a meaningful and useful format.
- The rules used to label the map must be rigorous and well defined.

- An effective means of ensuring these requirements is met is to define a classification system that is totally exhaustive, mutually exclusive, and hierarchical.
  - ✓ A totally exhaustive classification scheme—guarantees that everything in the image falls into a category: i.e., nothing is left unclassified.
  - ✓ A mutually exclusive classification scheme—means that everything in the image fits into one and only one category: i.e., an object in an image can be labeled only one category.
  - ✓ Total exhaustion and mutual exclusivity rely on two critical components:
    - a set of labels (e.g., white pine forest, oak forest. Non forest, etc.),
    - a set of rules (e.g., white pine forest must comprise at least 70 percent of the stand).

    Without these components. the image classification would be arbitrary and inconsistent.
  - ✓ Finally, hierarchical classification schemes— those that can be collapsed from specific categories into more general categories—can be advantageous.
    - For example, if it is discovered that white pine, red pine, and hemlock forest cannot be reliably mapped, these three categories could be collapsed into one general category called coniferous forest.

iii. Sampling Scheme

- An accuracy assessment very rarely involves a complete census or total enumeration of the classified image, since this data set is too large to be practical.
- To select an appropriate sampling scheme for accuracy assessment, some knowledge of the distribution of the vegetation/land cover classes should be known.
- Stratified random sampling has historically prevailed for assessing the accuracy of remotely sensed maps.
  - ✓ Stratified sampling has been shown to be useful for adequately sampling important minor categories, whereas simple random sampling or systematic sampling tended to oversample categories of high frequency and under sample categories of low frequency.

iv. Spatial Autocorrelation

- Because of sensor resolution, landscape variability, and other factors, remotely sensed data are often spatially autocorrelated.
- Spatial autocorrelation involves a dependency between neighboring pixels such that a certain quality or characteristic at one location has an effect on that same quality or characteristic at neighboring locations.

- Spatial autocorrelation can affect the result of an accuracy assessment if an error in a certain location can be found to positively or negatively influence errors in surrounding locations.
- The best way to minimize spatial autocorrelation is to impose some minimum distance between sample units.

v. Sample Size and Sample Unit

- An appropriate sample size is essential to derive any meaningful estimates from the error matrix.
- In particular, small sample sizes can produce misleading results.
- Sample sizes can be calculated using the equation from the multinomial distribution, ensuring that a sample of appropriate size is obtained.
- Some researchers have suggested using the binomial equation to compute sample size.
- Given the need to create an error matrix, however, the binomial equation is inappropriate. A general rule of thumb developed from many projects shows that sample sizes of 50 to 100 for each map category are recommended, so that each category can be assessed individually.
- In addition to determining appropriate sample size, an appropriate sample unit must be chosen.
- Historically, the sample units chosen have been a single pixel, a cluster of pixels, a polygon, or a cluster of polygons. A single pixel is a poor choice of sample unit, since it is an arbitrary delineation of the land cover and may have little relation to the actual land cover delineation.
    - ✓ Further, it is nearly impossible to align one pixel in an image to the exact same area in the reference data.
    - ✓ In many cases involving single pixel accuracy assessment, the positional accuracy of the data dictates a very low thematic accuracy.
- A cluster of pixels (e.g., a 3 by 3-pixel square) is always a better choice for the sample unit, since it minimizes registration problems.
- A good rule of thumb is to choose a sample unit whose area most closely matches the minimum mapping unit of the reference data.
    - ✓ For example, if the reference data have been collected in 2-hectare minimum mapping units, then an appropriate sample unit may be a 2-hectare polygon.

In Conclusion, failure to consider even one of these factors could lead to significant shortcomings in the accuracy assessment process. Therefore, the above factors must be considered to generate a valid error matrix.

Exercises

1. In the figure (table) below, calculate the overall accuracy, producer's accuracy and user's accuracy of the classified images in four classes forest, water, built-up area and agriculture.

	Forest	Water	Builtup	Agriculture
Forest	10	12	15	17
Water	11	12	15	20
Builtup	15	10	20	15
Agriculture	18	12	20	20

2. Why do we need to perform accuracy assessment of the results obtained from the image classification? What are the different metrics used for the accuracy assessment?
3. A classification with three classes were done. Ground truth is collected from 100 samples and data are summarized as follows:

		Reference		
Classified Map		Conifer	Hardwood	Water
	Conifer	50	5	2
	Hardwood	14	13	0
	Water	3	5	8

Calculate error of commission, error of omission, overall accuracy, producer's accuracy and user's accuracy.

