FUNDAMENTALS OFGEOINFORMATICS

CODE – 18KP2GO6

UNIT I: Introduction to Geoinformatics **-**Remote sensing, GIS and GNSS –Remote sensing: Historical development – Development of Remote Sensing in India – Electromagnetic Radiation – Interaction of EMR with earth surface and atmosphere – Ideal Remote Sensing - Platforms – Sensors.

GEOINFORMATICS

Introduction

The art, science and technology dealing with the acquisition, storage, processing, production, presentation and dissemination of geoinformation is called geoinformatics. According to Burrough (1987) it is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying of spatial data form the real world.

Geoinformatics is made up of Geographical Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS). It is the advancing science and technology, which can be used for research and development in any discipline. For a geographer, it is a powerful tool to generate and geocoded data and attribute database to help taking decisions appropriately for planning.

Geographical Information System (GIS) is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information i.e. data identified according to location. Parker (1988) defined GIS as "an information technology which stores, analyses, and display both spatial and non-spatial data.

Remote Sensing (RS) means acquiring information about a phenomena or object or surface while at distance from it (without being physical contact with it) Principles of Remote Sensing Different objects return different amount and kind of energy in different bands of the electromagnetic spectrum incident upon it. This property of the object depends on structural, physical and chemical composition, surface roughness, angle of incidence, intensity and wavelength of radiant energy, hence we can identify various objects by collecting and analyzing returned energy.

Stages in RS

- Emission of energy or EMR (Sun)
- Transmission of energy from the source to the surface of the earth as well as adsorption and scattering of energy in the atmosphere.
- Interaction of EMR with the earth surface Reflection.
- Transmission of the energy from the surface to the remote sensor.
- Sensor data output.
- Data transmission, processing and analysis

Platforms and Sensors Platform is a stage to mount the camera or sensor to acquire the information about a target. Based on their altitude above the earth surface they are Ground borne. Air borne and Space borne. Sensor is a device that gathers energy, converts it into a signal and presents it in a suitable form for obtaining information about the target under investigation. Two types of sensors : 1. Active and 2. Passive.

Resolution is defined as the ability of the system to render the information at the smallest discretely separable quantity in terms of distance (spatial), wavelength band of EMR (spectral), time (temporal) and radiation quantity (radiometric).

Image Interpretation An interpreter can derive lot of information by studying the quantitative and qualitative aspects of images and photographs. An image taken from air or space is a pictorial presentation of the pattern of a landscape. Two types of image interpretation. Visual Image Interpretation: Elements are Shape, Size, Tone, Shadow, Pattern, Texture, Location, Resolution, and Stereoscopic Appearance.

Digital Image Processing (DIP): can be categorized into the following types of computer—assisted operations:

(a) Image Rectification: aim at correcting distorted data

(b) Image Enhancement: increase the amount of information that can be visually interpreted form the data. E.g. Contrast, Edge, Band Ratioing.

(c) Image Classification: automatically categories all pixels in an image into land cover classes or themes. Two Types: (i) Unsupervised and (ii) Supervised classification: Ground truth sites should be large enough, well-distributed and readily identifiable on the toposheets and the image.

Objectives of GIS

- Optimization of efficiency of planning and decision making.
- Capacity to integrate information from various sources.
- Provide efficient means for data distribution and handing.
- Elimination of redundant data base.
- Complex analysis / query involving geographical referenced data to generate new information.

Elements of GIS

- Hardware: It is the physical unit (electronic machine) that ultimately performs the job. Monitor, printer, plotter, scanner digitizer etc.
- Software: A set of programs written to perform a specific job with the help of hardware.

Operating system: windows 2000, 2007, Windows XP, Windows Vista, Unix etc. GIS Software: Arcinfo, ArcGIS, Arcview, Erdas, GRAM, GRAM++, Idrisi, ILWIS, Autocadmap etc.

- Data: Two types of data a) Spatial data and b) Non-spatial (attribute) data.

• Liveware: Users or people.

• Data Model: A set of logical definitions for characterizing the geographical data in order to present spatial information and their attributes, the two approaches for data model are: 1. Raster representation and 2. Vector representation Followings are few raster file formats commonly used in geoinformatics .

