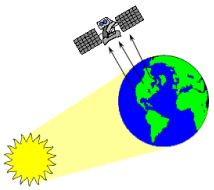
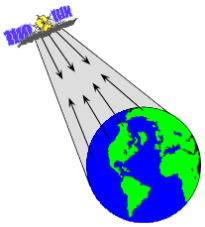
1.1 Concepts and definition of remote sensing

- All objects in earth surface will reflect or emit energy. Receiving this energy is called sensing.
- The sun is a source of energy or radiation, which provides a very convenient source of energy for remote sensing.
- The sun's energy is either **reflected**, as it is for visible wavelengths, or absorbed and then **reemitted**, as it is for thermal infrared wavelengths.
- The term remote sensing is defined as the science and art of acquiring information about a material object by making measurement, at a distance from (i.e., without coming into a physical contact with it) of the electromagnetic (EM) energy it radiates.
- These measurements are usually made using a sophisticated instrument called the sensor (e.g., a camera, an MSS (multispectral scanner) and radar (radio detection and ranging)), a device which carries out the measurements through the light (or electromagnetic radiation) reflected/emitted by the object.
- Thus, remote sensing includes all methods of obtaining pictures and other forms of electromagnetic records, mostly of the earth surface, from a distance, and their processing and interpretation.
- Remote Sensing data is one of the primary data sources in GIS analysis.
- Remote sensing offers the ability to observe and collect data for large areas relatively quickly, and is an important source of data for GIS.
- Remote sensing also replaces costly and slow data collection on the ground, ensuring in the process that areas or objects are not disturbed.
- Remote sensing makes it possible to collect data on dangerous or inaccessible areas.
- There are two main types of sensor:
    - Passive sensor and
    - Active sensor.
- **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.



- **Active sensor**, on the other hand, emits energy in order to scan objects and areas whereupon a sensor then detects and measures the radiation that is reflected or backscattered from the target. RADAR 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.



Components in Remote Sensing

Platform

- The vehicle which carries a sensor. i.e. satellite, aircraft, balloon, etc...

Sensors

- Device that receives electromagnetic radiation and converts it into a signal that can be recorded and displayed as either numerical data or an image.
- **One platform** can carry more than **one sensor**.

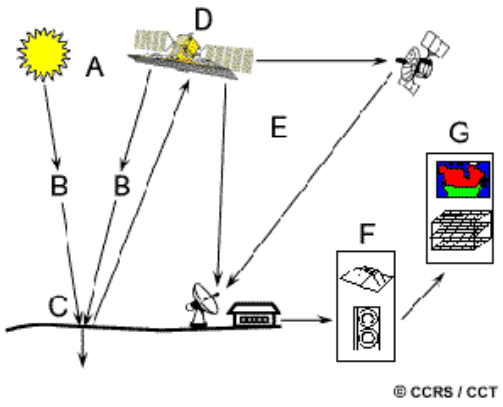
1.2 Uses and applications of Remote sensing

Some of the areas in which satellite remote sensing technology has been applied with varying degree of impact.

- **Meteorology** - Study of atmospheric temperature, pressure, water vapour, and wind velocity.
- **Oceanography**: Measuring sea surface temperature, mapping ocean currents, and wave energy spectra and depth sounding of coastal and ocean depths.
- **Glaciology**- Measuring ice cap volumes, ice stream velocity, and sea ice distribution.
- **Geology**- Identification of rock type, mapping faults and structure.
- **Geodesy**- Measuring the figure of the Earth and its gravity field.
- **Topography and cartography** - Improving digital elevation models.
- **Agriculture** for monitoring the biomass of land vegetation
- **Forest**- monitoring the health of crops, mapping soil moisture
- **Botany**- forecasting crop yields.
- **Hydrology**- Assessing water resources from snow, rainfall and underground aquifers.
- **Disaster warning and assessment** - Monitoring of floods and landslides, Monitoring volcanic activity, assessing damage zones from natural disasters.
- **Planning applications** - Mapping ecological zones, monitoring deforestation, monitoring urban land use.
- **Oil and mineral exploration**- Locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence.
- **Military**- developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements
- **Urban**- determining the status of a changes
- **Space program**- is the backbone of the space program

Principles and Process of Remote Sensing

- Remote sensing actually done from satellites as Landsat or airplane or on the ground.
- Remote sensing uses instruments that sensors to view the spectral, spatial and radiometric relations of observable objects and materials at a distance.
- Most sensing modes are based on sampling of photons corresponding frequency in the electromagnetic (EM) spectrum.
- The process involves an interaction between incident radiation and the targets of interest. The use of imaging systems where the following **seven** elements are involved.



i. Energy Source or Illumination (A) - The first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

ii. 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.

iii. 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.

iv. 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.

v. 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.

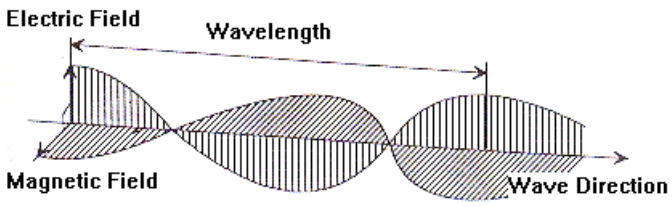
vi. Interpretation and Analysis (F) - The processed image is interpreted, visually and/or digitally or electronically, to extract information about the target, which was illuminated.

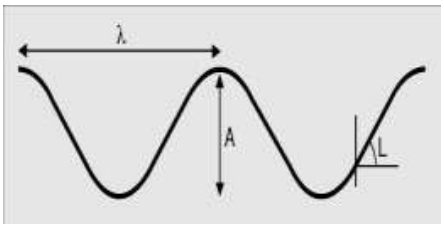
vii. Application (G) - The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

2. Electromagnetic energy and remote sensing

2.1 Introduction

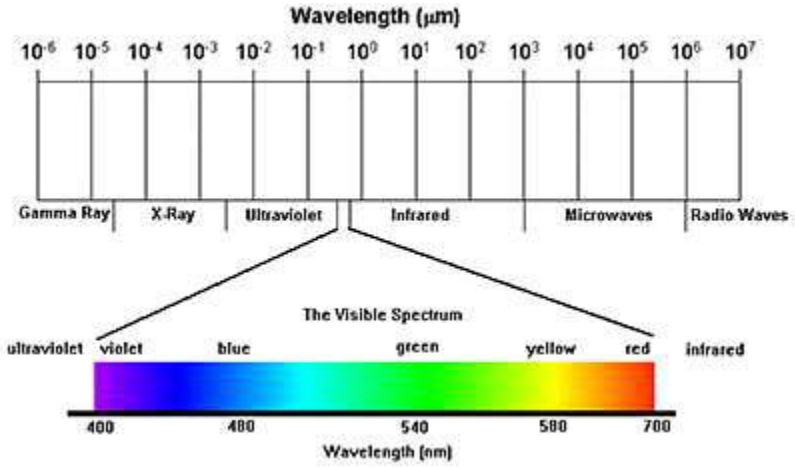
- Electromagnetic energy refers to all energy that moves with the speed of light in a harmonic wave pattern and broadly includes light, heat, and radio waves.
- This energy is identified in terms of wavelength (i.e., the distance between two successive waves) and frequency (i.e., the number of waves passing by a point in a unit of time).





2.2 Electromagnetic radiation

- Electromagnetic radiations are emitted, scattered or absorbed energy which can be measured with electromagnetic waves.
- Electromagnetic waves are energy transported through space in the form of periodic disturbances of electric and magnetic fields.
- All electromagnetic waves travel through space at the same speed, c = 2.99792458 x 10^8 m/s, commonly known as the speed of light.
- An electromagnetic wave is characterized by a frequency and a wavelength.
- Any object at a temperature above absolute zero radiates electromagnetic waves whose wavelength depends on the temperature.
- The total range of wavelengths, from a micrometre to metres, is commonly referred to as the electromagnetic spectrum (EM). **Wavelength units: 1mm = 1000 µm; 1µm=1000 nm.**



1-Gamma Rays <0.30 nm: This range is completely absorbed by the upper atmosphere and not available for remote sensing.

