TWO DAYS CAPSULE PROGRAMME ON REMOTE SENSING AND GIS FOR SCHOOL STUDENTS

Sponsored by

NATIONAL NATURAL RESOURCES MANAGEMENT SYSTEM
ISRO, Bangalore

Organised by

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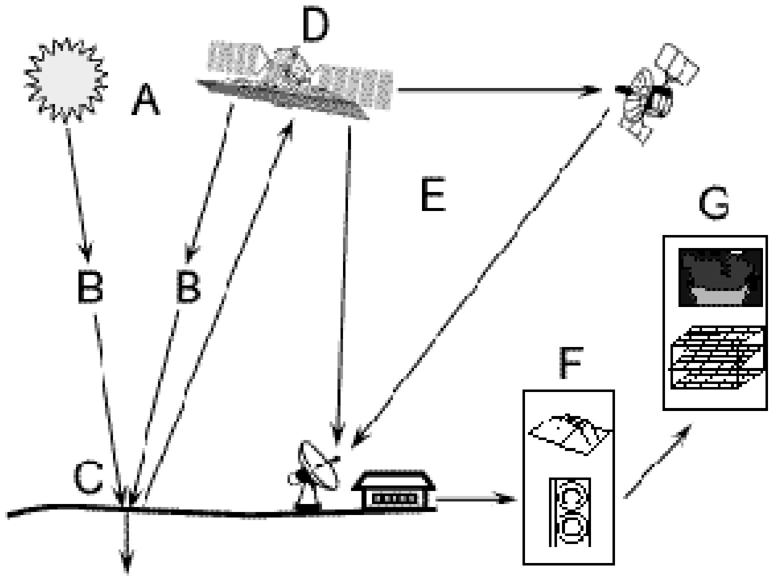
PRINCIPLES OF REMOTE SENSING

"Remote sensing is the science (art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."

In much of remote sensing, the process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Note, however that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.



1. 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.

2. 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.

3. 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.

4. 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.

5. 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).

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

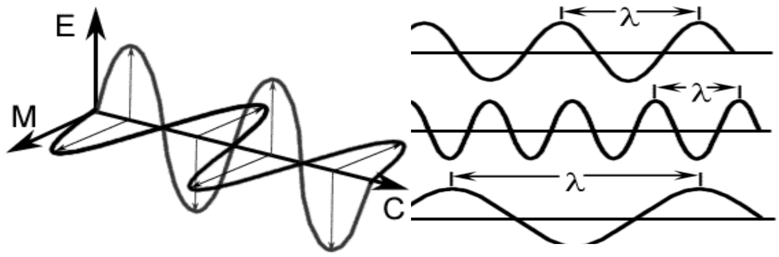
7. Application (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

Electromagnetic Radiation

As was noted in the previous section, 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.

All electromagnetic radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory. 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).

Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing. These are the wavelength and frequency.



The wavelength is the length of 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 is measured in metres (m) or some factor of metres such as nanometres (nm, 10^{-9} metres), micrometres (μm, 10^{-6} metres) (μm, 10^{-6} metres) or centimetres (cm, 10^{-2} metres). Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in hertz (Hz), equivalent to one cycle per second, and various multiples of hertz.

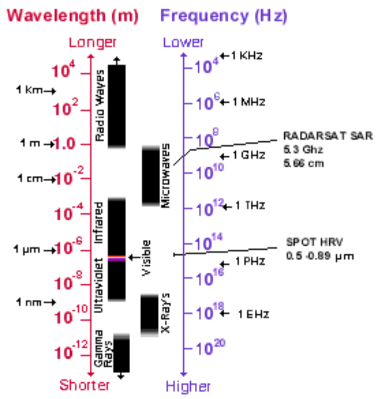
Wavelength and frequency are related by the following formula:

$$c = \lambda \nu$$

where:

λ = wavelength (m)
ν = frequency (cycles per second, Hz)
c = speed of light (3×10^8 m/s)

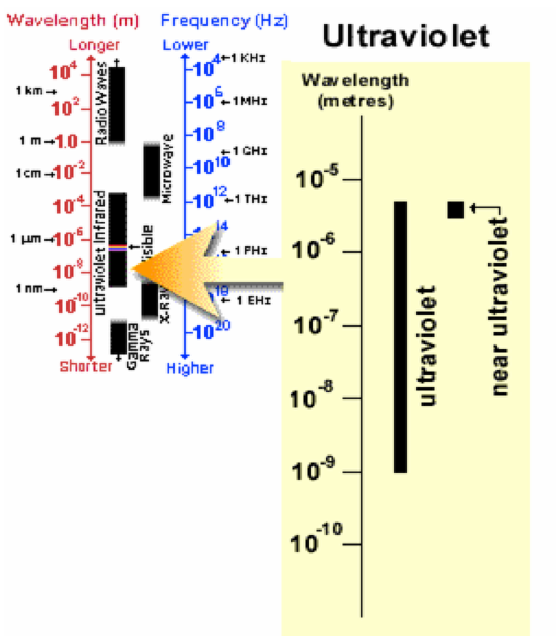
Therefore, the two are inversely related to each other. The shorter the wavelength, the higher the frequency. The longer the wavelength, the lower the frequency. Understanding the characteristics of electromagnetic radiation in terms of their wavelength and frequency is crucial to understanding the information to be extracted from remote sensing data.



The Electromagnetic Spectrum

The electromagnetic spectrum ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). There are several regions of the electromagnetic spectrum which are useful for remote sensing.

For most purposes, 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.



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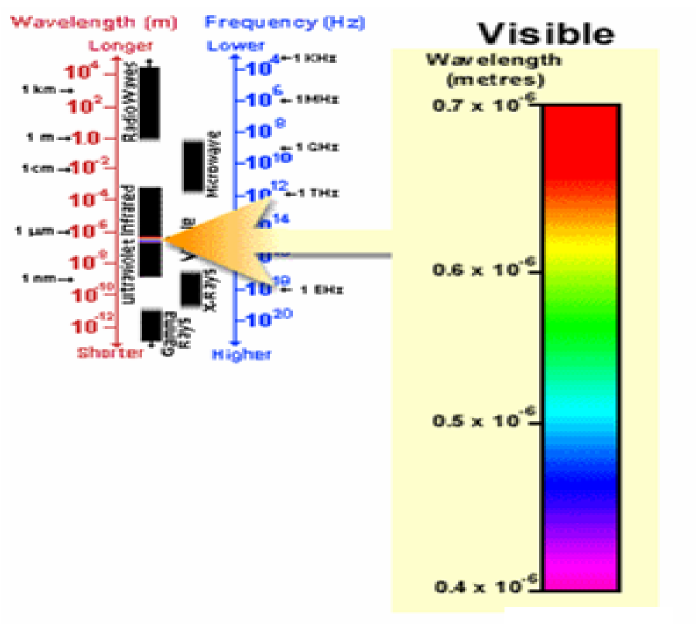

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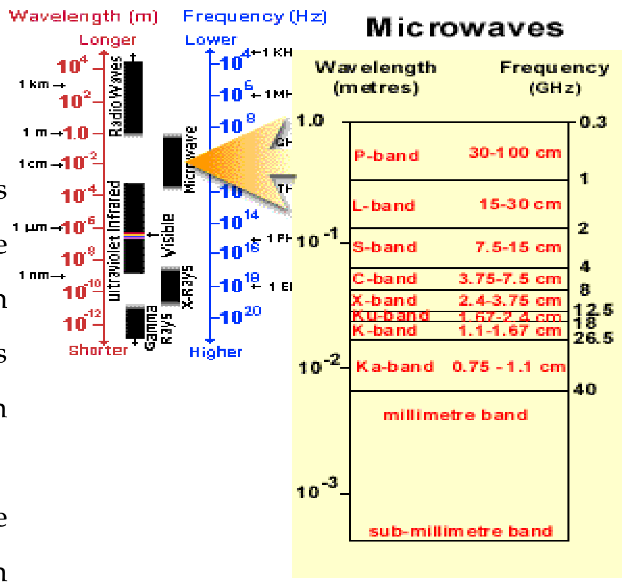
light which our eyes - our "remote sensors" - can detect is part of the visible spectrum. It is important to recognize how small the visible portion is relative to the rest of the spectrum.