4. What do you understand by unsupervised classification? Explain in detail the steps of unsupervised classification with flow diagram.
5. What do you understand by supervised classification? Explain in detail the steps of supervised classification with flow diagram.
6. Three land cover classes are classified on a satellite image. Ground truth is collected from 200 sample points and the data are summarized in the matrix shown below:

Classified Image	Field data		
	A	B	C
A	75	20	5
B	20	30	10
C	5	0	35

Calculate the error of commission, error of omission of all classes and the overall accuracy from the given error matrix.

7. There are two types of classification in image processing, i.e., supervised and unsupervised. Which one classification is best, give your opinion? Write the steps of supervised image classification in GIS environment.
8. What do you understand by digital image classification? Differentiate Supervised and Unsupervised Classification.

   Five land cover classes are classified on a satellite image. Ground truth is collected from 200 sample points and the data are summarized in the matrix shown below.

Calculate the error of commission, error of omission of all classes and the overall accuracy from the given error matrix.

		Field Data				
Classified Image		Forest	Grass	Maize	Buildings	Water
	Forest	30	10			
	Grass	8	30	12	1	
	Maize	2	4	40	3	1
	Buildings			3	30	1
	Water			1	4	20

9. What is image interpretation? List out all the visual interpretation elements and explain each of them in detail.
10. Write short notes on the following topics:
    - i. Image Space
    - ii. Feature Space
    - iii. Information Class
    - iv. Spectral Class
    - v. Clustering algorithms in Unsupervised Classification
    - vi. Supervised Classification rules
    - vii. Training Data
    - viii. Accuracy Assessment
    - ix. Confusing Matrix
    - x. Overall Accuracy
    - xi. Producer's Accuracy
    - xii. User's Accuracy
    - xiii. Commission Error
    - xiv. Omission Error
    - xv. Kappa Coefficient
11. What are the factors that needs to be considered to generate the valid error matrix?
12. Why is it necessary to perform the accuracy assessment of the remote sensing products?
13. What do you understand by accuracy assessment? Explain how the accuracy assessment can be performed.
14. Write your acquaintance towards map accuracy and thematic accuracy.
15. What do you understand by Contingency Matrix? Why is it necessary to generate the confusing matrix during the evaluation of classification errors?
16. How do you validate the results of image classification?
17. Write short notes on:
    - i. Pixel-based classification Vs Object-based Classification
    - ii. Sub-pixel classification
    - iii. Euclidian Distance
18. What do you understand by image classification? Explain the underlying principle of image classification.

Old Question Collection

Council for Technical Education and Vocational Training

Office of the Controller of Examinations

Sanothimi, Bhaktapur

Regular/Back Exam-2078/2079, Chaitra/Baishakh

Program: Diploma In Geomatics **Full Marks: 80**

Year/Part: II/II (2018, New) **Pass Marks: 32**

Subject: Remote Sensing **Time: 3 hrs.**

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Group 'A'

Attempt Any Four questions. [4x10=40]

1. Briefly explain the different components of remote sensing. Write the application areas of remote sensing and its advantages. [5+5]
2. Define the terms radiance, irradiance and reflectance. How does EMR interact with leaves/vegetation? Explain the spectral reflectance curve of vegetation with necessary figure. [4.5+1.5+4]
3. Differentiate between supervised and unsupervised classification. What are the image-preprocessing performed in remote sensing images? [10]
4. In the figure (table) below, calculate the overall accuracy, producers accuracy and users accuracy of the classified images in four classes forest, water, builtup area and agriculture. [10]

	Forest	Water	Builtup	Agriculture
Forest	10	12	15	17
Water	11	12	15	20
Builtup	15	10	20	15
Agriculture	18	12	20	20

5. Write short notes on : (Any Four) [4x2.5=10]
   a) Satellite orbits
   ii) Thermal remote sensing
   iii) Image enhancement
   iv) Geometric distortion and correction
   v) NDVI

Cont..........