2-X-Rays 0.03—30.0 nm: This range is completely absorbed by the atmosphere and not employed in remote sensing.

3-Ultraviolet: **0.03—0.40 µm**

i-Hard UV 0.03—0.3 µm: This range is completely absorbed by the atmosphere and not employed in remote sensing.

ii-Photographic UV 0.30—0.40 µm: This range is not absorbed by the atmosphere and detectable with film and photo detectors but with severe atmospheric scattering.

4-Visible Light: This narrow band of electromagnetic radiation extends from about 400 nm (violet) to about 700 nm (red). It‘s Available for remote sensing the Earth, can be imaged with photographic film.

Violet: 400 - 430 nm

Indigo: 430 - 450 nm

Blue: 450 - 500 nm: Because water increasingly absorbs electromagnetic (EM) radiation at longer wavelengths, band 1 provides the best data for mapping depth detail of water-covered areas. It is also used for soil-vegetation discrimination, forest mapping, and distinguishing cultural features

Green: 500 - 570 nm: The blue-green region of the spectrum corresponds to the chlorophyll absorption of healthy vegetation and is useful for mapping detail such as depth or sediment in water bodies. Cultural features such as roads and buildings also show up well in this band.

Yellow: 570 - 590 nm

Orange: 590 - 610 nm

Red: 610 - 700 nm: Chlorophyll absorbs these wavelengths in healthy vegetation. Hence, this band is useful for distinguishing plant species, as well as soil and geologic boundaries

5-Infrared: 0.7 to 300 µm wavelength. This region is sensitive to plant water content, which is a useful measure in studies of vegetation health. This band is also used for distinguishing clouds, snow, and ice, mapping geologic formations and soil boundaries. It is also responsive to plant and soil moisture content. This region is further divided into the following bands:

a-Near Infrared (NIR): 0.7 to 1.5 μm.
b-Short Wavelength Infrared (SWIR): 1.5 to 3 μm.
d-Mid Wavelength Infrared (MWIR): 3 to 8 μm.
e-Long Wavelength Infrared (LWIR): 8 to 15 μm.
f-Far Infrared (FIR): longer than 15 μm.

The NIR and SWIR are also known as the ***Reflected Infrared***, referring to the main infrared component of the solar radiation reflected from the earth's surface. The MWIR and LWIR are the ***Thermal Infrared***.

6-Microwaves (Radar) 1 mm to 1 m wavelength. Microwaves can penetrate clouds, fog, and rain. Images can be acquired in the active or passive mode. Radar is the active form of microwave remote sensing. Radar images are acquired at various wavelength bands

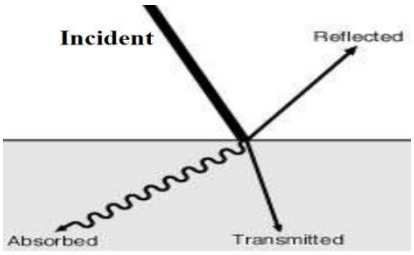
7-Radio and TV Waves: 10 cm to 10 km wavelength. The longest-wavelength portion of the electromagnetic spectrum.

2.2.1Energy interaction in the atmosphere

- The earth's surface is covered by a layer of atmosphere consisting of a mixture of gases and other solid and liquid particles.
- The gaseous materials extend to several hundred kilometres in altitude, though there is no well defined boundary for the upper limit of the atmosphere.
- The first 80 km of the atmosphere contains more than 99% of the total mass of the earth's atmosphere.
- The vertical profile of the atmosphere is divided into four layers: **troposphere**, **stratosphere**, **mesosphere** and **thermosphere**.

2.2.2 Energy interaction with the earth's surface

- When EM energy is incident upon any object there are three fundamental energy interactions that are possible. Various fractions of the incident energy are reflected, absorbed and/or transmitted.



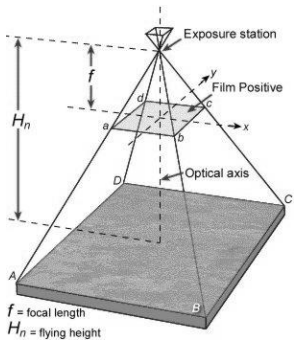
- By applying the principle of conservation of energy we can state the interrelationship between these interactions as: $\mathbf{E_I = E_R + E_A + E_T}$
- Where $\mathbf{E_I}$ denotes the incident energy, $\mathbf{E_R}$ denotes the reflected energy, $\mathbf{E_A}$ denotes the absorbed energy and $\mathbf{E_T}$ denotes the transmitted energy.
- Three points concerning this relationship should be noted: **First,** the proportions of energy reflected, absorbed and transmitted will vary for different targets depending on their material type and condition.
- **Second**, the proportion of reflected, absorbed and transmitted energy for a target will vary with wavelength.
- **Third,** note that in order to interpret multispectral images we need to understand the reflectance, absorption and transmittance properties of typical Earth surfaces, such as soil, water and vegetated surfaces, at these wavelengths.

3. Aerial imagery, Satellite imagery, and Platforms

- The vehicle which carries a sensor is known as platforms. They are two types of platform, i.e. satellite remote sensing and aerial photograph ex:-aircraft, balloon, etc...

3.1.1 Aerial photograph

A photograph taken from the air with the camera axis pointing downwards at the time of exposure is known as an aerial photograph. An aerial photograph differs from a normal photograph in that it gives a three dimensional view of the features it shows. An aerial camera mounted on an aircraft usually takes the aerial photographs. The camera can be so positioned that it can photograph the ground from any angle above the horizon. Besides the aerial photographs, there is another type of photograph known as horizontal photograph.



Types of Aerial photograph

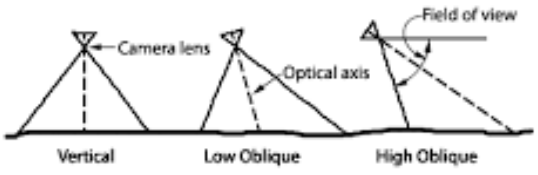
The photographs used for mapping and interpretation may be divided into the following four classes, depending on the orientation of the optical axis of the camera

(a) **Vertical photographs:** A photograph taken with the optical axis of the camera pointing vertically downwards is called a vertical photograph. However, a photograph taken with the optical axis inclined at an angle of ± 3º from the vertical is also classified as a vertical photograph.

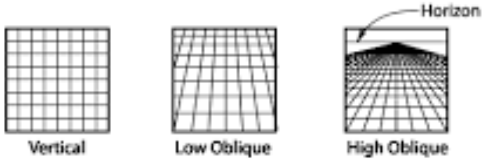
(b) **Oblique photograph:** A photograph taken with the optical axis of the camera tilted is called an oblique photograph. A photograph of this type covers a large area of the ground, but the quality of the image is far end of the photograph. The oblique photographs may be further divided into two categories, viz.,

(i) Low oblique photographs, in which the horizon does not appear. These photographs are sometimes used to compile reconnaissance maps of inaccessible area.

(ii) High oblique photographs, in which the tilt of the camera axis is sufficient to contain the horizon. Such photographs have been used in the past for extending the planimetric and height control when the available ground control was insufficient to provide the necessary accuracy.