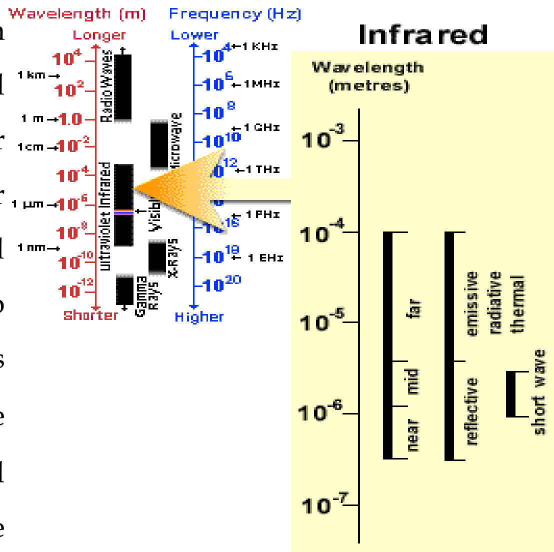
There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage. The visible wavelengths cover a range from approximately 0.4 to 0.7 µm. The longest visible wavelength is red and the shortest is violet. Common wavelengths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

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



Blue, green, and red are the primary colours or wavelengths of the visible spectrum. They are defined as such because no single primary colour can be created from the other two, but all other colours can be formed by combining blue, green, and red in various proportions.

The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength range from approximately 0.7 µm to 100 µm- more than 100 times as wide as the 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. Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion. The reflected IR covers wavelengths from approximately 0.7 µm to 3.0 µm. The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat. The thermal IR covers wavelengths from approximately 3.0 µm to 100 µm.



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Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance 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 and absorption.

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, he abundance of particles or gases, and the distance the radiation travels through the atmosphere. There are three (3) types of scattering which take place.

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 wavelengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere. The fact that the sky appears "blue" during the day is because of this phenomenon. 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 complete; this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.

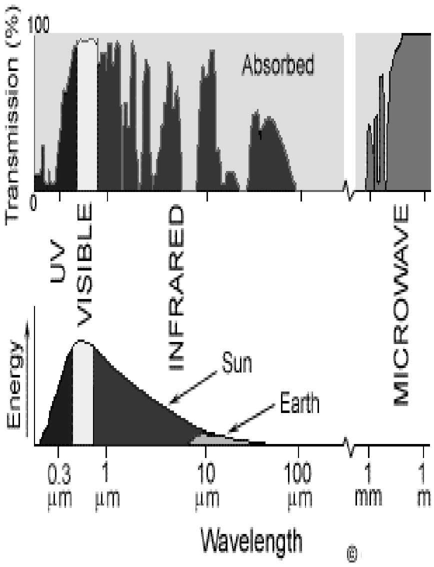
Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation. Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. Mie scattering occurs mostly in the lower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

The final scattering mechanism of importance is called nonselective scattering. This 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).

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 vapour are the three main atmospheric constituents which absorb radiation.

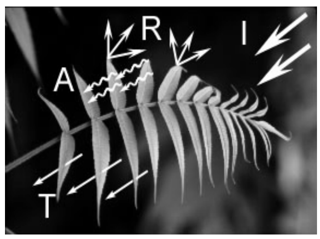
Ozone serves to absorb the harmful (to most living things) ultraviolet radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight.

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 longwave infrared and shortwave microwave radiation (between 22µmand 1m). 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).

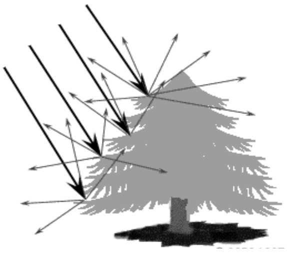


Because these gases absorb electromagnetic energy in very specific regions of the spectrum, they influence where (in the spectrum) we can "look" for remote sensing purposes. Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors are called atmospheric windows. By comparing the characteristics of the two most common energy/radiation sources (the sun and the earth) with the atmospheric windows available to us, we can define those wavelengths that we can use most effectively for remote sensing. 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. Note also that heat energy emitted by the Earth corresponds to a window around 10 µm in the thermal IR portion of the spectrum, while the large window at wavelengths beyond 1 mm is associated with the microwave region.

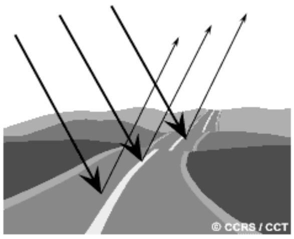
RADIATION - TARGET INTERACTIONS



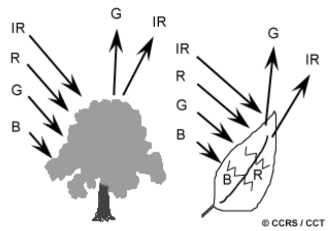
Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface. There are three (3) forms of interaction that can take place when energy strikes, or is **incident (I)** upon the surface. These are: **absorption (A)**; **transmission (T)**; and **reflection (R)**. The total incident energy will interact with the surface in one or more of these three ways. The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.



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 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**.

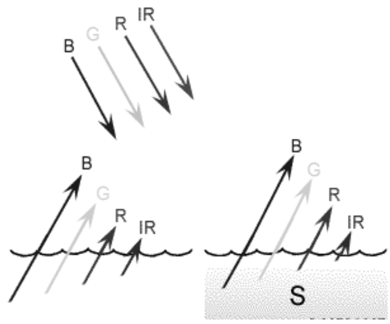


When a surface is smooth we get **specular** or mirror-like reflection where all (or almost all) of the energy is directed away from the surface in a single direction. **Diffuse** reflection occurs when the surface is rough and the energy is reflected almost uniformly in all directions. Most earth surface features lie somewhere between perfectly specular or perfectly diffuse reflectors. Whether a particular target reflects specularly or diffusely, or somewhere in between, depends on the surface roughness of the feature 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. Let's take a look at a couple of examples of targets at the Earth's surface and how energy at the visible and infrared wavelengths interacts with them.

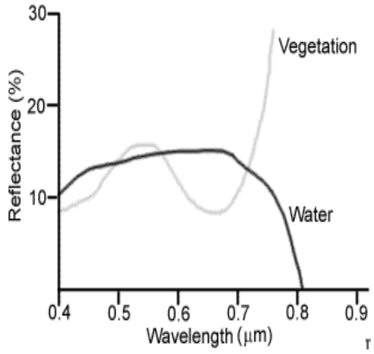


Leaves: A chemical compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths. Leaves appear "greenest" to us in the summer, when chlorophyll content is at its maximum. In autumn, there is less chlorophyll in the leaves, so there is 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.

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 is 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 topography of the water surface (rough, smooth, floating materials, etc.) can also lead to complications for water-related interpretation due to potential problems of specular reflection and other influences on colour and brightness.

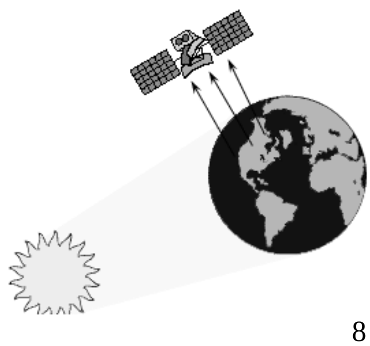


We can see from these examples that, depending on the complex make-up of the target that is being looked at, and the wavelengths of radiation involved, we can observe very different responses to the mechanisms of absorption, transmission, and reflection. By measuring the energy that is reflected (or emitted) by targets on the Earth's surface over a variety of different wavelengths, we can build up a **spectral response** for that object. By comparing the response patterns of different features we may be able to distinguish between them, where we might not be able to, if we only compared them at one wavelength. For example, water and vegetation may reflect somewhat similarly in the visible wavelengths but are almost always separable in the infrared. Spectral response can be quite variable, even for the same target type, and can also vary with time (e.g. "green-ness" of leaves) and location. Knowing where to "look" spectrally and understanding the factors which influence the spectral response of the features of interest are critical to correctly interpreting the interaction of electromagnetic radiation with the surface.

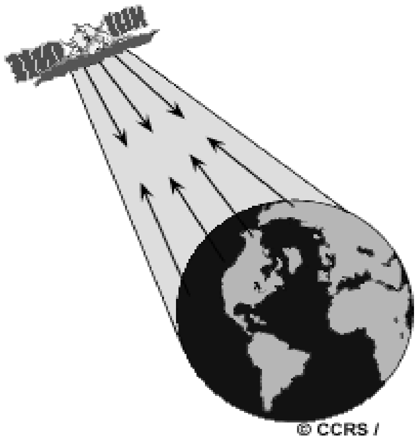


PASSIVE VS. ACTIVE SENSING

So far, throughout this chapter, we have made various references to the sun as a source of energy or radiation. The sun 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 **re-emitted**, as it is for thermal infrared wavelengths. Remote sensing systems which measure energy that is naturally available are called **passive sensors**. Passive sensors can only be used to detect energy when the naturally occurring energy is available. For all reflected energy, this can only take place during the time sun is illuminating the Earth. There is no reflected energy available from the sun Energy that is naturally emitted (such as thermal infrared) can be detected day or long as the amount of energy is large enough to be recorded.



Active sensors, on the other hand, provide their own energy source for illumination. 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. Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season. Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to better control the way a target is illuminated. However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets. Some examples of active sensors are a laser fluorosensor and a synthetic aperture radar (SAR).