•ADRG - National Geospatial-Intelligence Agency (NGA)'s ARC Digitized Raster Graphics

•BIL - Band Interleaved by Line (image format linked with satellite derived imagery)

•CADRG - National Geospatial-Intelligence Agency (NGA)'s Compressed ARC Digitised Raster Graphics (nominal compression of 55:1 over ADRG)

•ECRG - National Geospatial-Intelligence Agency (NGA)'s Enhanced Compressed ARC Raster Graphics (Better resolution than CADRG and no color loss)

•CIB - National Geospatial-Intelligence Agency (NGA)'s Controlled Image Base (type of Raster Product Format)

•Digital raster graphic (DRG) - digital scan of a paper USGS topographic map

•ECW - Enhanced Compressed Wavelet (from ERMapper). A compressed wavelet format, often lossy. •ESRI grid - proprietary binary and metadataless ASCII raster formats used by ESRI

•GeoTIFF - TIFF variant enriched with GIS relevant metadata

•IMG - ERDAS IMAGINE image file format

•JPEG2000 - Open-source raster format. A compressed format, allows both lossy and lossless compression.

•MrSID - Multi-Resolution Seamless Image Database (by Lizardtech). A compressed wavelet format, often lossy.

•netCDF-CF - netCDF file format with CF medata conventions for earth science data. Binary storage in open format with optional compression. Allows for direct web-access of subsets/aggregations of maps through OPeNDAP protocol. And Followings are few raster file formats commonly used in geoinformatics.

•Geography Markup Language (GML) - XML based open standard (by OpenGIS) for GIS data exchange •AutoCAD DXF - Contour elevation plots in AutoCAD DXF format

•Shapefile (SHP)- ESRI's open, hybrid vector data format using SHP, SHX and DBF files

•Simple Features - Open Geospatial Consortium specification for vector data •MapInfo TAB format - MapInfo's vector data format using TAB, DAT, ID and MAP files

•National Transfer Format (NTF) - National Transfer Format (mostly used by the UK Ordnance Survey)

•TIGER - Topologically Integrated Geographic Encoding and Referencing

•Cartesian coordinate system (XYZ) - Simple point cloud

•Vector Product Format - National Geospatial-Intelligence Agency (NGA)'s format of vectored data for large geographic databases.

•GeoMedia - Intergraph's Microsoft Access based format for spatial vector storage.

•ISFC - Intergraph's MicroStation based CAD solution attaching vector elements to a relational Microsoft Access database

•Personal Geodatabase - ESRI's closed, integrated vector data storage strategy using Microsoft's Access MDB format

•File Geodatabase - ESRI's file-based geodatabase format, stored as folders in a file system. ESRI also has an enterprise Geodatabase format for use in an RDBMS.

•Coverage - ESRI's closed, hybrid vector data storage strategy. Legacy ArcGIS Workstation / ArcInfo format with reduced support in ArcGIS Desktop lineup

•Spatial Data File - Autodesk's highperformance geodatabase format, native to MapGuide

•GeoJSON - a lightweight format based on JSON, used by many open source GIS packages

•SOSI Standard - a spatial data format used for all public exchange of spatial data in Norway Grid formats (for elevation) •USGS DEM - The USGS' Digital Elevation Model

•DTED - National Geospatial-Intelligence Agency (NGA)'s Digital Terrain Elevation Data

•GTOPO30 - Large complete Earth elevation model at 30 arc seconds

•SDTS - The USGS' successor to DEM Other formats

•Binary Terrain - The Virtual Terrain Project's Binary Terrain format

•Dual Independent Map Encoding (DIME) – A historic GIS file format, developed in the 1960s

•Well-known text (WKT) – ASCII spatial projection description (ESRI uses a *.prj extension)

•Well-known binary (WKB) - Binary spatial projection description

•World file - Georeferencing a raster image file (e.g. JPEG, BMP)

Need of GIS

Collector, SP, Administrators, Academicians- University, MLA & MP, Environmentalist, Agriculturist, Disaster management cell e.g. For agricultural management GIS has to be considered multidimensional with attribute dimension, spatial dimension &temporal dimension GIS offers capabilities of integrating multisector, multilevel and multiperiod database.

GIS satisfy the following specific needs

1) The ability to preprocess data from large stores into a form suitable for analysis, including operation such as reformatting, change of projection, resampling and generalizations.

2) Direct support for analysis and modeling, so that from of analysis, calibration of models, forecasting, and prediction are all handled through instruction to the GIS.

3) Post processing of result including such operations as reformatting, tabulation, report generation, and mapping. An information system is the chain of operations- planning, observation and collection of data- storage and analysis of data- Decision making process.

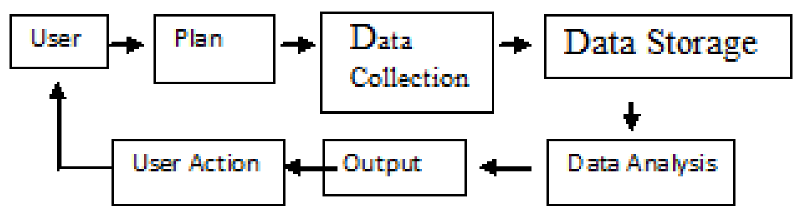


Fig. 1- Decision making process

Four key activities can be enhanced by using GIS

• Measurement

• Monitoring

• Mapping

• Modeling Contributing disciplines to GIS.