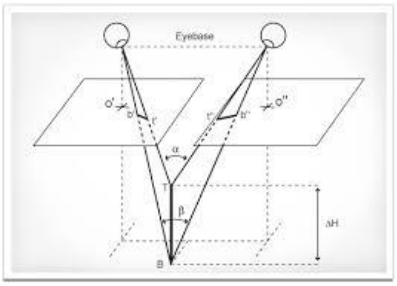


Camera orientation for various types of aerial photographs

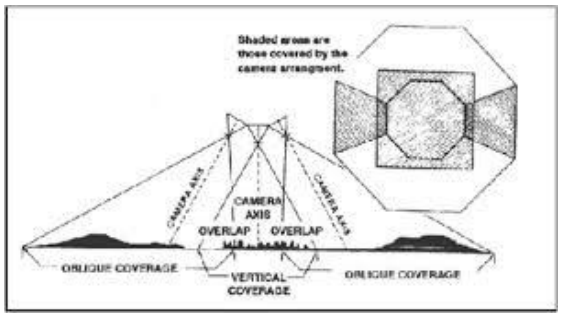


How a grid of section lines appears on various types of photos.

(c) **Convergent photographs**: A convergent photograph is a low oblique photograph taken with two camera exposed simultaneously at successive camera stations with the camera axes tilted from the vertical at a fixed angle in the direction of flight line, so that the forward exposure of the first station (S1) forms a stereopair with the backward exposure of the next station (S2). The angle of the tilt here is azimuthal (i.e., along the flight line – forward or backward).



(d) **Trimetragon photographs**: The trimetragon photographs are the photographs taken simultaneously with three camera, held in a single mount, of which one is held vertically and photographs the area below the plane, and the others, aligned at a right angles to the azimuth, are held obliquely at an angle of 60 º from the vertical and photograph the areas adjacent to the area being photographed by the vertical camera. Trimetragon photography is used for a rapid production of reconnaissance maps in small scales.



3.1.2 Space bone remote sensing

A satellite, as we all know, is an object that moves in a definite path around the parent planet. The launching of the satellites has enabled man to gather and study information on the earth's surface from orbital heights. The sensors mounted on a satellite look down to the earth and collect this information. Earth resource sensing from an orbiting space platform has certain unique characteristics:

(a) A satellite due to its vantage point in space can collect information about very large areas of the ground (synoptic view) under the fixed solar illumination. The near-vertical (orthographic) perspective of such image makes the images valuable for cartographic purpose and for recognising large scale features of the earth's surface.

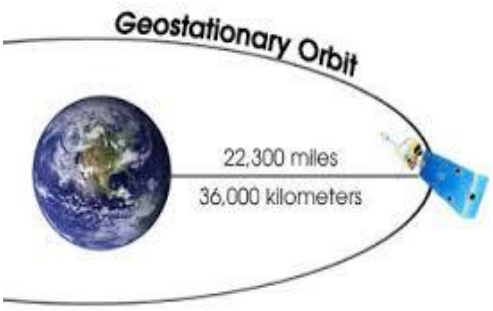
(b) The repetitive coverage at regular intervals provides an unequalled opportunity to monitor the dynamic features, such as changes (vegetation, water) and to exactly identify the static resource features of the earth.

(c) The satellite data are economical in price as compared to the airborne data and because of the long life span of a satellite.

There are two board types of satellites viz., (a) Natural (e.g.,) Moon (which is the only natural satellite of the earth) and (b) Artificial (e.g.,) Landsat, INSAT,SPOT and IRS. The artificial satellite can also be broadly divided into two groups, namely (i) Geostationary and (ii) Sun – synchronous.

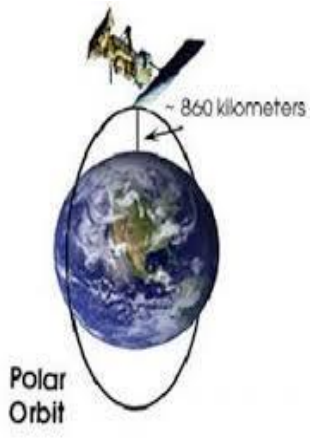
(i) ***Geostationary satellite***: - In general, an orbiting satellite changes its position in the sky continuously. But if a satellite launched on the equatorial plane travels at the same angular velocity at which the earth rotates and in the same direction, it

will remain above the same point on earth at all times. This possible when the orbital altitude is about 36,000 km.



A satellite which is stationary with respect to a given position of the earth is known as a geostationary satellite. A geostationary satellite is mainly deployed for communication satellite and meteorological earth observation. Ex: - INSAT series.

(ii) ***Sun-synchronous satellite***: - The earth satellite orbit in which the orbit plane is nearly polar and the orbital plane rotates at the same rate as the mean rotation rate of the earth around the sun (i.e., 0.9865º/day) is known as the sun-synchronous orbit. A sun-synchronous satellite is generally placed in an orbit with its altitude varying from 600 km to 1000 km.



Most remote sensing satellites take daytime images during the descending phase of the orbit whereas the night-time images are recorded during the ascending phase of the orbit.

Sun-synchronous satellite is also known as a polar or near polar orbiting satellite as it traverses from one pole to the other. It's used for study the earth resources and meteorology.

3.2 Scanners and cameras

Remote sensing is concerned with detecting and recording the electromagnetic radiation from a target area in the field of view of the sensor instrument.

The radiation may originate from different components of the target area, it may be the solar energy reflected or normal thermal/microwave energy emitted by the target or may be the reflection of the energy transmitted to the target by the sensor itself (as in the case of a camera with a flashlight). There are two different system of remote sensing data acquisition, namely:-

(a) **Passive sensor**: - A system which utilise a naturally-occurring source of energy, for ex: - Sun-rays are called a passive system. Taking a photograph of an object on a clear bright day.

(i) ***Photographic camera***: - the photographic camera records the images in the visible part of the spectrum and in the parts immediately adjacent to it, i.e., ultraviolet and infrared.

In this system, the camera lens produces the image which is recorded on a flexible film base. The distance between the lens of the camera and the film is called the focal length (f).

This camera works in the visible and near-infrared bands. Usually, the bands are blue (0.4 -0.5 µm),green (0.5-0.6 µm) red (0.6-0.7 µm) and infrared (0.7-1.1 µm)

(ii) ***Television camera***: - is operates on the same principle and in the same waveband as a photographic camera.

(iii) ***Return beam vidicon (RBV)***:- is the multiband version of the TV camera. This is a scanning system which records black and white visible information in a form similar to a television picture. It's made up of three independent multichannel TV cameras which take snapshot images of the surface of the earth. This sensing system was used in the first three satellites of the Landsat series. The three bands used in the Landsat satellite are the visible band from 0.475 to 0.575 μm (green-blue), from 0.580 to 0.680 μm (yellow-red) and from 0.678 to 0.830 μm (red-near infrared)

(iv) ***Electro-optical scanner***: - Besides the photographic and TV cameras, various scanning systems are utilised from air and space platforms for collecting the remote sensing data. A scanner is usually made up of a reception system comprising a mirror and photo electronic detectors. A scanner system does not image the entire scene instantaneously like a photographic camera. Instead, like a TV camera, it constructs the scene by recording a series of scan lines. The image from the scanner can be obtained in different grid sizes, varying from a few metres to a kilometre or more, the grid size being the limit of an identifiable object size. The scanner system builds up a picture from the spectral information and record in a wide range of spectral wavebands, from the ultraviolet to the microwave (0.3 to 15). Scanners may be broadly classified into two types, namely: (a) Whisk-broom scanner is made up of a single detector and a rotating mirror. The mirror is oriented in such a manner that, after it completes a rotation, the detector beam sweeps a straight line on the surface of the earth across the track of the satellite. (b) Push-broom scanner is other hand, has thousands of equally-spaced detectors which together act as a linear camera, recording one entire line. The push broom scanner has no moving parts and thus provides better signal levels.

(b) **<u>Active sensor</u>**: - A system which utilises a man-made source of energy is called an active system. Taking a photograph of an object in a dark place with the help of a flash bulb is an example. RADAR (radio detection and ranging) is an example of an active system.