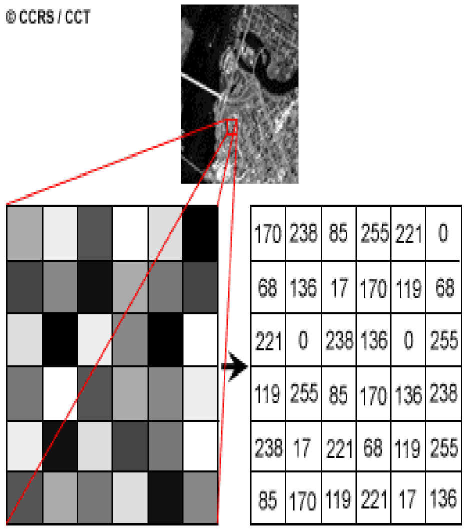
CHARACTERISTICS OF IMAGES

Before we go on to the next chapter, which looks in more detail at sensors and their characteristics, we need to define and understand a few fundamental terms and concepts associated with obtained by remote sensing technology.

Electromagnetic energy may be detected either photographically or electronically. The photographic process uses chemical reactions on the surface of light-sensitive film to detect and record energy variations. It is important to distinguish between the terms **images** and **photographs** in remote sensing. An image refers to any pictorial representation, regardless of what wavelengths or remote sensing device has been used to detect and record the electromagnetic energy.

A **photograph** refers specifically to images that have been detected as well as recorded on photographic film. The black and white photo to the left, of part of the city of

Ottawa, Canada was taken in the visible part of the spectrum. Photos are normally recorded over the wavelength range from 0.3 µmto 0.9 µm- the visible and reflected infrared. Based on these definitions, we can say that all photographs are images, but not all images are photographs. Therefore, unless we are talking specifically about an image recorded photographically, we use the term image.



A photograph could also be represented and displayed in a **digital** format by subdividing the image into small equal-sized and shaped areas, called picture elements or **pixels**, and representing the brightness of each area with a numeric value or **digital number**. Indeed, that is exactly what has been done to the photo to the left. In fact, using the definitions we have just discussed, this is actually a **digital image** of the original photograph! The photograph was scanned and subdivided into pixels with each pixel assigned a digital number representing its relative brightness. The computer displays each digital value as different brightness levels. Sensors that record electromagnetic energy, electronically record the energy as an array of numbers in digital format right from the start. These two different ways of representing and displaying remote sensing data, either pictorially or digitally, are interchangeable as they convey the same information (although some detail may be lost when converting back and forth).

In previous sections we described the visible portion of the spectrum and the concept of colours. We see colour because our eyes detect the entire visible range of wavelengths and our brains process the information into separate colours. Can you imagine what the world would look like if we could only see very narrow ranges of wavelengths or colours? That is how many sensors work. The information from a narrow wavelength range is gathered and stored in a **channel**, also sometimes referred to as a **band**. We can combine and display channels of information digitally using the three primary colours (blue, green, and red). The data from each channel is represented as one of the primary colours and, depending on the relative brightness (i.e. the digital value) of each pixel in each channel, the primary colours combine in different proportions to represent different colours.

When we use this method to display a single channel or range of wavelengths, we are actually displaying that channel through all three primary colours. Because the brightness level of each pixel is the same for each primary colour, they combine to form a **black and white image**, showing various shades of gray from black to white. When we display more than one channel each as a different primary colour, then the brightness levels may be different for each channel/primary colour combination and they will combine to form a **colour image**.

SATELLITES AND DATA PRODUCTS

ADVANTAGES OF SPACE BORNE REMOTE SENSING

Due to the advantages mentioned below, many countries started deploying remote sensing satellites for mapping and monitoring their natural resources. The characteristics of some important remote sensing satellites are mentioned below. In addition several other satellites like ERS, JERS, RADARSAT, Quickbird, Ikonos etc and meteorological satellites like NOAA, Meteosat etc. are widely used for mapping natural and man-made features on the surface of earth.

- Synoptic view: mega patterns within landscapes, seascapes, and icescapes are emphasized. Major biologic, tectonic, hydrologic, and geomorphic factors stand out distinctly.
- Repetitive coverage: Repeated images of the same regions, taken at regular intervals over periods of days, years, and decades, provide data bases for recognizing and measuring environmental changes.
- Multispectral data: Satellite sensors are designed to operate in many different portions of the electromagnetic spectrum utilizing atmospheric windows.
- Low-cost data

EARTH RESOURCE (LAND OBSERVATION) SATELLITES

LANDSAT

- Aims to provide global coverage high-resolution multi-spectral imagery for better information concerning earth resources, environmental change, and impacts of human activities.
- The first Landsat, originally called ERTS for Earth Resources Technology Satellite, were developed and launched by NASA on July 23, 1972. The program was renamed Landsat 1 in 1975
- In 1986 Landsat operations were turned over to EOSAT, a commercial company that sought to earn a profit from sales of Landsat images and data. Under EOSAT, the operation of Landsat was tailored for users that could afford expensive data. Academic and governmental users were largely excluded from the high-cost Landsat market.
- Landsat 6 was designed and built under EOSAT supervision. The satellite suffered a launch failure in 1993; it is presumably somewhere on the seafloor in the South Pacific Ocean.

- In 1992, the U.S. Congress passed and President Bush signed Land Remote Sensing Policy Act that returned future Landsat operations to the public realm, beginning with Landsat 7 in the late 1990s. The scientific mission of Landsat 7 is entirely consistent with this legislated goal.
- NASA built and launched the satellite Landsat 7 on April 15, 1999. NASA will continue to operate the satellite until Oct. 2000, at which time flight operations will be turned over to EDC. The EDC will archive all Landsat 7 data.
- Landsat 7 carries an Enhanced Thematic Mapper plus (ETM+), which provide continuity of Landsat TM data with enhanced spectral and spatial resolution.
- Currently operational satellites include Landsat 5, launched March 1985, and Landsat 7.
- Each of these sensors collected data over a swath width of 185 km, with a full scene being defined as 185 km x 185 km.

SENSORS ON LANDSATS

RBV CAMERA

- Use special television cameras, the Return Beam Vidicon (RBV) as the imaging instrument on Landsat 1.
- Three bands: 0.47-0.57 µm, 0.58-0.68 µm, 0.69-0.83µm.
- the RBV cameras were afflicted with an unexplained electrical problem and were quietly shut down a month after the launch of Landsat 1.

MSS (MULTI-SPECTRAL SCANNER)

- An across-track scanning system. The scanning mirror oscillates through an angular +/- 5.78 degrees off nadir;
- 11.56 degree Field Of View (FOV) results in swath width of about 185km;
- 6 parallel detectors sensitive to 4 spectral bands view ground simultaneously;
- When not viewing Earth, detectors were exposed to internal light and sun calibration sources;
- Spatial resolution - 68 m cross-track, 83 m along track;
- Typical scene contains about 2340 scan lines with about 3240 pixels per line;
- Routine collection of MSS data ceased in 1992, as the use of TM data, starting on Landsat 4, superseded the MSS.

TM (THEMATIC MAPPER)

- TM sensor is also across-track scanning system; The number of detectors per band was increased to 16 for the non-thermal channels compared with 6 for MSS. Sixteen scan lines are captured simultaneously for each non-thermal spectral band, and four for thermal band.

- TM scanning system uses an oscillating mirror which scans during both the forward (west-to-east) and reverse (east-to-west) sweeps of the scanning mirror. This increases the dwell time and improves the geometric and radiometric integrity of the data. TM sensor achieves higher image resolution, sharper spectral separation, improved geometric fidelity, and greater radiometric accuracy and resolution than the MSS sensor.
- Spatial resolution 30m for band1-5 and 120m for band 6 (thermal).
- All TM bands are quantized as a range of 256 digital numbers (8 bit data).
- Revisit period: every 16 days

Band Number	**Wave Length Range**	**Resolution**
Band 1	0.45to0.52	30
Band 2	0.52to0.60	30
Band 3	0.63 to 0.69	30
Band 4	0.76 to 0.90	30
Band 5	1.55 to 1.75	30
Band 6	10.40 to 12.50	120
Band 7	2.08 to 2.35	30

SPOT SATELLITES

- SPOT (Système Pour l'Observation de la Terre) is a series of Earth observation imaging satellites designed and launched by CNES (Centre National d'Etudes Spatiales) of France, with support from Sweden and Belgium.
- SPOT-1 was launched in 1986, with successors following every three or four years.
- All satellites are in sun-synchronous, near-polar orbits at altitudes around 832 km above the Earth, which results in orbit repetition every 26 days. They have equator crossing times around 10:30 AM local solar time.
- SPOT was designed to be a commercial provider of Earth observation data, and was the first satellite to use along-track (pushbroom) scanning technology.
- The viewing angle of the sensors can be adjusted to look to either side of the satellite's vertical (nadir) track, allowing off-nadir viewing which increases the satellite's revisit

capability. This ability to point the sensors up to 27° from nadir, allows SPOT to view within a 950 km swath and to revisit any location several times per week. As the sensors point away from nadir, the swath varies from 60 to 80 km in width. This oblique viewing capability increases the revisit frequency of equatorial regions to three days (seven times during the 26 day orbital cycle). Areas at the latitude of 45º can be imaged more frequently (11 times in 26 days) due to the convergence or orbit paths towards the poles.