•Geography

•Cartography

•Computer software

•Surveying

•Photogammetry

•Remote Sensing Technology

•Mathematics/Statistics

Steps in GIS analysis

• Importing Data

• Georeferencing

• Digitizing and editing

• Data analysis:

a) network analysis

b) Digital Elevation Model (DEM).

c) Morphometric analysis, etc.

• Query Building.

Global Positioning System (GPS) also called as NAVSTAR GPS (Navigational System with Time and Ranging) was created by the U.S. Department of Defense for defense reasons. This system is being used for many civil applications now a days. It is a system of earth-orbiting satellites transmitting precisely timed signals (a similar system of Russian Federation:

GLONASS - global navigation satellite system) which provides direct measurement of position on the Earth's surface and the location is expressed in latitude/longitude. The GPS receiver measures the travel time of signals transmitted from triangulated satellites. It calculates the satellites' latitude, longitude, altitude and speed. GPS provides an address to every square meter of the earth's surface.

3. The Five Main Points of Global Positioning System

1. The basis of the GPS system is triangulation from the satellites. Triangulation is when distance is measured using the travel time of radio messages from satellite.

2. Two receivers are needed; the first receiver acts as a "reference point". It is stationary and monitors, transmits and records the corrections to errors. The second receiver is placed in a position that is recorded and calculates position of satellite

(with data). Then it compares the answer with a known position; the difference is the error in the GPS signal.

3. The satellite and the receiver generate the same pseudo-random code at the same time. The distance to a satellite is determined by measuring the time it takes for a radio signal to reach us from that satellite.

4. This code allows for the GPS system to work with very low power signals and small antenna.

5. Distance to satellites is measured by accurate timing, using atomic clocks on board. Four satellite range measurements will reduce errors in timing.

Three major segments:

(i) Space Segment; Consists of 24 satellites at an altitude of 20200 km above the earth surface.

(ii) Ground control segment; Five ground stations distributed around the earth for monitoring and controlling the satellite system continuously

(iii) The user segment: includes all those who use GPS tracking equipment to receive GPS signals to satisfy positioning requirements.

REMOTE SENSING

Definition

Remote sensing has been defined in many ways. It is the science, art and technique of obtaining information about an object or phenomena, through electromagnetic radiations, from a distance without any physical touch or contact.

It can also be defined as the science and technology by which the characteristics of objects of interest can be identified, measured or analyzed without direct contact.

According to Dr. Nicholas Short, Remote sensing is a technology for sampling electromagnetic radiation to acquire and interpret non-immediate geospatial data from which to extract information about features and objects on the Earth's land surface, oceans and atmosphere. As the land surface features are changing with the change of environmental conditions, remote sensing encompasses all such degree of dynamism under each satellite pass over the earth surface.

According to National Aeronautics and Space Administration (NASA) remote sensing is the acquisition and measurement of data/information on some property (ies) of a phenomenon, object or material by a recording device not in physical, intimate contact with the feature(s) under surveillance; techniques involve amassing knowledge pertinent to environments by measuring force fields, electromagnetic radiation, or acoustic energy employing cameras, radiometer and scanners, lasers, radio frequency receivers, radar systems, sonar, thermal devices, seismographs, magnetometers, gravimeters, scintillometers and other instruments. This is rather a comprehensive definition highlighting the extensive fields, tools, techniques and scope of remote sensing.

John R Jensen has defined remote sensing as the acquiring data about an object without touching it. Canada Centre for Remote Sensing (CCRS) has defined remote sensing as the science and to some extent art of acquiring information about the earth`s surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing and applying that information. It is simple definition but there is no mention about electromagnetic radiation as medium of sensing and the term "distance" from where the object is sensed otherwise the idea of `Remote` will disappear.

Historical overview

The concept of photography was developed by Greek mathematician Aristotle by using a pinhole camera in the 5^{th} and 4th centuries.

Photography was originally invented in the early 1800s.

The world’s first chemical photograph was taken in 1826 by Joseph Niépce of France using a process known as heliography.

The word "photograph" was coined in 1839 by Sir John Herschel and is based on the Greek meaning "drawing, writing", together meaning "drawing with light".