Group 'B'

Attempt **Any Eight** questions. [8x5=40]

6. What do you mean by platform in remote sensing? Briefly explain the types of sensor platforms used in remote sensing. [1+4]
7. What is Electromagnetic Spectrum? Which regions of Electromagnetic Spectrum are useful for remote sensing? What is the significance of atmospheric windows? [1+1+3]
8. Differentiate between active and passive remote sensing. List out some operational satellites of remote sensing. [4+1]
9. Briefly explain the different types of scattering in atmosphere. [5]
10. Briefly explain Along Track and Across Track Scanners. Which one is more advantageous and why? [5]
11. What do you mean by resolution of images? Explain in brief the spatial and spectral resolution. [1+4]
12. What is spatial filtering? Briefly explain the basic principles and types of spatial filter. [5]
13. What is image interpretation? List out all the visual image interpretation elements and explain any 3 of them in brief. [1+4]
14. Why do we need to perform accuracy Assessment of the results obtained from image Classification? What are the different metrics used for accuracy assessment? [2+3]
15. The image has 0.7 reflectance in Red and 0.6 in NIR. Calculate NDVI and interpret the result. [5]

Good Luck !

Council for Technical Education and Vocational Training

Office of the Controller of Examinations

Sanothimi, Bhaktapur

Regular/Back Exam-2077, Chaitra

Program:	**Diploma in Geomatics Engineering**	**Full Marks: 80**
Year/Part:	**II/II (2018 New Course)**	**Pass Marks: 32**
Subject:	**Remote Sensing**	**Time: 3 hrs**

Candidates are required to give their answers in their own words as far as practicable.
The figures in the margin indicate full marks.

Attempt Any Eight questions.

1. What do you understand by remote sensing? Explain the components of remote sensing with neat and clean diagram. [2+8]

2. a) Explain why: (a) sky appears blue. [2+2]
   (b) fog and clouds appear white

   b) How does EM Radiation interact with the atmosphere? Why the best atmospheric conditions for remote sensing in the visible portion of the spectrum are around noon on a sunny day with no clouds and no pollution, highlight the reasons. [4+2]

3. a) What do you understand by spectral Reflectance curve? Why is it necessary to construct spectral reflectance curve? Draw spectral reflectance curve of water and vegetation. [1+2+2]

   b) Define Radiance. In Remote Sensing, radiation reflected from targets are of specular and Diffuse types. Explain them with figures and examples. [1+4]

4. A classification with three classes were done. Ground truth is collected from 100 samples and data are summarized as follows. [10

		Reference		
		Conifer	Hardwood	water
Classified map	Conifer	50	5	2
	Hardwood	14	13	0
	Water	3	5	8

Calculate error of commission, error of omission overall accuracy, producer's accuracy and user's accuracy.

Cont...

5. Define sensor along with its types. Explain in brief the types of satellite orbits. [2+8]

6. Define image interpretation and image enhancement. Explain in detail the image interpretation elements. [2+8]

7. a) What do you mean by spatial and spectral resolution? Explain why there is compromise between the spatial and spectral Resolution in Remote sensing. Provide example to support your argument. [2+3]

   b) What do you understand by unsupervised classification? Explain in detail the steps of supervised classification with flow diagram. [1+

8. a) How one or more bands of RS image can be displayed in monitor? Explain.

   b) What is line striping in RS image? How can you remove line striping? Why geometric correction is required in RS image? [1+

9. Write short notes on : (Any Four) [4x2

   a) Image mosaic
   b) Atmospheric window
   c) Temporal Resolution
   d) Haze correction
   e) High pass filter

Good Luck !

Council for Technical Education and Vocational Training

Office of the Controller of Examinations

Sanothimi, Bhaktapur

Regular/Back Exam-2077, Chaitra

Program: Diploma in Geomatics Engineering **Full Marks: 80**

Year/Part: II/II (2018 New Course) **Pass Marks: 32**

Subject: Remote Sensing **Time: 3 hrs**

Candidates are required to give their answers in their own words as far as practicable.
The figures in the margin indicate full marks.

Attempt Any Eight questions.

1. What do you understand by remote sensing? Explain the components of remote sensing with neat and clean diagram. [2+8]

2. a) Explain why (a) sky appears blue [2+2]
   b) fog and clouds appear white

   b) How does EM Radiation interact with the atmosphere? Why the best atmospheric conditions for remote sensing in the visible portion of the spectrum are around noon on a sunny day with no clouds and no pollution, highlight the reasons. [4+2]

3. a) What do you understand by spectral Reflectance curve? Why is it necessary to construct spectral reflectance curve? Draw spectral reflectance curve of water and vegetation. [1+2+2]

   b) Define Radiance. In Remote Sensing radiation reflected from targets are of specular and Diffuse types. Explain them with figures and examples. [1+4]

4. A classification with three classes were done. Ground truth is collected from 100 samples and data are summarized as follows [10

		Reference		
		Conifer	Hardwood	water
Classified map	Conifer	50	5	2
	Hardwood	14	13	0
	Water	3	5	8

Calculate error of commission, error of omission, overall accuracy, producer's accuracy and user's accuracy.