- By pointing both HRV sensors to cover adjacent ground swaths at nadir, a swath of 117 km (3 km overlap between the two swaths) can be imaged. In this mode of operation, either panchromatic or multispectral data can be collected, but not both simultaneously.
- The off-nadir viewing also provides the capability of acquiring imagery for stereoscopic coverage.
- Its fine spatial resolution and pointable sensors are the primary reasons for its popularity.

SENSORS

PAN AND XS

- The SPOT satellites each have two identical (twin) high-resolution visible (HRV) imaging instruments, which can be operated independently and simultaneously.
- Each HRV is capable of sensing either in a high spatial resolution single-channel panchromatic (PLA) mode, or a coarser spatial resolution three-channel multispectral (MLA) mode.
- Along-track scanning system;
- Each along-track scanning HRV sensor consists of four linear arrays of detectors: one 6000 element array for the panchromatic mode recording at a spatial resolution of 10m and one 3000 element array for each of the three multispectral bands, recording at 20 m spatial resolution.
- The swath width for both modes is 60 km at nadir.
- The imagery has always been expensive, about $1000-2000 per panchromatic or
- multispectral scene, about $4000 for both PAN and XS imagery for a study area.

IRS SATELLITES

- The Indian Space Research Organization has launched several IRS satellites since 1988, including IRS-1A, 1B, 1C, 1D, P6 (Resourcesat) and Cartosat-1.
- The Indian Remote Sensing (IRS) satellite series, combines features from both the Landsat MSS/TM sensors and the SPOT HRV sensor.
- The third satellite in the series, IRS-1C, launched in December, 1995 has three sensors: a single-channel panchromatic (PAN) high-resolution camera, a medium resolution four channel Linear Imaging Self-scanning Sensor (LISS-III), and a coarse resolution two channel Wide Field Sensor (WiFS).
- IRS P6 launched in the year of 2003 and has a spatial resolution of 5.8 mts (Multispectral & PAN mode).
- AWiFS (Advanced Wide Field Sensor) has a spatial resolution of 56 mts having 4 spectral bands.
- Cartosat-1 spatial resolution of 2.5 mts, It has two cameras operating in the same orbit to produce stereo pairs.

IRS SENSORS

PAN

- The high-resolution panchromatic data are useful for urban planning and mapping space applications.

LISS-III

- The four LISS-III multispectral bands are similar to Landsat's TM bands 1 to 4, and are excellent for vegetation discrimination, land-cover mapping, and natural resource planning.

LISS-IV

- Three spectral bands are similar to LISS-3 bands of 2,3 & 4 and the spatial resolution is 5.8 mts which is very much useful for large scale mapping.

WiFS

- The WiFS sensor is useful for regional scale vegetation monitoring because of repetivity.

Sensor LISS - I			
Resolution	Swath	Repetitvity	Spectral Bands
72.5 m	148 km.	22 days	0.45 - 0.52 microns (B1)
			0.52 - 0.59 microns (B2)
			0.62 - 0.68 microns(B3)
			0.77 - 0.86 microns (B4)
Sensor LISS – II			
Resolution	Swath	Repetitvity	Spectral Bands
36.25 m	74 x 2 km.	22 days	0.45 - 0.52 microns (B1)
			0.52 - 0.59 microns (B2)
			0.62 - 0.68 microns(B3)
			0.77 - 0.86 microns (B4)
Sensor LISS – III			
Resolution	Swath	Repetitvity	Spectral Bands
23.5 m (visible and near IR region)	141 km (visible and near IR region)	24 days	B2 0.52 - 0.59
			B3 0.62 – 0.68
			B4 0.77 – 0.86
70.5 m (shortwave IR region)	148 km (shortwave IR region)		B5 1.55 – 1.70
Sensor LISS - IV			
Resolution	Swath	Repetitvity	Spectral Bands
5.8 m at nadir	23.9 km (multispectral mode)	5 days for stereo pairs	B2 0.52 - 0.59
			B3 0.62 - 0.68
			B4 0.77 - 0.86
Sensor AWiFS			
Resolution	Swath	Repetitvity	Spectral Bands
56 m (nadir) 70 m (at field edge)	370 km each head 740 km (combined)	5 days (80% of the area)	B2 0.52 - 0.59
			B3 0.62 - 0.68
			B4 0.77 - 0.86
			B5 1.55 - 1.70
Sensor WiFS			
Resolution	Swath	Repetitvity	Spectral Bands
188 m	770 km	3 days	0.62 - 0.68 microns (visible)
			0.77 - 0.86 microns (near infra-red)
Sensor PAN			
Resolution	Swath	Repetitvity	Spectral Bands
5 .8 m	70 km (3 x 23.33 km)	5 days +/- 26 degrees	0.50 - 0.75 microns

COMMERCIAL HIGH-RESOLUTION SATELLITES

- In 1994, the US decided to allow commercial companies to market high resolution remote sensing data

IKONOS

- Space Imaging, Inc.
- IKONOS 1 was launched on
-
- September 24,1999 after the failure on April 27, 1999.
- Spatial resolution: 1m for panchromatic (0.45-0.90 μm), 4 m for four multispectral bands:

  band 1: 0.45-0.52 μm;

  band 2: 0.52-0.60 μm;

  band 3: 0.63-0.69 μm;

  band 4: 0.76-0.90 μm
- Pushbroom scanning system
- Normal swath: 13 km at nadir
- Revisit period: 3 days
- Orbit altitude 681 km
- sun-synchronous orbit.
- Accurcy: 12m horizontal, 10m vertical with no ground control

DATA PRODUCTS

The Remotely sensed data is supplied in two basic forms namely

1. Analog form (False Colour Composite, Diapositives and Paper prints)
2. Digital form (Magnetic Media like CCT, Catridge, Floppy and CD)

FCC (FALSE COLOUR COMPOSITES)

False Colour Composites are most widely used remote sensing data products, which are printed on Glossy paper. The product is called as False Colour Composite (FCC) because the colours represented on the print are not the original colours. The reflected radiation in green, red and infrared regions of electromagnetic spectrum are represented by blue, green and red colours in a Standard FCC. The FCC of IRS 1A,B,1C and 1D multispectral images are normally supplied at a scale of 1:50,000 in correspondence to Toposheets and the IRS P6 images are available at 1:12,500 scale. Some of the data products are available at different scale.

DIAPOSITIVES AND PAPER PRINTS

Diapositives have film as the base material (PVC) and are used in photogrammetric plotters. Paper prints are used for carrying to the field and for visual interpretation (offline).

DIGITAL PRODUCTS

The satellites data products are widely supplied in digital format in various magenetic media like DAT, CCT, floppy, CD etc. This type of products are used when one chooses digital image processing for analysis of remote sensing data. The data will be supplied in different image formats like GIF, JPEG, BIL, BIP, BSQ etc. depending on the data supplier.

INTRODUCTION TO GEOGRAPHICAL INFORMATION SYSTEMS

INTRODUCTION

Database is a collection of inter related information on a specific subject, stored in a computer. A computer program used to organize the database is called database management system (DBMS) through which the data can be retrieved, updated and manipulated periodically. The systems that analyses and transforms the data into useful information are called as Information Systems.

DEFINITION

Geographic Information System (GIS) consists of powerful set of tools designed to capture, store, update, manipulate, analyze, organize and display the geographically referenced data. It is an abstract representation of the position of the real world features with its quantitative and qualitative information.

GIS is both, a database system with specific capabilities for spatially referenced data as well as a set of operations for working with the data. "**Every object present on the Earth can be geo-referenced**", is the fundamental key of associating any database to GIS. Geographic reference or spatial reference is referring an object on the earth with a defined coordinate system (latitudes and longitudes).

COMPONENTS OF GIS

Geographical information systems have four important components namely computer hardware, set of application software tools, data and skilled people.

Computer hardware: The computer hardware includes the components or devices to convert the conventional maps into digital form, to store the data, print/display the analyzed results.

Software tools: The software for a geographical information system essentially has the following functionalities

i) Data input and verification

ii) Data storage and database management

iii) Data output and presentation

iv) Data transformation

v) Interaction with user

Data: Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. The digital map forms the basic data input for GIS. Tabular data related to the map objects can also be attached to the digital data. A GIS will integrate spatial data with other data resources

Skilled people: Skilled human are essential for data and query input and writing programs for data analysis etc.

GEOGRAPHIC DATASETS

The geographic datasets consists of two types of data

i) Geographic location of the object (spatial data)
ii) Qualitative / quantitative information about the object (attribute data or non-spatial data)

SPATIAL DATA

Geographic position refers to the fact that each feature has a location that must be specified in a unique way. To specify the position in an absolute way a coordinate system is used. Internationally there are many different coordinate systems in use.