Radar is an active system in which short pulses of electromagnetic energy are transmitted in a microwave or cm wavelength region and the echoes received back are recorded in order of arrival and put in a line on an image tube in the form of small light dots.

The radar remote sensing system uses an antenna fixed below the aircraft or spacecraft and faces the side of the antenna platform. There are two basic types of radar.

(i) ***The real aperture system*** uses an antenna of the maximum practical length and produces a narrow angular beam in the azimuth (i.e., flight) direction. The physical length of the antenna platform limits the physical length of the antenna.

(ii) ***The synthetic aperture system*** uses a small antenna with suitable electronics to give the antenna the effect of a longer dimension. This antenna transmits a beam narrower than that produced by the antenna in the real aperture system.

The operation of an active microwave system is fundamentally different from that of the other sensing systems. The most apparent feature of the former, that is, radar, is its sidelighted character, i.e., its look direction is downwards but to the side of the platform. This system is generally referred to as a side-looking radar (SLR) or side-looking airborne radar (SLAR).

3.3 Image data characteristics

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.***

1-Tone refers to the relative brightness or colour of objects in image. Generally, tone is the fundamental element for distinguishing between different targets or features.

2-Shape refers to the general form, structure, or outline of individual objects. 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 or rectangular shape.

3-Size of objects in an image is a function of scale. 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.

4-Pattern refers to the spatial arrangement of visibly discernible objects.

5-Texture refers to the arrangement and frequency of tonal variation in particular areas of an image. Smooth textures are most often the result of uniform, even surfaces, such as fields are grasslands. A target with a rough surface and irregular structure, such as a forest.

6-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.

7-Association of certain features with others helps in the identification of feature, for example, sand-dunes are associated with deserts.

Image Processing

What is an Image?

An image is an array, or a matrix, of square pixels (picture elements) arranged in columns and rows.

Black and white image

In a (8-bit) greyscale image each picture element has an assigned intensity that ranges from 0 to 255. A grey scale image is what people normally call a black and white image, but the name emphasizes that such an image will also include many shades of grey.

Each pixel has a value from 0 (black) to 255 (white). The possible range of the pixel values depend on the colour depth of the image, here 8 bit = 256 greyscales

Pixel Values, DN

Pixel Values: The magnitude of the electromagnetic energy (or, intensity) captured in a digital image is represented by positive digital numbers.

The digital numbers (DN) are in the form of binary digits (or 'bits') which vary from 0 to a selected power of 2

Image Type	Pixel Value	Color Levels
8-bit image	28 = 256	0-255
16-bit image	216 = 65536	0-65535
24-bit image	224 = 16777216	0-16777215

Digital image processing

- Image is manipulated using computer
- Image → mathematical operation → new image
- Application areas:
  - Image rectification and restoration
  - Image enhancement
  - Image interpretation / classification

Image restoration

- Errors due to imaging process are removed
- Geometric errors
  - position of image pixel is not correct one when compared to ground
- Radiometric errors
  - measured radiation do not correspond radiation leaving ground
- Aim is to form faultless image of scene

Sources of error

- Movement of imaging platform
- Instrument
- Atmosphere
- Object

Geometric correction

- Position of image pixel is not correct when compared to ground
- Errors due to instrument, movement of imaging platform and object are removed
- Known errors in geometry:
  - Earth cirvature and rotation
  - Topography
  - Imaging geometry
- Rectification to map projection
  - Geometric transformation

  - Interpolation of pixel digital numbers
- Geometric correction is made
  - automatically using orbital parameters or
  - manually using ground control points
- Alternatives
  - orbital parameters
  - ground control points
  - orthocorrection
- Most accurate results by combining all

Geometric correction using orbital parameters

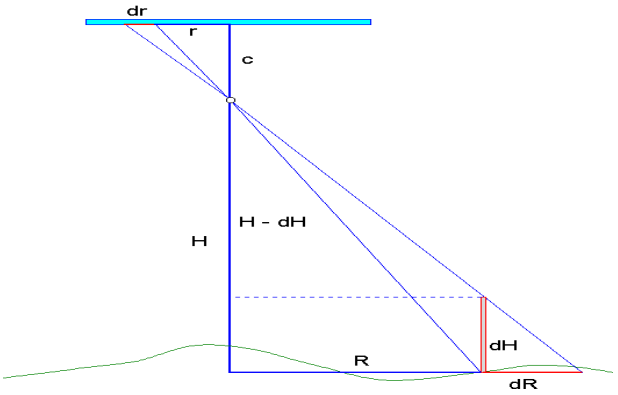
- Information about
  - position of satellite (XYZ)
  - attitude (ωφκ)
- Correction can be low quality due to poor orbital information
- Knowledge about scanning geometry, movement of object and topography (DEM) will increase accuracy
- Accuracy of correction depends on quality of used information
- Some examples about accuracy using orbital parameters:
  - NOAA AVHRR: 5 km - 1.5 km
  - Spot 1-4: 350 m
  - Spot 5: 50 m
- Ground control points: accuracy should be better than 1 pixel
  - depends also mathematical model and topographic variations
- Orthocorrection most accurate

Manual correction:

- Ground control points (GCPs):
  - image coordinates are measured from image
  - map coordinates from map or georeferenced image
- GCPs are known and well distinguished ground features
  - crossroads, buildings, small lakes, small islands, features in waterline
- More GCPs is better
- When transformation between image coordinate system and map coordinate system is defined using polynomials, minimum number of points:
  - 1st degree polynomial: 3 points
  - 2nd degree: polynomial: 6 points
- Software searches corresponding points from image to be georeferenced and image in map coordinate system
- This can be based on
  - correlation between subimages
  - recognizable features (linear like roads or lakes)
- These points are used as GCPs
- Software produces many (e.g. 200-300 points for Landsat ETM-image)
  - user has to select which can be used
- Automatization is needed when there are many images and/or it has to be made daily

Topographic error

- Property of imaging system using central projection
- Image of object is in incorrect place due to height variations



Orthocorrection

- Topographic error is removed by changing the perspective of image from central projection to orthogonal projection
- DEM is needed

Image formation

Image acquisition can be modelled with image degradation model:

$$f(x) * h(x) + n(x) = g(x)$$

g(x): acquired image
h(x): filter corresponding to averaging effects due to atmosphere and instrument
n(x): random errors due to instrument and data transmission
f(x): scene

Inverse filtering

- Errorness image of scene f(x) should be acquired by making inverse process to known image g(x)
- Image degradation model in frequency domain:

  $G(u)=F(u)H(u)+N(u)$
- Ideal inverse filtering

  $F_e(u) = G(u)/H(u) - N(u)/H(u)$
- In practice difficult to solve
  - zeros in H(u)
  - effect of N(u) increases
- Usually radiometric correction is divided to different phases which are corrected individually

Radiometric correction

In order that measurements taken with different instruments and differents dates are comparable

Aim: radiance or reflectance

- Radiance ($W/m^2/sr$):

physical term which describes intensity of radiation leaving ground to some direction

- Reflectance:

Radiance / incoming irradiance

Equation:

$R = (Lmax-Lmin)/255*DN + Lmin$

OR

$R=Gain*DN + offset$

Other corrections

- Sun zenith angle:

  DN'=DN / SIN(sunq)
- Ground is illuminated differently when Sun zenith angle changes
  - seasonal differences
- Distance between Sun and Earth
- This distance varies according to seasons

Image Enhancement

- To improve the visual interpretability of an image by increasing the apparent distinction between the features of the scene
- This objective is to create new image from the original image in order to increase the amount of information that can be visually interpreted from the data
- Enhancement operations are normally applied to image data after the appropriate restoration procedures have been performed
- Point operations:
    - modify the brightness value of each pixel independently
- Local operations:
    - modify the value of each pixel based on neighboring brightness values