The first black and white aerial photograph was taken in the year 1860 by James Wallace Black from the height of 2,000 feet in Boston by using hot air balloon and during the year 1861 colour photographs were taken by James Clerk Maxwell.

In 1897, Alfred Nobel became the first human being in the world to succeed in capturing an aerial photo with the help of a rocket mounted camera.

In 1859 Gaspard Tournachon took an oblique photograph of a small village near Paris from a balloon. With this picture the era of earth observation and remote sensing had started.
His example was soon followed by other people all over the world.
During the period 1900-1914, continuous development with respect to film, mounting base of cameras, height from earth surface etc took place in the field of

aerial photography for improving the quality of photographs and the ground coverage.

Evolution of satellite Remote Sensing in India

Following the successful demonstration flights of Bhaskara-1 and Bhaskara-2 - experimental Earth observation satellites developed and built by ISRO (Indian Space Research Organization) - and launched in 1979 and 1981, respectively, India began the development of an indigenous IRS (Indian Remote Sensing Satellite) program.

India realized quite early that sustaining its space program in the long run would depend on indigenous technological capabilities (in particular, US export restrictions made this clear).

India under its different earth observation missions and programmes has launched varieties of satellites which have been proved to be an indispensable tool for natural resource mapping, monitoring, management and planning including environmental assessment at global, regional and local levels.

The success of missions and developmental programmes has been based on its judicious scientific approach of selecting multi- space platform, multi resolution, and synoptic viewing capabilities.

Keeping this in mind, besides building satellites, India embarked as well on satellite launch vehicle development in the early 1970s.

As a consequence, India has two very capable launch systems at the start of the 21st century, namely PSLV (Polar Satellite Launch Vehicle) and GSLV (Geosynchronous Satellite Launch Vehicle). IRS is the integrated LEO (Low Earth Orbit) element of India's NNRMS (National Natural Resources Management System) with the objective to provide a long-term space borne operational capability to India for the observation and management of the country's natural resources (applications in agriculture, hydrology, geology, drought and flood monitoring, marine studies, snow studies, and land use).

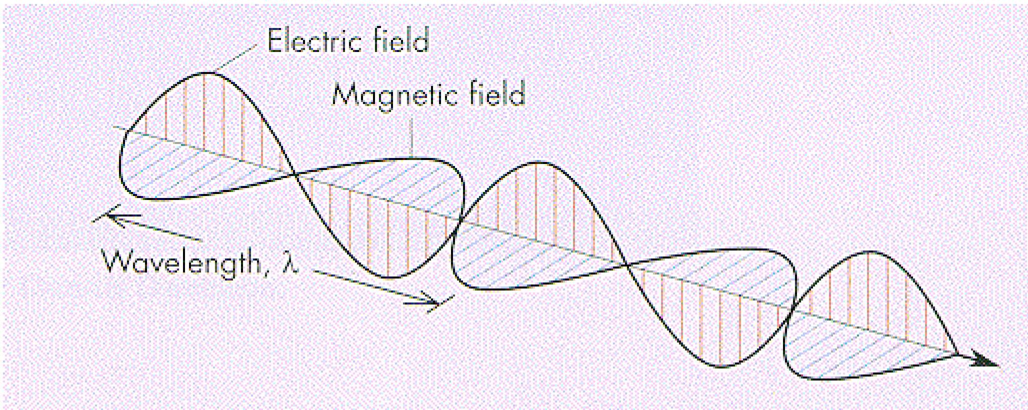
The intend of the program is to create an environment of new perspectives for the Indian research community as a whole, to stimulate the development of new technologies and applications, and to utilize the Earth resources in More meaningful ways.

Note: The INSAT system is India's GEO (Geosynchronous Earth Orbit) element, providing for simultaneous domestic communications and earth observation functions.

ELECTROMAGNETIC RADIATION

Electromagnetic radiation is energy that is propagated through free space or through a material medium in the form of electromagnetic waves, such as radio waves, visible light, and gamma rays. The term also refers to the emission and transmission of such radiant energy.

The Scottish physicist James Clerk Maxwell was the first to predict the existence of electromagnetic waves. In 1864 he set forth his electromagnetic theory, proposing that light--including various other forms of radiant energy--is an electromagnetic disturbance in the form of waves. In 1887 Heinrich Hertz, a German physicist, provided experimental confirmation by producing the first man-made electromagnetic waves and investigating their properties. Subsequent studies resulted in a broader understanding of the nature and origin of radiant energy.