ATTRIBUTE DATA

The attributes refer to the properties of spatial entities. They are often referred to as non-spatial data since they do not in themselves represent location information. They are represented in tabular form as shown

District Name	Population	Literacy rate
Chennai	61,42,347	85%
Thiruvallur	15,84,784	73%
Kanchipuram	29,74,377	68%

REPRESENTATION OF SPATIAL OBJECTS

Geographic object can be represented as points, lines, areas, and continuous surfaces.

POINT DATA

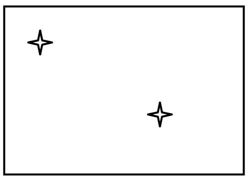
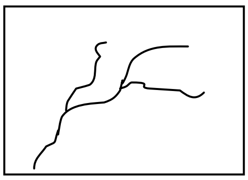
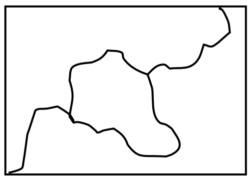
Points are the simplest type of spatial data. They are-zero dimensional objects with only a position in space but no length. Hospitals, railway stations, parks etc are represented using points.

LINE DATA

Lines (also termed segments or arcs) are one-dimensional spatial objects. Besides having a position in space, they also have a length. Linear features like roads, rivers etc are represented in the form of line.

AREA DATA

Areas (also termed polygons) are two-dimensional spatial objects with not only a position in space and a length but also a width (in other words they have an area). Features like lakes, forest, taluks etc are represented using polygons.

POINT **LINE** **POLYGON**

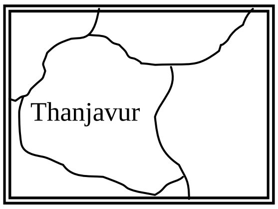
RASTER AND VECTOR DATA

DATA ANALYSIS

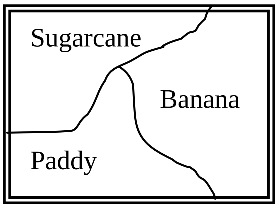
There are various types of analysis that can be carried out in GIS. Overlay analysis, neighborhood analysis, terrain analysis and network analysis are widely carried out for various applications

OVERLAY ANALYSIS

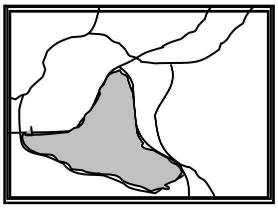
This analysis is performed over more than one layer of information. For example, when the user needs to know about the area under paddy cultivation in Thanjavur district, it requires two GIS layers namely the district map and as well as crop cover map. Now the analysis is performed to know the required information



District Map



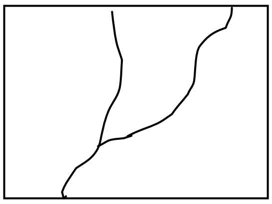
Crop Cover Map



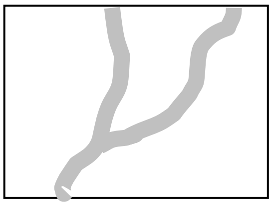
Output Map

NEIGHBORHOOD ANALYSIS

Neighbourhood analysis is used to find the proximity of a location of interest. Buffer analysis is also a type of neighbourhood analysis generally used. If a river is likely to be flooded, and the people living 1.5 km either side of the bank are to be evacuated immediately then a buffer of 1.5 km on the either side can be generated to identify the places of evacuation and to assess the damage.



Input Map



Output buffer Map

TERRAIN ANALYSIS

Terrain analysis is used to generate continuously varying surfaces like elevation models. Here the continuous surface is generated with the help of discrete point elevation data. The elevation models can be further used to create slope, aspect maps etc and also for view shed analysis.

NETWORK ANALYSIS

This analysis is extremely helpful in traffic management issues. Using this tool, optimal routing, congestion management, travel demand modeling etc can be done. For example, shortest route from the origin point to the destination point can be found out using this analysis.

COMPONENTS OF GIS

Geographic Information System (GIS) is a combination of hardware and software, which facilitates inputting, storage, processing, integrating, analyzing and presentation of both spatial and non-spatial data.

The GIS has three important components viz. Computer hardware, set of software modules and a proper organizational context apart from the data which is the most important part of GIS and its quality and quantity reflects on the result. The GIS is also capable of integrating a variety of data types from various sources. These three components should be in a balance, if the system is to function satisfactorily.

COMPUTER HARDWARE

The general hardware components of the geographic information system are a computer keyboard, a color monitor and the below mentioned peripherals.

Hardware Requirement (General)

a. **workstation based**

RAM -256 MB or higher
Processor – Silicon Graphics and its equivalent
HDD – 20 GB
Monitor – SVGA color monitor – 21”
Drives – Floppy, DAT, Cartridge, CD-ROM
Operating System – UNIX, INDY, WINDOWS NT, WINDOWS XP.

b. **PC based**

RAM – 128 MB or higher
Processor – INTEL PII and its equivalent
HDD -20 GB
Monitor – SVGA color monitor – 15”
Drives – Floppy, DAT, Cartridge, CD-ROM

Operating System – DOS and Windows 98, WINDOWS NT, WINDOWS 2000, WINDOWS XP

FUNCTION OF PERIPHERALS

Various functions of hardware peripherals are listed below

Disk drive – the CPU is linked to disk drive storage unit, which gives space for storing data and programs.
Digitizer – Used to convert data from maps and documents into digital form and send them to the computer.
Plotter – It is used to display the result of the data processing
Tape drive – It is used to communicate with other systems
The Visual – It is used to control the computer and peripherals. Otherwise known as terminals.

The software package for a GIS consists of four basic technical modules or in other words the four functions of GIS are:

The basic modules of a sub-system are

a. Data input and verification
b. Data storage, retrieval and management
c. Data manipulation, analysis and modeling
d. Data output and presentation

DATA INPUT AND VERIFICATION

This covers all aspects of transforming data captured in the form of existing maps, filed observations and sensors, into a compatible digital form.

BUILDING A GIS DATABASE

The database can be established through digitizing, scanning and onscreen digitizing, loading files from other sources, or entering data from a personnel computer. Maps and files created can be directly transferred to GIS.

Surveying helps to collect GIS data when topographic features, boundaries or area must be defined or measured. Satellite derived coordinates from a Global Positioning System can also be included in the database. Photgrammetry also offers the advantage of dependable verification of data collected and serves as a valuable tool for map revision. Of late scanned aerial photographs, digital aerial photographs and digital satellite data can contribute to building the GIS database.

The data provided will be either in vector form or in digital form. Scanned maps/digital cameras provide raster data, which again should be converted into vector data and stored.

DATA STORAGE AND DATA BASE MANAGEMENT

This concerns with the way in which the data about the position and attributes of geographic entities are structured and organized both with respect to how they must be handled in the computer and how they are received by the users.

MANIPULATION OF DATABASE

The DBMS helps us to organize information into a meaningful structure. Its capabilities provide for viewing, editing and querying and in the process keeps in tact the value of geo-relational database.

Viewing refers to the functions of browsing, panning, zooming and keeping multiple windows at a time. Viewing helps the users to obtain an idea of the geo-relational database while carrying out the data analysis. Employing the editing facilities of GIS, the user can modify the structure and contents of the database so as to update, regulate imported data, correct the errors found and optimize its structure. Manipulation of database in GIS refers to the process of integrating the database for further operations. This is required to improve the analysis and reporting, sorting and indexing, joining and extracting and reclassification are major functions of manipulation.

Querying is meant to generate useful information needed to support the process of planning and decision making. Basic spatial query, Structural Query Language (SQL) and other types of queries are available to the users. SQL is used to access RDBMS. The queries are necessary to establish the patterns, trends and simulations.

DATA ANALYSIS AND MODELING

This embraces two operations

1. Transformation is needed to remove errors from the data or to manipulate the inputs as per user needs as data files for analysis.
2. Analysis through suitable recording on the same data to suit the problem in question and resorting to various modeling techniques.

The key objective of a GIS is the analysis of complex relationships contained in the database. These relationships, representing the multitude of geographic, descriptive and statistical data, must be readily accessible for a variety of queries and analyses. By exploring the spatial dimension, spatial analysis introduces a framework that can largely enhance decision making process and problem solving. Generating buffers, searching nearest neighbor, establishing connectivity and contiguity and overlaying polygons are the operations involved in the analysis. Because of the analytical capabilities and tools GIS possess, the user can employ GIS for carrying out site suitability analysis, pollution effect analysis, minimum cost routing, municipal planning etc.

Data output and presentation

An important feature of any information system is report generation, which involves creation of special thematic map displays using graphic technique. The displays represent an extremely powerful tool for both summarization and operations within the spatial and non-spatial database. The report may be generated in any format subjected to the device used for display.