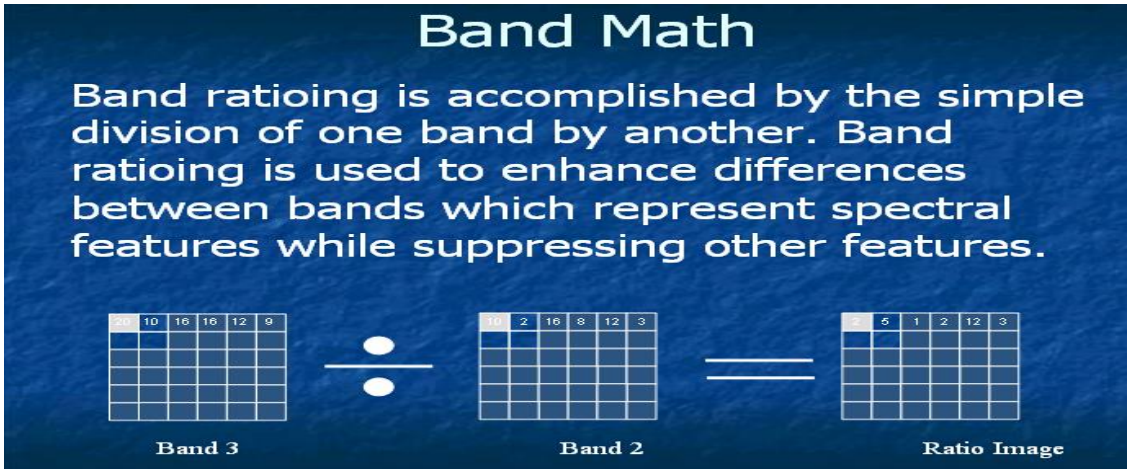
1. Contrast manipulation
    - Thresholding
    - Stretching
    - Slicing
2. Spatial feature manipulation
    - Filtering
    - Edge enhancement
    - Fourier analysis
3. Multi-image manipulation

Edge Enhancement

- Edge-enhanced images attempt to preserve local contrast and low-frequency brightness information, for example related to linear features such as roads, canals, geological faults, etc.
- Edge enhancement is typically implemented in three steps:
    - High-frequency component image is produced using the appropriate kernel size. Rough images suggest small filter size (e.g. 3 × 3 pixels) whereas large sizes (e.g. 9 × 9) are used with smooth images
    - All or a fraction of the gray level in each pixel is added back to high-frequency component image
    - The composite image is contrast-stretched

Multi-Image Manipulation

- Spectral rationing
- Ratio images are enhancements resulting from the division of DNs in one spectral band by the corresponding values in another band.

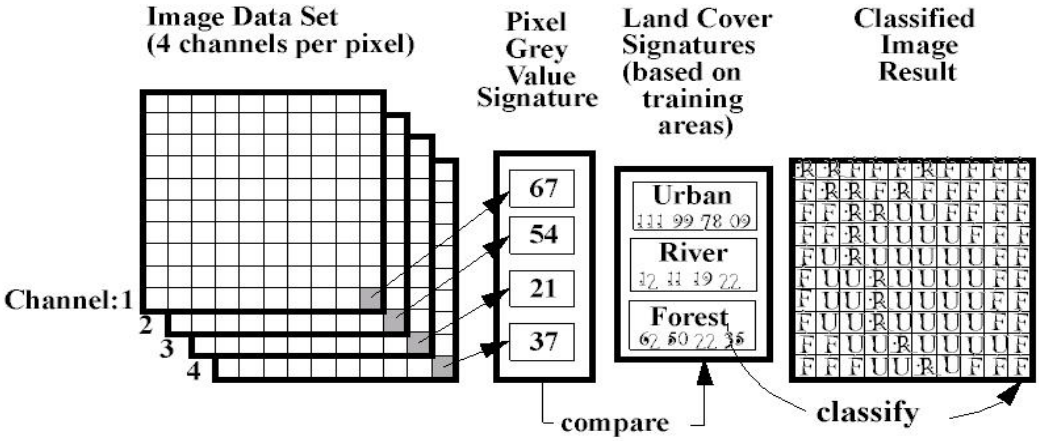


Ratio Images

- Used for discriminating subtle spectral variations that are masked by the brightness variations
- Depends on the particular reflectance characteristics of the features involved and the application at hand
- Ratio images can also be used to generate false color composites by combining three monochromatic ratio data sets.
- Advantage: combining data from more than two bands and presenting the data in color

Image classification

- ***Digital image classification*** is assigning pixels to classes (categories)
  - Each pixel has as many digital values as there are bands
  - Compare the values to pixels of known composition and assign them accordingly
  - Each class (in theory) is homogenous



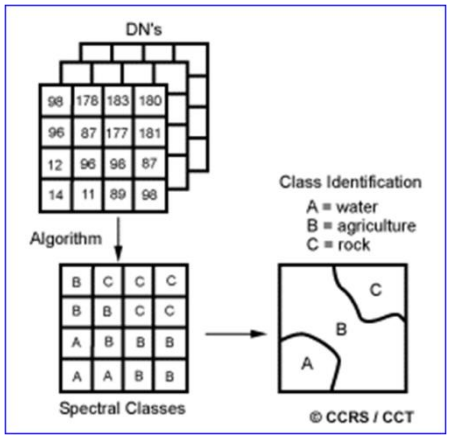
Direct uses

- Produce a map of land-use/land-cover

- **Indirect use**
  - Classification is an intermediate step, and may form only one of several data layers in a GIS
    - Water map vs water quality GIS
- ***Classifier*** is a computer program that does some sort of image classification
  - Many different types available
  - No one method is "best"
- Simplest is a point or spectral classifier
  - Considers each pixel individually
    - Simple and economic
    - Can't describe relation to neighboring pixels
- ***Spatial neighborhood classifiers*** consider groups of pixels
  - More difficult to program and more expensive
- ***Supervised*** vs ***Unsupervised*** classification
- Supervised requires the analyst to identify known areas
- Unsupervised determines a set number of categories based on a computer algorithm
- ***Hybrid classifiers*** are a mix of the two

Unsupervised 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.

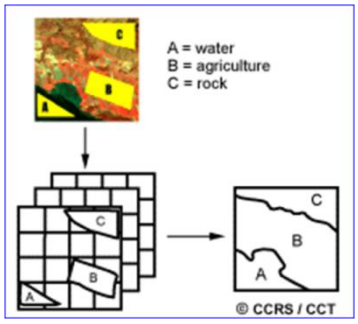
- **Advantages**
  - Requires no prior knowledge of the region
  - Human error is minimized
  - Unique classes are recognized as distinct units
- **Disadvantages**
  - Classes do not necessarily match informational categories of interest
  - Limited control of classes and identities
  - Spectral properties of classes can change with time

Unsupervised classification technique

- Distance Measures are used to group or cluster brightness values together
- Euclidean distance between points in space is a common way to calculate closeness
  - Euclidean metric is the "ordinary" distance between two points that one would measure with a ruler, and is given by the Pythagorean formula.

$$a^2 + b^2 = c^2$$

Supervised classification



Identify known a priori through a combination of fieldwork, map analysis, and personal experience as training sites; the 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.

Training sites selection

- Based on known a priori through a combination of fieldwork, map analysis, and personal experience
- **on-screen selection** of polygonal training data (ROI), and/or
- **on-screen seeding** of training data (ENVI does not have this, Erdas Imagine does).
  - The *seed program* begins at a single *x, y* location and evaluates neighboring pixel values in all bands of interest. Using criteria specified by the analyst, the seed algorithm expands outward like an amoeba as long as it finds pixels with spectral characteristics similar to the original seed pixel. This is a very effective way of collecting homogeneous training information.
- From spectral library of field measurements.

Start with knowledge of class types.