It has been established that time-varying electric fields can induce magnetic fields and that time-varying magnetic fields can in like manner induce electric fields. Because such electric and magnetic fields generate each other, they occur jointly, and together they propagate as electromagnetic waves. An electromagnetic wave is a transverse wave in that the electric field and the magnetic field at any point and time in the wave are perpendicular to each other as well as to the direction of propagation. In free space (i.e., a space that is absolutely devoid of matter and that experiences no intrusion from other fields or forces), electromagnetic waves always propagate with the same speed--that of light (299,792,458 m per second, or 186,282 miles per second)--independent of the speed of the observer or of the source of the waves.

Electromagnetic radiation has properties in common with other forms of waves such as reflection, refraction, diffraction, and interference. Moreover, it may be characterized by the frequency with which it varies over time or by its wavelength. Electromagnetic radiation, however, has particle-like properties in addition to those associated with wave motion. It is quantized in that for a given frequency, its energy occurs as an integer times h, in which h is a fundamental constant of nature known as Planck's constant. A quantum of electromagnetic energy is called a photon. Visible light and other forms of electromagnetic radiation may be thought of as a stream of photons, with photon energy directly proportional to frequency.

Electromagnetic radiation spans an enormous range of frequencies or wavelengths, as is shown by the electromagnetic spectrum. Customarily, it is designated by fields, waves, and particles in increasing magnitude of frequencies--radio waves, microwaves, infrared rays, visible light, ultraviolet light, X rays, and gamma rays. The corresponding wavelengths are inversely proportional, and both the frequency and wavelength scales are logarithmic.

Electromagnetic radiation of different frequencies interacts with matter differently. A vacuum is the only perfectly transparent medium, and all material media absorb strongly some regions of the electromagnetic spectrum. For example, molecular oxygen (O_2), ozone (O_3), and molecular nitrogen (N_2) in the Earth's atmosphere are almost perfectly transparent to infrared rays of all frequencies, but they strongly absorb ultraviolet light, X rays, and gamma rays. The frequency (or energy equal to hv) of X rays is substantially higher than that of visible light, and so X rays are able to penetrate many materials that do not transmit light. Moreover, absorption of X rays by a molecular system can cause chemical reactions to occur. When X rays are absorbed in a gas, for instance, they eject photoelectrons from the gas, which in turn ionize its molecules. If these processes occur in living tissue, the photoelectrons emitted from the organic molecules destroy the cells of the tissue. Gamma rays, though generally of somewhat higher frequency than X rays, have basically the same nature. When the energy of gamma rays is absorbed in matter, its effect is virtually indistinguishable from the effect produced by X rays.

There are many sources of electromagnetic radiation, both natural and man-made. Radio waves, for example, are produced by cosmic objects such as pulsars and quasars and by electronic circuits. Sources of ultraviolet radiation include mercury vapour lamps and high-intensity lights, as well as the Sun. The latter also generates X rays, as do certain types of particle accelerators and electronic devices.

Energy Interactions with Atmosphere and Earth Surface

Introduction

In many respects, remote sensing can be thought of as a reading process. Using various sensors, we remotely collect data that may be analyzed to obtain information about the objects, areas or phenomena being investigated. In most cases the sensors are electromagnetic sensors either airborne or space borne for inventorying. Two basic processes involved in electromagnetic remote sensing of earth resources are Data Acquisition and Data Analysis. The elements of Data Acquisition are (a) Energy source, (b) Propagation of energy through the atmosphere, (c) Energy interactions w i t h earth surface features, (d) Airborne and/ or space borne sensors, (e) Generation of sensor data. Data analysis process involves examining the data in pictorial form or numerical form, analysis and presentation to the end users. In this article electromagnetic energy interaction in atmosphere and with earth surface are presented.

Energy Interaction in Atmosphere

Irrespective of its source, all radiation detected by remote sensors passes through some distance, or path length, of atmosphere. The path length involved can vary widely. For example, space photography results from sunlight that passes through the full thickness of the earth's atmosphere twice on its journey from source to sensor. On the other hand, an airborne thermal sensor detects energy emitted directly from objects on the earth, so a single, relatively short atmospheric path length is involved. The net effect of the atmosphere varies with these differences in path length and also varies with the magnitude of the energy signal being sensed, the atmospheric conditions present, and the wavelengths involved. Because of the varied nature of atmospheric effects, we treat this subject on a sensor-by-sensor. The atmosphere can have a profound effect on, among other things, the intensity and spectral composition of radiation available to any sensing system. These effects are caused principally through the mechanisms of atmospheric scattering and absorption.

Scattering

Atmospheric scattering is unpredictable diffusion of radiation by particles in the atmosphere. Rayleigh scatter is common when radiation interacts with atmospheric molecules and other tiny particles that are much smaller in diameter than the wavelength of the interacting radiation. The effect of Rayleigh scatter is inversely proportional to the fourth power of wavelength. Hence, there is a much stronger tendency for short wavelengths to be scattered by this scattering mechanism than long wavelengths.