GIS systems

a) Workstation Based Systems

CGIS – Canadian Geographic Information Systems

One of the largest and most sophisticated systems in existence.

ERDAS – Earth Resources Data Analysis System

Software packages for overlay mapping and satellite image analysis running on DEC, Data General and other machines.

ESRI – Environmental System Research Institute

ARCGIS - Fully integrated system of mainly vector based overlay geographic information system including RDBMS capabilities. Grid based operations and digital terrain models using TIN are also supported.

IIS – International Imaging System

Highly sophisticates and very powerful hardware/software used for many GIS applications. Image analysis systems include own hardware linked to DEC PDP-11 and VAX-11 and other machines.

INTERGRAPH (Geo Media) – highly sophisticated turnkey interactive graphics

UNIRAS – Systems with specialist applications in mapping

The UNIRAS line includes nine packages for various GIS applications in full color from raster and vector mapping to krigging. These packages are supported on CDC, CRAY, DEC VAX and IBM machines.

b) PC based systems

ERDAS – Earth Resources Data Analysis System

The ERDAS system runs on IBM and COMPAQ microcomputers that are fitted with suitable extra processors and graphic devices.

ESRI – Environmental System Research Institute

Arc info – Fully integrated system of mainly vector –based overlay.

TYDAC – raster system using quadtree structures supported by IBM-AT.

IDRISI – A grid based Geographic Analysis System for 16-bit microcomputers

SPANS – Both vector and raster data analysis facilities with TIN modeling. For data storage, uses quadtree technique.

PAMAP – Vector as well as raster data analysis capabilities with modeling facilities.

VISUAL IMAGE INTERPRETATION TECHNIQUES

INTRODUCTION

Visual image interpretation is the act of examining (photographic) images for the purpose of identifying objects and judging their significance. Photo interpretation, photographic interpretation, and image interpretation are other widely used terms. This definition suggests that visual image interpretation would adopt the 'object view' or 'discrete perception' of the physical world.

Visual image interpretation consists of *detection*, *recognition* and *identification*, *classification* and *delineation* of objects in aerial or space imagery, where:

Detection	-	the mere discovery that something is there
Recognition & identification	-	Something is recognised and identified as a known object by its shape, size and other visible properties
Classification	-	The objects or features get their specific name or term according to some classification system
Delineation	-	A boundary is drawn around the selected object or features and an appropriate code is placed

BASIC CHARACTERISTICS USED IN VISUAL IMAGE INTERPRETATION

There are certain fundamental photo-elements or image characteristics seen on image which aid in visual interpretation of satellite imagery. Most applications consider the following basic characteristics, or variations of them: tone or colour, shape, size, pattern, texture, shadow, height, site and association.

TONE AND COLOUR

Photo *tone* and photo *colour* are determined by the proportions of energy reflected, absorbed and transmitted by features in the terrain vary at different wavelengths of the electromagnetic spectrum. Human beings can differentiate between approximately 40-50 individual shades of grey in black-and-white imagery. This number might even be too optimistic. The number of distinguishable shades increases greatly when colour photography is used.

SHAPE AND HEIGHT

Shape refers to the general form, configuration, or outline of individual objects. In exceptional cases, height can be the only differentiating property. Remotely sensed imagery often contains monoscopic cues (i.e. characteristics such as shadows which are observable in single images) that can be used to appreciate the height or depth of an object.

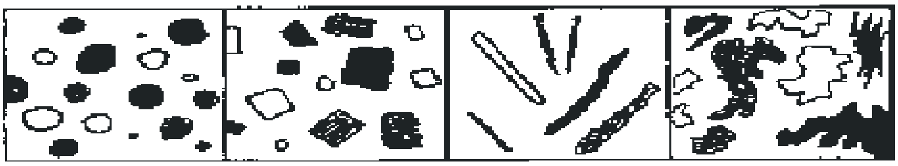


Figure 3. Example of shape nomenclature.

Many objects have very unique shapes that may significantly facilitate their positive identification in aerial or space imagery.

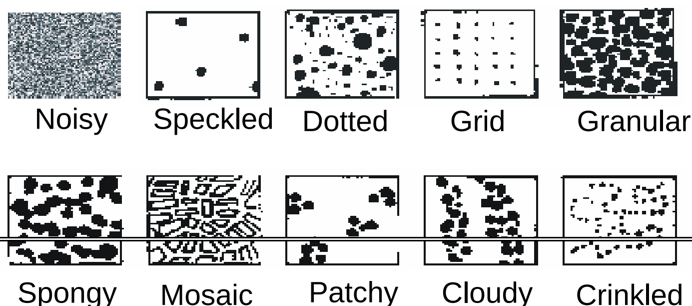
SIZE

The *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. 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 commercial property, whereas small buildings would indicate residential use.

PATTERN

Pattern relates to the spatial arrangement of features. The repetition of certain general forms or relationships is characteristic of many objects, both natural and constructed, and gives objects a pattern that aids the interpreter in recognising them.

Figure 1. Pattern elements with a linear shape.



For example, the ordered spatial arrangement of fruit trees in an orchard is clearly distinct from that of a natural forest stand.

TEXTURE

Texture is the frequency of tonal change on an image. Texture is produced by an aggregation of unit features that are too small to be discerned individually on the image, such as tree leaves and leaf shadows. It is a product of their individual shape, size, pattern, shadow, and tone. It determines the overall visual smoothness or coarseness of image features. As the scale of the image is reduced, the texture of any given area becomes progressively finer and ultimately disappears.

SHADOW

Shadows are important in two opposing respects: (1) the shape of a shadow affords an impression of the profile view of objects (which aids identification) and (2) objects within shadows reflect little light and are difficult to discern on an image (which hinders recognition). Most aerial photography is taken within ± 2 hours of solar noon to avoid extensive shadows in the imagery. When interpreting imagery of hilly land with substantial shadows, it is a good practice to orient the imagery so that the shadows fall toward the image interpreter. This keeps the analyst from experiencing pseudoscopic illusion, where low points in the terrain appear high and vice versa.

SITE, SITUATION AND ASSOCIATION

Site refers to topographic or geographic location. A site has physical or socio-economic characteristics that may be helpful for proper object identification.

Situation refers to how certain objects in the scene are organised and oriented relative to one another. For example, the spatial organisation of raw materials, buildings, pipelines and finished products is indicative of the type of economic activity in industrial zones.

Association refers to the fact that when you find a certain phenomenon or activity, you almost invariably encounter related features or activities. Site, situation and association are rarely used independently when analysing an image. Rather, they are used in combination to arrive at a logical conclusion.

IMAGE INTERPRETATION STRATEGIES

An image interpretation strategy can be defined as a disciplined procedure that enables the interpreter to relate geographic patterns on the ground to their appearance on the image.

FIELD OBSERVATION

Field observations, as an approach to image interpretation, are required when the image and its relationship to ground conditions are so imperfectly understood that the interpreter is forced to go to the field to make identification. In effect the analyst is unable to interpret the image from knowledge and experience at hand and must gather field observations to ascertain the relationship between the landscape and its appearance on the image. Field observations are, of course, a routine dimension of any interpretation as a check on accuracy or a means of familiarization with a specific region. Here their use as an interpretation strategy refers to the fact that when they are required for the interpretation, their use reflects a rudimentary understanding of the manner in which a landscape is depicted on a specific image.

DIRECT RECOGNITION

Direct recognition is the application of an interpreter's experience, skill, and judgment to associate the image patterns with informational classes. The process is essentially a qualitative, subjective analysis of the image using the elements of image interpretation as visual and logical clues.

INTERPRETATION BY INFERENCE

Interpretation by inference is the use of a visible distribution to map one that is not itself visible on the image. The visible distribution acts as a surrogate, or proxy for the mapped distribution. An example: Soils are defined by vertical profiles that cannot be directly observed by remotely sensed imagery. But soil distributions are sometimes very closely related to patterns of landforms and vegetation that are recorded on the image. Application of this strategy requires a complete knowledge of the link between the proxy and the mapped distribution; attempts to apply imperfectly defined proxies produce inaccurate interpretations.

PROBABILISTIC INTERPRETATIONS

Probabilistic interpretations are efforts to narrow the range of possible interpretations by formally integrating nonimage information into the classification process, often by means of quantitative classification algorithms. For example, knowledge of the crop calendar can restrict the likely choices for identifying crops of a specific region. If it is known that winter paddy is harvested in January, the choice of crops for interpretation of a March image can be restricted to eliminate paddy as a likely choice and thereby avoid a potential classification error. Often such knowledge can be expressed as a statement of probability. Possibly certain classes might favor specific topographic sites but occur over a range of sites, so a decision rule might express this knowledge as a 0.90 probability of finding the class on a well-drained site, but only a 0.05 probability of finding it on a poorly drained site. Several such statements systematically incorporated into the decision-making process can improve classification accuracy.