- Classes are chosen at start
- ***Training samples*** are created for each class
- Ground truth used to verify the training samples.
- Quite a few algorithms. Here we will look at:

  Parallelepiped

  Maximum likelihood

Advantages

- Analyst has control over the selected classes tailored to the purpose
- Has specific classes of known identity
- Does not have to match spectral categories on the final map with informational categories of interest
- Can detect serious errors in classification if training areas are missclassified

Disadvantages

- Analyst imposes a classification (may not be natural)
- Training data are usually tied to informational categories and not spectral properties
  - Remember diversity
- Training data selected may not be representative
- Selection of training data may be time consuming and expensive
- May not be able to recognize special or unique categories because they are not known or small

Training data

- Specify corner points of selected areas
- Assume that the correct ID is known
- Often requires ancillary data (maps, photos, etc.)
- Field work often needed to verify

- Key Characteristics of Training areas
  - ***Number*** of pixels
    - Have several training areas for one category
    - A total of at least 100 pixels per category
  - ***Number*** depends on the number of categories, their diversity, and resources available
    - More areas also allow discarding ones that have too high a variance
  - ***Shape*** –not important, usually rectangular for ease
- More Key Characteristics
  - ***Locations*** must be spread around the image and be easily transferred from map to image
  - ***Size*** must be large enough to estimate spectral characteristics and variations
    - Varies with sensor type and resolution
    - Varies with heterogeneity of area
  - ***Uniformity*** means that each training set should be as homogenous as possible.

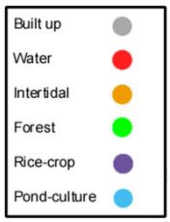
Supervised classification methods

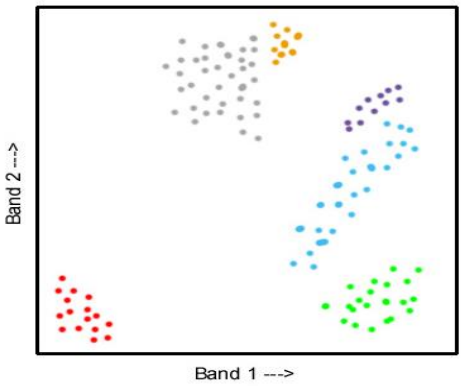
- Various supervised classification algorithms may be used to assign an unknown pixel to one of *m* possible classes. The choice of a particular classifier or decision rule depends on the nature of the input data and the desired output. ***Parametric*** classification algorithms assumes that the observed measurement vectors X_c obtained for each class in each spectral band during the training phase of the supervised classification are Gaussian; that is, they are normally distributed. ***Nonparametric*** classification algorithms make no such assumption.
- Several widely adopted **nonparametric** classification algorithms include:
  - one-dimensional *density slicing*
  - parallepiped,
  - minimum distance,
  - nearest-neighbor, and
  - neural network and expert system analysis.
- The most widely adopted **parametric** classification algorithms is the:
  - maximum likelihood.
  -

- Hyperspectral classification methods
  - Binary Encoding
  - Spectral Angle Mapper
  - Matched Filtering
  - Spectral Feature Fitting
  - Linear Spectral Unmixing

Parallelepiped

- Also known as ***box decision rule***, or ***level-slice procedure***
  - Based on the values of the training data
- For each training region determine the range of values observed in each band.
- These ranges form a spectral box (or parallelepiped) which is used to classify this class type.
- Assign new image pixels to the parallelepiped which it fits into best.
- Pixels outside all boxes can be unclassified or assigned to the closest one.
- Problems with classes that exhibit high correlation between bands. This creates long 'diagonal' data-sets that don't fit well into a box.





Basic principle of GIS

1.1 Definitions:-

The definition of GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world. A system for capturing, storing, checking, manipulating, analysis and displaying data which are spatially referenced to the earth surface (Geographic of the area).

The geographical information system (GIS) is a computer based system that provides four sets of capabilities to handle Georeferenced data

- Input
- Data management
- Manipulation and Analysis
- Output

The geographical data represent phenomena from the real world in terms of

(a) Their position with respect to a known coordinate system.

(b) Their attributes that is unrelated to position. (Such as colour, cost and pH)

(c) Their spatial interrelation with each other which describe how they are linked together.

1.2 Components of GIS

The geographical information system (GIS) has three important components such as

1. Computer hardware
2. Software
3. Proper organization context including skilled people.

Computer Hardware

- A processor with sufficient power to run the software.
- Sufficient memory for the storage of large volumes of data.
- A good quality, high resolution colour graphic screen.
- Data input and output devices. (for example: Scanners, keyboard, printer and plotters)

The computer has a hard disk drive for storing data and programs, but extra storage can be provided via a network or optical CD-ROM and other derive. A digitizer or a scanner is used to convert maps and documents into digital forms so that they can be used by the computer programs. A plotter or a printer or any other kind of displaying device is used to present the results of the data processing.

Computer software

The GIS software includes the programs and the user interface for driving the hardware. GIS software is essential to input, generate, store, transform, analysis, manipulate and displaying geographic information or data. A good GIS software requires user friendly, functionalities, compatibilities, updatability, documentation and cost effectiveness.

The GIS software may be split into five functional groups.

1. Data input and verification
2. Data storage and Database management
3. Data output and presentation
4. Data transformation
5. Interaction with the user.

1.3 GIS Subsystem

A GIS has four main functional subsystems, these are

1. A data input subsystems
2. A data storage and retrieval subsystem
3. A data manipulation and analysis subsystem.
4. A data output and displaying subsystem.

1. A data input subsystems

- Allows the user to capture, collect and transform spatial and thematic data into digital form.
- The data inputs are usually from a combination of hard copy maps, Aerial photographs, Remote sensed images reports, survey documents etc.

2. A data storage and retrieval subsystem.

- Data organizes, spatial and attribute in a form which permits it to be quickly retrieval by the user for analysis and permits accurate updates to be made to database.
- This component usually involves use of a database management system (DBMS) for maintaining attribute data.

3. A data manipulation and analysis

- This subsystem is commonly said to be the heart of GIS.
- The data manipulation and analysis subsystem allows the user to define and execute spatial and attribute procedures to generate derived information.

4. A data output and displaying subsystem.

- Allows the user to generate graphic display, normally maps and tabular reports representing derived information products.

1.4 Purpose of GIS

- Allow for the integration of data hitherto confined to independent domains (e.g property maps and air photos).
- Data to maps permits the succinct communication of complex spatial patterns (e.g environmental sensitivity).
- Provides answers to spatial queries
- Perform complex spatial modelling (what if scenarios for transportation planning, disaster planning, resource management, utility design.
- GIS provide quick and easy access to large volumes of data.
- The ability to:-
  - Select detail by area or theme
  - Link or merge one data set with another
  - Analyze spatial characteristics of data
  - Search for particular characteristics or features in an area
  - Update data quickly and cheaply
  - Model data and assess alternatives.
- It's also providing output capabilities (maps, graphs, address lists and summary statistics).