A "blue" sky is a manifestation of Rayleigh scatter. In the absence of scatter, the sky would appear black. But, as s u n light interacts with the earth's atmosphere, it scatters the shorter (blue) wavelengths more dominantly than the other visible wavelengths. Consequently, we see a blue sky. At sunrise and sunset, however, the sun's rays travel through a longer atmospheric path than during mid-day. With the longer path, the scatter (and absorption) of short wavelengths is so complete that we see only the less-scattered, longer wavelengths of orange and red.

Rayleigh scatter is one of the primary cause of "haze" in imagery. Visually, haze diminishes the "crispness," on an image. In colour photography, it results in a bluish-grey cast to an image, particularly when taken from high altitude. Haze can often be eliminated, or at least minimized, in photography by introducing, in front of the camera lens, a filter that does not transmit short wavelengths.

Another type of scatter is Mie scatter, which exists when atmospheric particle diameters essentially equal the energy wavelengths being sensed. Water vapour and dust are major causes of Mie scatter. This type of scatter tends to influences longer wavelengths compared to Rayleigh scatter. Although Rayleigh scatter tends to dominate under most atmospheric conditions, Mie scatter is significant in slightly overcast ones.

A more bother some phenomenon is nonselective scatter, which comes about when the diameters of the particles causing scatter are much larger than the energy wavelengths being sensed. Water droplets, for example, cause such scatter. They commonly have a diameter in the 5 to 100 µm (mocrometer, 10 m) range and scatter all visible and -6 reflected IR wavelengths about equally. Consequently, this scattering is "nonselective" with respect to wavelength. In the visible wavelengths (Approx. 0.4 to 0.7 µm), equal quantities of blue, green, and red light are scattered, making fog and clouds appear white.

Absorption In contrast to scatter, atmospheric absorption results in the effective loss of energy to atmospheric constituents. This normally involves absorption of energy at a given wavelength. The most efficient absorbers of solar radiation in this regard are water vapour, carbon dioxide, and ozone. Because these gasses tend to absorb electromagnetic energy in specific wavelength bands, they strongly influence "where we look" spectrally with any given remote sensing system. The wavelength ranges in which the atmosphere is particularly transmissive of energy are referred to as atmospheric windows.

The atmospheric absorption characteristics of electromagnetic energy. The most common sources of energy is solar energy and the energy emitted from earth. In Figure spectral regions in which the atmosphere blocks energy are shown. Remote sensing data acquisition is limited to the non blocked spectral regions, called "atmospheric windows". The spectral sensitivity range of the eye (t he "visible" range) coincides both with an atmospheric window and the peak level of energy from t he sun. Emitted "heat" energy from the earth, is sensed through the windows at 3 to 5μm and 8 to 14μm using such devices as thermal scanners. Multispectral scanners sense simultaneously through multiple, narrow wavelength ranges that can be located at various points in the visible through the thermal spectral region. Radar and passive microwave systems operate through a window in the 1 mm to 1 m region.

Energy Interaction with Earth Surface Feature

When electromagnetic energy is incident on any given earth surface feature, three fundamental energy interactions with the feature are possible. This is illustrated in Figure for an element of the volume of a water body. Various fractions of the energy incident o n the element are reflected, absorbed, and or transmitted. Applying the principle of conservation of en ergy, we can state the interrelationship between these three energy interactions as $EI(\lambda) = ER(\lambda) + EA(\lambda) + ET(\lambda)$

where E denotes the incident energy, E denotes the I R reflected energy, E A denotes the absorbed energy and E T denotes the transmitted energy, with all energy components being a function of wavelength λ. The above equation is an energy balance equation expressing the interrelationship between the mechanisms of reflection, absorption, and transmission. Two points concerning this relationship should be noted. First, the proportions of energy reflected, absorbed, and transmitted will vary for different earth features, depending on their material type and condition. These differences permit us to distinguish different features on an image. Second, the wavelength dependency means that, even within a given feature type, the proportion of reflected, absorbed, and transmitted energy will vary at different wavelengths. Thus, two features may be indistinguishable in one spectral range and be very different in another wavelength band. Within the visible portion of the spectrum, these spectral variations result in the visual effect called colour. For example, we call objects, "blue" when they reflect highly in the blue portion of the visible spectrum, "green" when they reflect highly in the green spectral region, and so on. Thus, the eye utilizes spectral variations in the magnitude of reflected energy in the visible region to discriminate between various objects.