DETERMINISTIC INTERPRETATION

A fifth strategy, deterministic interpretation, is the most rigorous and precise approach. Deterministic interpretations are based upon quantitatively expressed relationships that tie image characteristics to ground conditions. In contrast with the other methods, most information is derived from the image itself. Photogrammetric analysis of stereo pairs for terrain information is a good example. A scene is imaged from two separate positions along a flight path, and the photogrammetrist measures the apparent displacement. Based upon knowledge of the geometry of the photographic system, a topographic model of the landscape can be reconstructed. The result is therefore the derivation of precise information about the landscape using only the image itself and knowledge of its geometric relationship with the landscape. Relative to the other methods, very little non-image information is required.

INTERPRETATION TECHNIQUES

Certain image interpretation techniques, when properly applied, can improve the quality and quantity of useful information extracted from imagery. Among the techniques being refined are methods for using (1) methodical procedures, (2) efficient search techniques, (3) knowledge of factors governing image formation, (4) the background and training of the interpreter, (5) the concept of “convergence of evidence”, (6) the “conference system”, (7) information available in analogous areas, (8) reference materials, (9) simple and sophisticated equipment, and (10) acquiring field data.

IMAGE INTERPRETATION KEYS

Image interpretation keys are valuable aids for summarizing complex information portrayed as images and have been widely used for image interpretation. Such keys serve either or both of two purposes: (1) a means of training inexperienced personnel in the interpretation of complex or unfamiliar topics, and (2) a reference aid for experienced interpreters to organize information and examples pertaining to specific topics.

An image interpretation key is simply reference material designed to permit rapid and accurate Identification of objects or features represented on aerial images. A key usually consists of two parts, a collection of annotated or captioned images or stereograms and a graphic or word description, possibly including sketches or diagrams. These materials interpreter may know that certain soil conditions can be expected where steep slopes and dense forest are found together; and others are expected where the dense forest coincides with gentle slopes.

VISUAL IMAGE INTERPRETATION EQUIPMENT

Manual interpretation can usually be conducted with relatively simple, inexpensive equipment, although some of the optional items can be expensive. A few visual interpretation equipments and their usefulness are given below:

1. Light Table - *to interpret the FCC paper print images*
2. Procom - *to interpret FCC transparencies*
3. Stereoscope – *stereoscopic viewing of aerial photographs for detailed mapping*
4. Image magnifier – *to identify the of small features in the imge/AP*
5. Height finder – *to estimate the topographic elevation from the stereo aerial photographs*
6. Zoom Transfer Scope – *visual matching of images at different scales*

PREPARATION FOR INTERPRETATION

In general the interpreter should be able to work at a large, well-lighted desk or work table with convenient access to electrical power. Often it is useful to be able to control lighting with blackout shades or dimmer switches. Basic equipment and materials, in addition to the items described above, include a supply of translucent drafting film, an engineer's scale, together with protractors, triangles, dividers, and other drafting tools. Maps, reference books, and other supporting material should be available as required.

If the interpretation is made from paper prints, special care must be taken to prevent folding, tracing or rough use that will cause the prints to become worn.

If transparencies are used, special care must be taken in handling and storage. The surface of the transparency must be protected by a transparent plastic sleeve or it must be handled only with clean cotton gloves.

DIGITAL IMAGE PROCESSING

INTRODUCTION

A digital image is an array of numbers depicting spatial distribution of a certain field parameters (such as reflectivity of EM radiation, emissivity, temperature or some geophysical or topographical elevation. Digital image consists of discrete picture elements called pixels. Associated with each pixel is a number represented as DN (Digital Number) that depicts the average radiance of relatively small area within a scene. The range of DN values being normally 0 to 255. The size of this area effects the reproduction of details within the scene. As the pixel size is reduced more scene detail is preserved in digital representation. Remote sensing images are recorded in digital forms and then processed by the computers to produce images for interpretation purposes. Images are available in two forms - photographic film form and digital form. Variations in the scene characteristics are represented as variations in brightness on photographic films. A particular part of scene reflecting more energy will appear bright while a different part of the same scene that reflecting less energy will appear black.

DATA FORMATS FOR DIGITAL SATELLITE IMAGERY

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

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

Digital image analysis is usually conducted using Raster data structures - each image is treated as an array of values. It offers advantages for manipulation of pixel values by image processing system, as it is easy to find and locate pixels and their values. Disadvantages becomes apparent when one needs to represent the array of pixels as discrete patches or regions, where as Vector data structures uses polygonal patches and their boundaries as fundamental units for analysis and manipulation. Though vector format is not appropriate to for digital analysis of remotely sensed data.

IMAGE RESOLUTION

Resolution can be defined as "the ability of an imaging system to record fine details in a distinguishable manner". A working knowledge of resolution is essential for understanding both practical and conceptual details of remote sensing. Along with the actual positioning of spectral bands, they are of paramount importance in determining the suitability of remotely sensed data for a given applications. The major characteristics of imaging remote sensing instrument operating in the visible and infrared spectral region are described in terms as follow:

- Spectral resolution
- Radiometric resolution
- Spatial resolution
- Temporal resolution

Spectral Resolution refers to the width of the spectral bands. As different material on the earth surface exhibit different spectral reflectances and emissivities. These spectral characteristics define the spectral position and spectral sensitivity in order to distinguish materials.

Radiometric Resolution or radiometric sensitivity refers to the number of digital levels used to express the data collected by the sensor. It is commonly expressed as the number of bits (binary digits) needs to store the maximum level. For example Landsat TM data are quantised to 256 levels (equivalent to 8 bits). Here also there is a tradeoff between radiometric resolution and signal to noise. There is no point in having a step size less than the noise level in the data.

Spatial Resolution of an imaging system is defines through various criteria, the geometric properties of the imaging system, the ability to distinguish between point targets, the ability to measure the periodicity of repetitive targets ability to measure the spectral properties of small targets.

Temporal resolution refers to the frequency with which images of a given geographic location can be acquired. Satellites not only offer the best chances of frequent data coverage but also of regular coverage. The temporal resolution is determined by orbital characteristics and swath width, the width of the imaged area. Swath width is given by 2htan (FOV/2) where h is the altitude of the sensor, and FOV is the angular field of view of the sensor.

How to Improve Your Image?

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

- Analog image processing
- Digital image processing.

Digital Image Processing is a collection of techniques for the manipulation of digital images by computers. The raw data received from the imaging sensors on the satellite platforms contains flaws and deficiencies. To overcome these flaws and deficiencies inorder to get the originality of the data, it needs to undergo several steps of processing. This will vary from image to image depending on the type of image format, initial condition of the image and the information of interest and the composition of the image scene. Digital Image Processing undergoes three general steps:

- Pre-processing
- Display and enhancement
- Information extraction

IMAGE ENHANCEMENT TECHNIQUES

Image Enhancement techniques are instigated for making satellite imageries more informative and helping to achieve the goal of image interpretation. The term enhancement is used to mean the alteration of the appearance of an image in such a way that the information contained in that image is more readily interpreted visually in terms of a particular need. The image enhancement techniques are applied either to single-band images or separately to the individual bands of a multiband image set. These techniques can be categorized into two:

- Spectral Enhancement Techniques
- Multi-Spectral Enhancement Techniques

SPECTRAL ENHANCEMENT TECHNIQUES

Following is the some of image processing techniques which is used to rectify the images in a better manner.

- **Density Slicing**
- **Contrast Stretching**
- **Linear Contrast Stretch**
- **Histogram Equalisation**
- **Gaussian Stretch**
- **Multi-Spectral Enhancement Techniques**

IMAGE ARITHMETIC OPERATIONS

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

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

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

Band Ratioing or Division of images is probably the most common arithmetic operation that is most widely applied to images in geological, ecological and agricultural applications of remote sensing. Ratio Images are enhancements resulting from the division of DN values of one spectral band by corresponding DN of another band.

PRINCIPAL COMPONENT ANALYSIS (PCA)

Principal Components Analysis (PCA) is related to another statistical technique called factor analysis and can be used to transform a set of image bands such that the new bands (called principal components) are uncorrelated with one another and are ordered in terms of the amount of image variation they explain. The components are thus a statistical abstraction of the variability inherent in the original band set.

CONVOLUTION FILTERS

Low-Pass (Smoothing) Filters

Low-pass filters reveal underlying two-dimensional waveform with a long wavelength or low frequency image contrast at the expense of higher spatial frequencies. Low-frequency information allows the identification of the background pattern, and produces an output image in which the detail has been smoothed or removed from the original. A 2-dimensional moving-average filter is defined in terms of its dimensions which must

High-Pass (Sharpening) Filters

Simply subtracting the low-frequency image resulting from a low pass filter from the original image can enhance high spatial frequencies. High -frequency information allows us either to isolate or to amplify the local detail. If the high-frequency detail is amplified by adding back to the image some multiple of the high frequency component extracted by the filter, then the result is a sharper, de-blurred image. High-pass convolution filters can be designed by representing a PSF with positive centre weight and negative surrounding weights. A typical 3x3 Laplacian filter has a kernal with a high central value, 0 at each corner, and -1 at the centre of each edge. Such filters can be biased in certain directions for enhancement of edges.