Cont...

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5. Define sensor along with its types. Explain in brief the types of satellite orbits. [2+8]

6. Define image interpretation and image enhancement. Explain in detail the image interpretation elements. [2+8]

7. a) What do you mean by spatial and spectral resolution? Explain why there is compromise between the spatial and spectral Resolution in Remote sensing. Provide example to support your argument. [2+3]

   b) What do you understand by unsupervised classification? Explain in detail the steps of supervised classification with flow diagram. [1+4]

8. a) How one or more bands of RS image can be displayed in monitor? Explain. [5]

   b) What is line striping in RS image? How can you remove line striping? Why geometric correction is required in RS image? [1+2+2]

9. **Write short notes on : (Any Four)** [4x2.5=10]

   a) Image mosaic
   b) Atmospheric window
   c) Temporal Resolution
   d) Haze correction
   e) High pass filter

Good Luck !

Council for Technical Education and Vocational Training

Office of the Controller of Examinations

Sanothimi, Bhaktapur

Regular/Back Exam-2076, Falgun/Chaitra

Program:	**Diploma in Geomatics Engineering**	**Full Marks:40**
Year/Part:	**III/I (2010)**	**Pass Marks:16**
Subject:	**Remote Sensing**	**Time: 1.5 hrs**

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Attempt (Any Eight) questions

1. What do you understand by remote sensing? Briefly explain remote sensing process with labeled diagram. Note: Diagram is Compulsory. [1+4]
2. What is Earth's Atmospheric window? Write down the region of electromagnetic spectrum where atmospheric window exists. Why atmospheric window matters in remote sensing? [5]
3. What do you mean by Reflectance curve? Write the different phenomena occurs during the signal in contact with atmosphere. [1+4]
4. Define line stripping in an image? What are the sources of line stripping? How low pass filter differ from high pass filter? [1+1+3=5]
5. Classify the Remote sensing according to their platforms. Write about pushbroom sensors. [3+2]
6. What do you mean by spatial and spectral resolution? Explain why there is compromise between the spatial and spectral resolution in remote sensing. Provide example to support your argument. [5]
7. Three land cover classes are classified on a satellite image. Ground truth is collected from 200 sample points and the data are summarized in the matrix shown below: [2+2+1]

Classified Image	Field data		
	A	B	C
A	75	20	5
B	20	30	10
C	5	0	35

Calculate the error of commission, error of omission of all classes and the overall accuracy from the given error matrix.

8. There are two types of classification in image processing i.e. supervised and unsupervised. Which one classification is best give your opinion? Write the steps of supervised classification in GIS Environment. [3+2]
9. Write short notes on the following. You should define the terms and briefly their relevance to remote sensing. (any Two). [2.5x2=5]
   a. Colour composites and its used
   b. Visual Image Interpretation c) Geo-stationary orbits

Good Luck!

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Council for Technical Education and Vocational Training
Office of the Controller of Examinations
Sanothimi, Bhaktapur
Regular/Back Exam-2075, Falgun/Chaitra

Program: Diploma in Geomatics Engineering — Full Marks: 40
Year/Part: III/I (2010) — Pass Marks: 16
Subject: Remote Sensing — Time: 1.5 hrs

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Attempt All questions.

1. Give your opinion about Remote Sensing. List and describe the elements of Remote Sensing. [1+1+3]
2. Define spectral reflectance curve. Explain how EMR interacts with bare soil with spectral reflectance curve? [1+4]
3. Write down the phenomena which occurs when EMR interacts with atmosphere. [5]
4. List down the image interpretation elements and explain about three of them. [2+3]
5. What is image pre-processing? Explain different types of resampling methods. [1+4]
6. Explain the following terms: [2x2.5=5]
   a) Spatial resolution
   b) NDVI
7. Define image classification. Differentiate supervised and unsupervised classification. [1+4]
8. Define atmospheric windows. Write down the advantages of remote sensing techniques in comparison to other ground techniques in brief. [1+4]

Good Luck

Council for Technical Education and Vocational Training

Office of the Controller of Examinations

Sanothimi, Bhaktapur

Regular/Back Exam-2074, Falgun/Chaitra

Program: Diploma in Geometrics Engineering		Full Marks 40
Year/Part: III/I [New]		Pass Marks 16
Subject: **Remote Sensing**		*Time: 1:30 hrs*

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Attempt **Any Eight** Questions.