Spectral Reflectance of Vegetation, Soil and Water

Figure shows typical spectral reflectance curves for three basic types of earth features: Healthy green vegetation, Dry bare soil (grey-brown loam), and Clear lake water. The lines in this figure represent average reflectance curves compiled by measuring a large sample of features. Note how distinctive the curves are for each feature. In general, the configuration of these curves is an indicator of the type and condition of the features to which they apply. Although the reflectance of individual features will vary considerably above and below the average, these curves demonstrate some fundamental points concerning spectral reflectance. For example, spectral reflectance curves for healthy green vegetation almost always manifest the "peakand-valley" configuration illustrated in

The valley s in the visible portion of the spectrum are dictated by the pigments in plant leaves. Chlorophyll, for example, strongly absorbs energy in the wavelength bands centered at about 0.45 and 0.65 µm. Hence, our eyes perceive healthy vegetation as green in colour because of the very high reflection of green energy. If a plant is subject to some form of stress that interrupts its normal growth and productivity, it may decrease or cease chlorophyll production. The result is less chlorophyll absorption in the blue and red bands. Often the red reflectance increases to the point that we see the plant turn yellow (combination of green and red).

Spatial and Temporal Effects

Having looked at the spectral reflectance characteristics of vegetation soil, and water, we should recognize that these broad feature types are normally spectrally separable. However, the degree of separation between types is a function of "where we look" spectrally. For example, water and vegetation might reflect nearly equally in visible wavelengths, yet these features are almost always separable in reflective infrared wavelengths. Because spectral responses measured by remote sensors over various features often permit an assessment of the type and/or condition o f t h e features, these responses have often been referred to as spectral signatures. Spectral reflectance and spectral emittance curves (for wavelengths greater than 3.0 µm) are often referred to in this manner. The physical radiation measurements acquired over specific terrain features at various wavelengths are also often referred to as the spectral signatures for those features. Although it is true that many earth surface features manifest very distinctive spectral reflectance and/or emittance characteristics, these characteristics result in spectral "response patterns" rather than in spectral "signatures". The reason for this is that the term signature tends to imply a pattern that is absolute and unique. This is not the case with the spectral patterns observed in the natural world. As we have seen, spectral response patterns measured by remote sensors may be quantitative but they are not absolute. They may be distinctive but they are not necessarily unique.

Concept

Remote sensing is the acquisition of information about an object without coming in physical contact of that object. And ‘sensor’ is a device that helps in gathering of information (amount of EMR emitted or reflected by the object). In other words, ‘sensor’ is the remote sensing device that records wavelengths of energy.

Generally, these sensors are mounted or fixed with a ‘platform’. Therefore, ‘platform’ is termed as a vehicle that carries remote sensing device (Fig. 1).