FREQUENCY DOMAIN FILTERS

The Fourier transform of an image, as expressed by the amplitude spectrum is a breakdown of the image into its frequency or scale components. Filtering of these components use frequency domain filters that operate on the amplitude spectrum of an image and remove, attenuate or amplify the amplitudes in specified wavebands. The frequency domain can be represented as a 2-dimensional scatter plot known as a fourier spectrum, in which lower frequencies fall at the centre and progressively higher frequencies are plotted outward.

IMAGE CLASSIFICATION

Image Classification has formed an important part of the fields of Remote Sensing, Image Analysis and Pattern Recognition. In some instances, the classification itself may form the object of the analysis. Digital Image Classification is the process of sorting all the pixels in an image into a finite number of individual classes. The classification process is based on following assumptions:

- *Patterns* of their DN, usually in multichannel data (Spectral Classification).
- *Spatial relationship* with neighbouring pixels
- Relationships between the data accquired on different dates.

Pattern Recognition, Spectral Classification, Textural Analysis and Change Detection are different forms of classification that are focused on 3 main objectives:

1. Detection of different kinds of features in an image.
2. Discrimination of distinctive shapes and spatial patterns
3. Identification of temporal changes in image

Fundamentally spectral classification forms the bases to map objectively the areas of the image that have similar spectral reflectance/emissivity characteristics. Depending on the type of information required, spectral classes may be associated with identified features in the image (supervised classification) or may be chosen statistically (unsupervised classification). Classification has also seen as a means to compressing image data by reducing the large range of DN in several spectral bands to a few classes in a single image. Classification reduces this large spectral space into relatively few regions and obviously results in loss of numerical information from the original image. There is no theoretical limit to the dimensionality used for the classification, though obviously the more bands involved, the more computationally intensive the process becomes. It is often wise to remove redundant bands before classification.

Classification generally comprises four steps:

- ***Pre-processing***, e.g., atmospheric, correction, noise suppression, band ratioing, Principal Component Analysis, etc.
- ***Training*** - selection of the particular features which best describe the pattern
- ***Decision*** - choice of suitable method for comparing the image patterns with the target patterns.
- ***Assessing the accuracy*** of the classification

The informational data are classified into systems:

1.Supervised and **2.Unsupervised**

SUPERVISED CLASSIFICATION

In this system each pixel is supervised for the categorization of the data by specifying to the computer algorithm, numerical descriptors of various class types. There are three basic steps involved in typical supervised classification.

TRAINING STAGE

The analyst identifies the training area and develops a numerical description of the spectral attributes of the class or land cover type. During the training stage the location, size, shape and orientation of each pixel type for each class.

CLASSIFICATION STAGE

Each pixel is categorised into landcover class to which it closely resembles. If the pixel is not similar to the training data, then it is labeled as unknown. Numerical mathematical approaches to the spectral pattern recognition have been classified into various categories.

1. **Measurements on Scatter Diagram**
2. **Minimum Distance to Mean Classifier/Centroid Classifier**
3. **Parallelepiped Classifier**
4. **Gaussian Maximum Likelihood Classifier**

This method determines the variance and covariance of each theme providing the probability function. This is then used to classify an unknown pixel by calculating for each class, the probability that it lies in that class. The pixel is then assigned to the most likely class or if its probability value fail to reach any close defined threshold in any of the class, be labeled as unclassified. Reducing data dimensionally before hand is a\one approach to speeding the process up.

UNSUPERVISED CLASSIFICATION

This system of classification does not utilize training data as the basis of classification. This classifier involves algorithms that examine the unknown pixels in the image and aggregate them into a number of classes based on the natural groupings or cluster present in the image. The classes that result from this type of classification are spectral classes. Unsupervised classification is the identification, labeling and mapping of these natural classes. This method is usually used when there is less information about the data before classification.

There are several mathematical strategies to represent the clusters of data in spectral space.

1. **Sequential Clustering**

In this method the pixels are analysed one at a time pixel by pixel and line by line. The spectral distance between each analysed pixel and previously defined cluster means are calculated. If the distance is greater than some threshold value, the pixel begins a new cluster otherwise it contributes to the nearest existing clusters in which case cluster mean is recalculated.

2. **Statistical Clustering**

It overlooks the spatial relationship between adjacent pixels. The algorithm uses 3x3 windows in which all pixels have similar vector in space. The process has two steps

1. Testing for homogeneity within the window of pixels under consideration.
2. Cluster merging and deletion

2. **Iso Data Clustering (Iterative Self Organising Data Analysis Techniques)**

Its repeatedly performs an entire classification and recalculates the statistics. The procedure begins with a set of arbitrarily defined cluster means, usually located evenly through the spectral space.

4. **RGB Clustering**

It is quick method for 3 band, 8 bit data. The algorithm plots all pixels in spectral space and then divides this space into 32 x 32 x 32 clusters. A cluster is required to have minimum number of pixels to become a class. RGB Clustering is not biased to any part of the data.

GIS APPLICATIONS

INTRODUCTION

The applications of GIS range from simple database query systems to complex analysis and decision support systems. Areas of application can range from natural resources management to crime control and real-time applications like flood warning and war front operations. Central, State and Local governments could use GIS for rezoning, utilities planning and funding allocation.

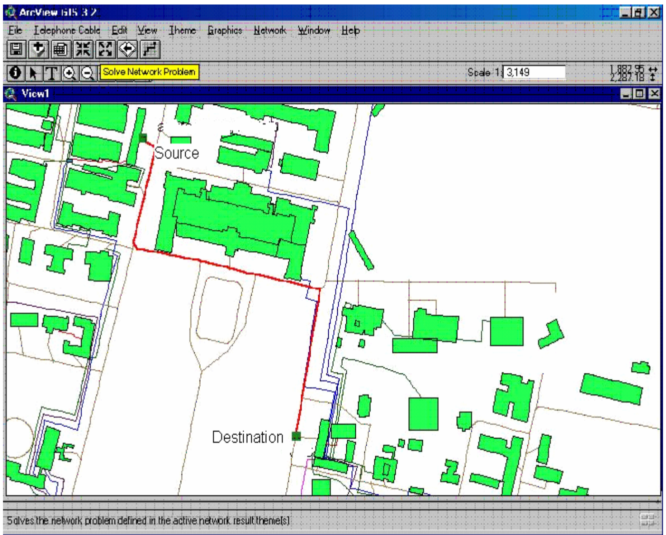
NEED OF GIS

- GIS provide the data spatially
- Lots of data are coming from different sources / Layers. These are to be considered for making better decisions.
- Answer the questions of location such as where, why, and how.
- Solve problems and make decisions.
- See patterns and trends that spreadsheets alone won't portray.

APPLICATIONS

Shortest Path Identification

In the given map, the shortest path is identified from source to destination



GIS IN POLICE DEPARTMENT – CASE STUDY

1. In case of robbery, there is a call from a house to police station.
2. Using the Phone number the house is traced and located in the GIS environment.
3. The roads around that house are blocked.
4. The information about the house is collected from GIS.
5. Locating Patrolling Vehicle Using GPS.
6. Shortest Route to destination for the arrival of patrolling is located.

GIS IN POLICE DEPARTMENT

MAJOR APPLICATIONS OF GIS ARE AS FOLLOWS:

- LandUse Suitability for urban development planning
- Transportation Route Planning
- City map updating and tourist guide maps
- Telecommunication network planning using Topographic and Landuse analysis
- Route and Corridor planning for rail, road and highways
- Location of tourism development sites like beach resorts
- Election Booth Locations
- Forecasting analysis of socio economic changes
- Demand forecast and market monitoring
- Analysis of accident prone areas
- Waste disposal site location
- Landslide hazard zoning
- Floods Zone mapping
- Periodic monitoring of Natural resources
- Environmental impact assessment of mining, Thermal power plants and river valley projects.
- Estimation of Acreage, Yield and production for major and minor crops.
- Agricultural management – Crop Water requirement for command area.
- Biomass and tree volume modeling in plantation crops.
- Wildlife habitat analysis
- Identification of groundwater recharge areas.
- Snow and Glacier melt runoff estimation and modeling

SOME OF THE INDUSTRIES USING GIS APPLICATIONS ARE:

• **Electric/Gas Utilities** • **Business/Marketing** • **Telecommunications** • **Transportation Logistics** • **Petroleum & Mining** • **Pipeline** • **Water & Wastewater** • **Health Care** • **National Agencies** • **Environmental Mgmt.** • **Local Government**	• **Public Sector** • **Retail** • **Military/Intelligence** • **Mapping** • **Land Use Planning** • **Real Estate & Cadastral** • **Site Location** • **Agriculture** • **Forestry** • **Land Use Planning** • **Risk Management**