1. Define Remote Sensing? What are the advantages of remote sensing technique? Explain briefly. (2+3)
2. How does electromagnetic radiation interact with the atmosphere? What are the reasons, why the best atmospheric conditions for remote sensing in the visible portion of the spectrum are around noon on a sunny day with no clouds and no pollution? (3+2)
3. Write down the differences between active and passive sensors. What is the advantage of active sensors over the passive sensors ? You should include figures and examples where appropriate. (3+2)
4. What do you mean by spectral reflectance curve? Why is it important to construct spectral reflectance curve? Draw spectral reflectance curve of water and vegetation. (1+2+2)
5. Five land cover classes are classified on a satellite image. Ground truth is collected from 200 sample point and data are summarized in the matrix shown below: (2+2+1)

Classified Image	Field Data				
	Forest	Grass	Maize	Buildings	Water
Forest	30	10			
Grass	8	30	12	1	
Maize	2	4	40	3	1
Building			3	30	1
Water			1	4	20

Calculate the error of commission, error of omission of all classes and the overall accuracy from the error matrix.

6. Discuss the various per-processing stage that are applied to remotely sensed data to enable quantitative analysis to be undertaken. (5)

7. What do you mean by digital image classification? Explain the differences between supervised and unsupervised image classification. (1+4)

8. The Remote sensing image are captured from the two sensors- multispectral sensor and thermal sensor. Which sensor provides image with the highest spatial resolution between the two? Explain why (use figure if necessary) Write down the application areas of thermal remote sensing. (1+2+2)

9. Write short notes on: (**Any Two**) (2x2.5)
   a) Image Mosaic
   b) Visual Image Interpretation
   c) Hyper remote sensing

Good Luck!

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omponent of remote sensing (Basic concepts (figure)

→ NDVI

→ Image classification of RS

M spectrum

nteraction with atmosphere
Type of scatering

nteraction with target

pectrol Signature curve of vegetation, water, curve

Sym. No. ....

Council for Technical Education and Vocational Training
Office of the Controller of Examination
Sanothimi, Bhaktapur

Regular/Back Exam Chaitra, 2071

Program: Diploma in Geomatics Eng.
Year/Part: III /I
Subject: Remote Sensing

Full Marks: 40
Pass Marks: 16
Time: 1.30 hrs.

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks

Attempt (Any Seven) questions. Question no.8 is compulsory.

1. Explain the basic concept of remote sensing. List out some applications of remote sensing. [3.5+1.5=5]
2. What is specular and diffuse reflection? Explain the spectral reflectance curve of vegetation. [2+3=5]
3. How does EMR interact with atmosphere? Why do cloud and fog appears white to us? [3.5+1.5=5]
4. What is image Pre-processing? Briefly explain two methods of image enhancement techniques. [1+4=5]
5. Explain the terms: spatial resolution, spectral resolution and temporal resolution. [2+1.5+1.5=5]
6. What are the basic steps involved in supervised classification of images? [5]
7. Briefly explain two modes or methods of scanning systems (Along Track and Across Track Scanners). Which one is more advantageous and why? [4+1=5]

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ks: 16

0 hrs.

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8. Write short notes no: (Any Four). [4x2.5=10]

(a) Sensor Platforms

(b) NDVI

(c) Spatial Filtering

(d) Thermal Remote Sensing

(e) Active vs passive remote sensing.

The End

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Regular/Back Exam Chaitra, 2070

Program: Diploma in Geometics Engineering — Full Marks: 40

Year/Part: III / I — Pass Marks: 16

Subject: Remote Sensing — Time: 1.30 hrs

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Attempt Any Seven questions. Q.n. 8 is compulsory.

1. What is remote sensing? List and briefly explain the basic components of remote sensing [1+1.5+2.5=5]
2. What is spectral reflectance? How does EMR interact with leaves/vegetation? Explain the spectral reflectance curve of vegetation [1+1.5+2.5=5]
3. Differentiate between active and passive remote sensing. Discuss some of the applications of remote sensing [2.5+2.5=5]
4. What is image pre-processing? Explain three common methods of resampling [1+4=5]
5. Explain the terms: spatial resolution, radiometric resolution and temporal resolution [2+1.5+1.5=5]
6. What is spatial filtering? Briefly explain the basic principles and types of spatial filter. [1.5+3.5=5]
7. What is image interpretation? List out all the visual interpretation elements and explain any 3 of them in brief. [1+4=5]
8. Write short notes on: **(Any Four).** [4x2.5=10]
   (f) EM spectrum
   (g) Supervised classification
   (h) NDVI
   (i) Image enhancement
   (j) Atmospheric scattering

The End

Scanned with CamScanner