GIS applications

Virtually anyone who needs information that can be tied to a location on earth (i.e. people through their addresses or features through their geographic locations)

- Hydro geologists monitor water quality and relate to land use
- Biologists can track trends in invader species spread over years
- Ecologists can assess suitable habitat for a species
- Businessmen can study feasibility of a new location
- Engineers can find least-cost path for a new road

Some other applications

- Urban Planning, Management & Policy
  - Zoning, subdivision planning, Land acquisition, Economic development, Code enforcement. Housing renovation programs, Emergency response, Crime analysis, Tax assessment
- Environmental Sciences
  - Monitoring environmental risk, Modeling storm water runoff, Management of watersheds, floodplains, wetlands, forests, aquifers, Environmental Impact Analysis, Hazardous or toxic facility siting, Groundwater modeling and contamination tracking
- Political Science
  - Redistricting, Analysis of election results
  - Predictive modeling
- Civil Engineering/Utility
  - Locating underground facilities, Designing alignment for freeways, transit, Coordination of infrastructure maintenance
- Business
  - Demographic Analysis, Market Penetration/ Share Analysis, Site Selection
- Education Administration
- Attendance Area Maintenance, Enrollment Projections, School Bus Routing
- Real Estate
  - Neighborhood land prices, Traffic Impact Analysis, Determination of Highest and Best Use
- Health Care
  - Epidemiology, Needs Analysis, Service Inventory

For applications of GIS

We need five (M) of Applied GIS:

- Mapping
- Measuring
- Monitoring
- Modeling
- Managing

1.5 GIS Capabilities

- Data capture / input:
  - input data by digitizing, scanning, or direct coordinate entry
  - edit data in the GIS to correct errors or add features
  - label the spatial features so they can be identified (names or codes)
- Management:
  - Link attribute data to spatial objects
  - Link to external databases
  - Make changes in existing databases
  - Update database features
  - Import and export from/to other GIS or DBMS
  - Combine map sheets to create large databases
  - Match the edges of neighbouring map sheets
- Manipulation:
  - Make maps from different sources compatible so that they can be drawn on top of each other.
  - Transformation of coordinates, projection change
- Analysis: query.
  - select features by their attributes:
    "Find all districts with literacy rates < 60%"
  - select features by geographic relationships
    "Find all family planning clinics within this district"
  - combined attributes/geographic queries
    "Find all villages within 10km of a health facility that have high child mortality" query
  - buffer: find all settlements that are more than 10km from a health clinic
  - point-in-polygon operations: identify for all villages into which vegetation zone they fall
  - polygon overlay: combine administrative records with health district data
  - geocoding/address matching: match an address list with a street map
  - network operations: find the shortest route from village to hospital
- Modelling
  - Identify or predict a process that has created or will create a certain spatial pattern
    Diffusion: how is the epidemic spreading in the province?
    Interaction: where do people migrate to?
    What-if scenarios: if the dam is built, how many people will be displaced?
- Display/output:
  - Exploratory: Visualize pattern and identify anomalies compare information in map space and data space
  - Cartography: Produce high quality map output for publication create a digital or paper census atlas, export map output to other packages

Coordinate systems

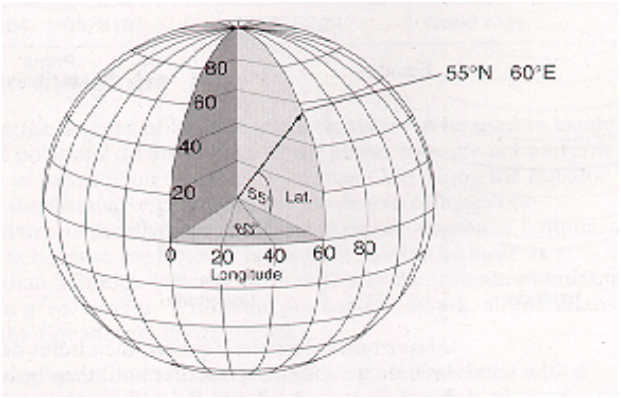
What is a coordinate system?

- Coordinate systems enable geographic datasets to use common locations for integration.
- A coordinate system is a reference system used to represent the locations of geographic features, imagery, and observations such as GPS locations within a common geographic framework.

Each coordinate system is defined by:

- Its measurement framework which is either geographic (in which spherical coordinates are measured from the earth's center) or planimetric (in which the earth's coordinates are projected onto a two-dimensional planar surface).
- Unit of measurement (typically feet or meters for projected coordinate systems or decimal degrees for latitude–longitude).
- The definition of the map projection for projected coordinate systems.
- Other measurement system properties such as a spheroid of reference, a datum, and projection parameters like one or more standard parallels, a central meridian, and possible shifts in the x- and y-directions.

What is a coordinate?



- Features on spherical surfaces are not easy to measure
- Features on planes are easy to measure and calculate
  - distance
  - angle
  - area
- Coordinate systems provide a measurement framework.

Universal Transverse Mercator (UTM).

- Based on the Transverse Mercator projection
- 60 zones (each 6° wide)
- Y-0 set at south pole or equator
- Ethiopia falls into UTM zones of 37.

Types of coordinate Systems

There are two types of coordinates system

- Geographic coordinates system
- Projected coordinates system

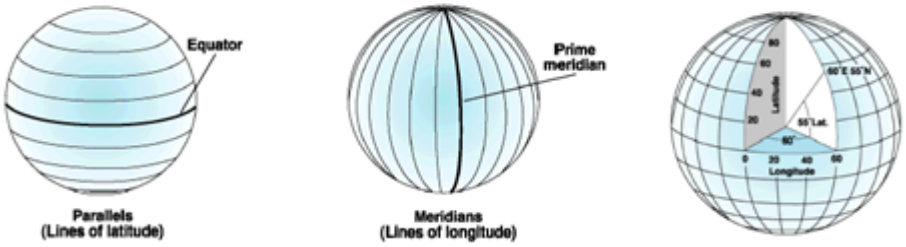
Geographic Coordinate Systems (GCS)

- Location measured from curved surface of the earth
- Measurement units latitude and longitude
  - Degrees-minutes-seconds (DMS)
  - Decimal degrees (DD) or radians (rad)

Projected Coordinate Systems (PCS)

- Flat surface
- Units can be in meters, feet, inches
- Distortions will occur, except for very fine scale maps

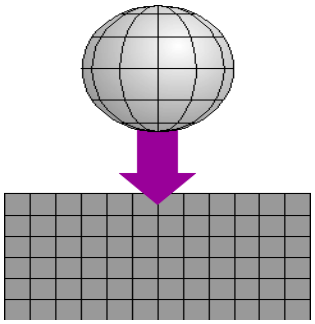
Geographic Coordinate System



- Parallels - east to west – 0° at the Equator (0 °-90 °)
- Meridians – north to south – 0° at the Prime Meridian (0 °-180 °)
- Latitude and longitude are angular measurements made from the center of the earth to a point on the surface of the earth

Map Projection

- A map projection is a mathematical formula for representing the curved surface of the earth on a flat map.
  - wide variety of projections possible
  - each projection will create a different type of distortion
  - Distortions are inherent in maps
  - The Earth is round, a map is flat



- ✓ 3D surface is transformed to create a flat surface
- ✓ This transformation, usually by a mathematical conversion, is commonly referred to as map projection
- ✓ A 2D surface is imagined around the Earth and is referred as projection surface

Projection for accurate mapping

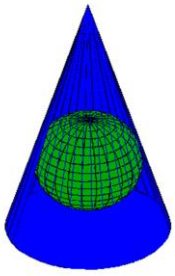
- Earth is neither a perfect sphere nor a spheroid
- Local irregularities
- Earth surveyed many times to determine semi-minor and semi-major axis
- Semi-minor and semi-major axis that fits well one region may not fit well another region

Type of Projection

- Projection surfaces are Conic, cylindrical, and planar

Conic Projection

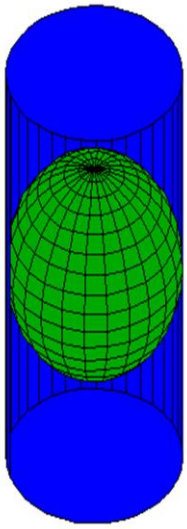
- The most simple conic projection is tangent to the globe along a line of latitude
- This is called a standard parallel for a projection
- The meridians are projected onto the conical surface, meeting at the apex
- latitudes are projected as rings onto the conical surface



Conical Projection Surface

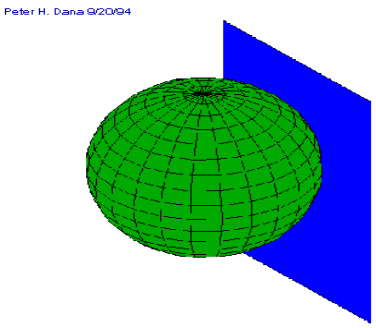
Cylindrical projections

- Cylindrical projections may also have one line of tangency or two lines of secancy around the globe.
- Mercator projection is one of the most common cylindrical projections, and the Equator is usually its line of tangency.
- Meridians are geometrically projected onto the cylindrical surface, and latitude parallels are mathematically projected, producing graticular angles of 90 degrees.
- For more complex cylindrical projections the cylinder is rotated thus changing the lines used for tangency or secancy.
- The cylinder can be 'cut' along, any meridian to produce the final cylindrical projection.
- The meridians are equally spaced, while the spacing between parallel lines of latitudes increases toward the poles.
- This projection is conformal and display true direction along straight lines.



Cylindrical Projection Surface

Transverse Mercator uses meridians as their tangential contact line. Oblique Cylinders are rotated around a great circle line located anywhere between the Equator and the meridians. In these complex projections most meridians and the lines of latitudes are not straight. In all cylindrical projections, the line of tangency or lines of secancy have no distortion and thus are lines of equidistance. Other geographical properties



Planar Projection Surface

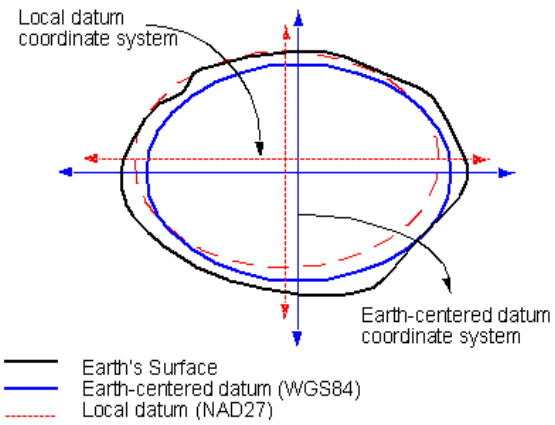
Datum

A datum is a set of reference points on the earth's surface against which position measurements are made, and (often) an associated model of the shape of the earth (reference ellipsoid) to define a geographic coordinate system.

It consists of:

1) A spheroid (ellipsoid) with a spherical coordinate system and an origin.
2) A network of points that have been accurately surveyed.

A system that allows us to place a coordinate system on the earth's surface.



In GIS data (in vector data) is categorized into two parts.

Spatial data:

- The data which include geographic location information of a point, line or polygon object.
- It is also known as geospatial data or geographic information it is the data or information that identifies the geographic location of features and boundaries on Earth, such as natural or artificial features.
- Spatial data is usually stored as coordinates and topology, and is data that can be mapped.

Attribute data:

- The data which include any other non-location information related to a point, a line, or a polygon.
- Attribute data is information appended in tabular format to spatial features.
- The spatial data is the where and attribute data can contain information about the what, where, and why.
- Attribute data provides characteristics about spatial data.

GIS data models are:

1. **Spatial data models:** Traditionally spatial data model has been stored and presented in the form of a map. Two basic types of spatial data models have evolved for storing geographic data digitally. These are referred to as:

Raster and vector data model

- A raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.
- Vector data is not made up of a grid of pixels. Instead, vector graphics are comprised of vertices and paths. The three basic symbol types for vector data are points, lines and polygons (areas).

Advantages of the raster model:

- A simple data structure—a matrix of cells with values, representing a coordinate, and sometimes linked to an attribute table.
- A powerful format for intense statistical and spatial analysis.
- The ability to represent continuous surfaces and perform surface analysis.
- The ability to uniformly store points, lines, polygons, and surfaces.
- Capability to perform faster overlays (than vector datasets) with complex data.
- The same cell-based structure is used to represent all feature types;
    - Therefore, all feature types may be treated the same.
    - This uniform structure allows you to combine a variety of geographic features in one geoprocessing operation (for example, query, overlay, or expression).
    - You can combine a surface (elevation) with area features (forestry), linear features (rivers and roads), and point features (wells) in the same analysis.
- Compatible with remote sensing images and all results images of spatial data scanning.
- The application software is cheaper.

Disadvantages of the raster model:

- Inherent spatial inaccuracies due to the cell-based feature representation.
- Datasets can be very large.
- Projection and transformation coordinate is not easily.
- Difficult in representation topology connections.

Advantages of the vector model:

- Need a small space or place for storage data (disc).
- One layer can be connected with or many attribute for saving the space of storage data.
- Easily makes connection between topology and network.
- Have a high spatial resolution.
- Graphic representation spatial data closely likes man-handed map.
- Very good in correction limits, apparent and clear for making administration maps and owned-lands.
- Easily for making projection and coordinates transformation.

Disadvantages of the vector model:

- Have a complex data structures.
- Data not easily for manipulates.
- Users cannot create owned programs for applications needed.
- Needs a long time only for all the process.
- Vector data often out-of-date.
- Not compatible with remote sensing images data.
- Needs more an expensive software and hardware.
- Overlay vector layers with simulant needs a long time

Attribute Data Models:

a. **Tabular model:** stores attribute data as sequential data files with fixed formats, for the location of attribute values in a predefined record structure. This type of data model is outdated in the GIS format.
b. **Hierarchical model**: organizes data in a tree structure. Data is structured downward in a hierarchy of tables. Any level in the hierarchy can have unlimited children, but any child can have only one parent. Hierarchical DBMS have not gained any noticeable acceptance for use within GIS.
c. **Network Model:** organizes data in a network or plex structure. Any column in a plex structure can be linked to any other. Like a tree structure, a plex structure can be described in terms of parents and children. This model allows for children to have more than one parent.
d. **Relational Model:** organizes data in tables. Each table, is identified by a unique table name, and is organized by rows and columns. Each column within a table also has a unique name. Columns store the values for a specific attribute, e.g. cover group, tree height. Rows represent one record in the table. In a GIS each row is usually linked to a separate spatial feature, e.g. a forestry stand. Accordingly, each row would be

comprised of several columns, each column containing a specific value for that geographic feature.

e. **Object Oriented Model**: for the creation of intelligent "geodatabases" that combine the properties of objects with their behavior. ArcInfo implements objects in a modern and standard way. Each object is defined as a separate component or building block. This allows users to create their own object-oriented models that extend the base model.

Map Design & Layout

The Map Design Process

- Choosing a Map Size, Elements of a map composition, The Design Filter and Planar Organization of Visual Elements

Elements of a Map Composition

Title and Subtitle, Legend, Scale Bar, Inset Map, Credit Note, Date, Logo and North Arrow

Maps typically include a title, legend, scale, explanatory text, directional indicator, sources and credits, a border, insets, and locator maps. These map pieces are systematically arranged around and upon the map.

Consider all the elements you will include on your map, as well as the overall map layout, early in the map-making process. Link decisions on map layout to your goals for your map and the final medium. Together these will shape your choices of map content, scale and the kind of information you include on and surrounding your map.

Map layout is intuitive and some people are better at it than others. It is relatively easy to experiment and create good map layout, particularly with map-making software. When map layout succeeds, map readers will not notice: they will focus on the content of the map. When map layout fails, the map reader will notice: an awkward layout distracts the map reader from the subject and goals of the map.

Title

Titles are important map elements, and type *size* should be *two to three times* the size of the type on the map itself. A subtitle, in smaller type, is appropriate for longer titles or more complex map subjects.

Legends

The legend is the graphic guide that you provide to your audience. You do not always need to provide symbols for all of the information used in your maps.

Scale

Large scale maps should always include a scale. Maps that inform the user about differences in distance or area should also include a scale. Small scale maps may not need a scale, as scale varies greatly with world or continental projections.

Verbal and visual scales make more sense to the average reader. Include a visual scale if the map will be reprinted or resized.