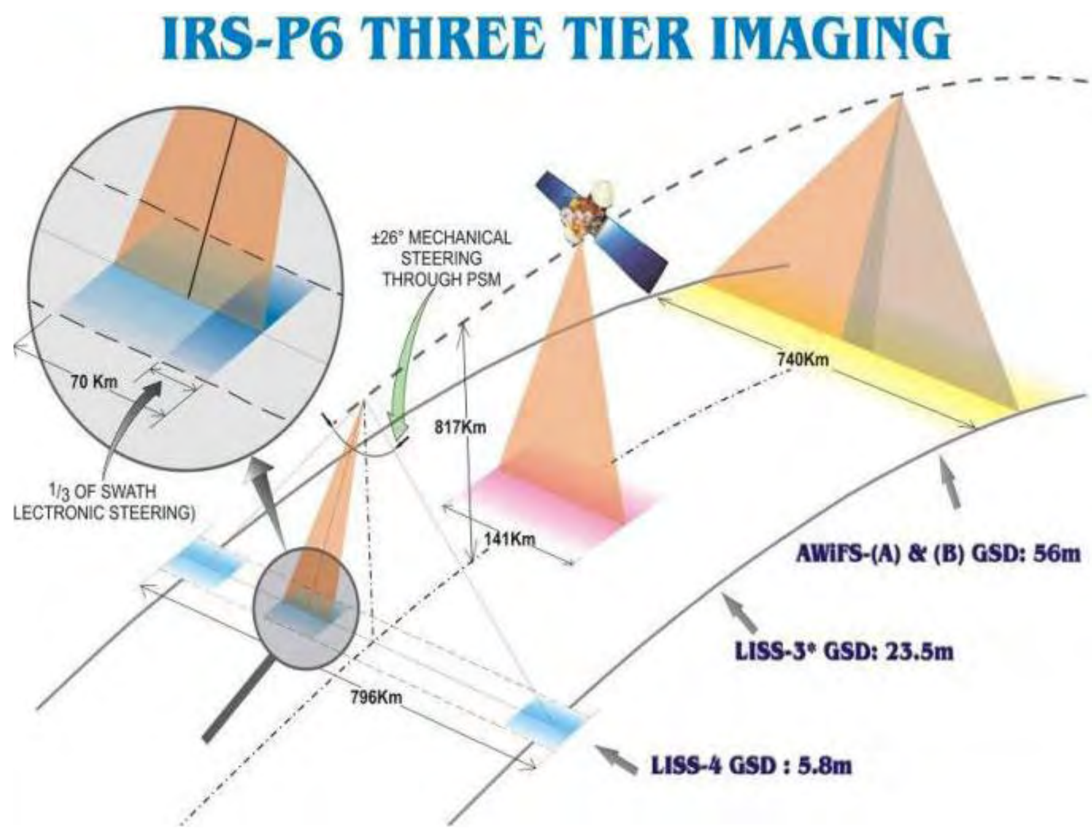
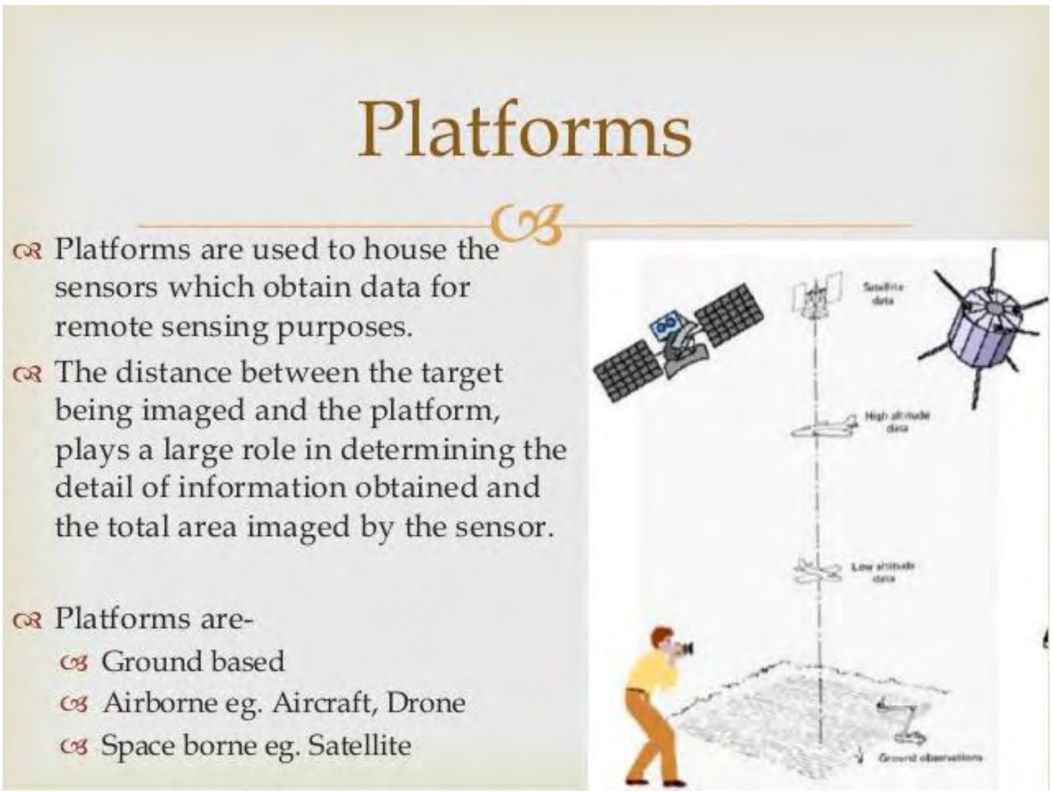


Fig.1: Indian remote sensing platform and sensor.

PLATFORM

Platform is a stage where sensor or camera is mounted to acquire information about a target under investigation. According to Lillesand and Kiefer (2000), a platform is a vehicle, from which a sensor can be operated. For remote sensing applications, sensors should be mounted on suitable stable platforms. These platforms can be ground based, air borne or space borne based. As the platform height increases the spatial resolution and observational area increases. Thus, higher the sensor is mounted; larger the spatial resolution and synoptic view is obtained. The types or characteristics of platform depend on the type of sensor to be attached and its application. Depending on task, platform can vary from ladder to satellite. For some task sensors are also placed on ground platforms. Though aircrafts and satellites are commonly used platforms, balloons and rockets are also used.



Type of Platforms:

Platforms can vary from stepladders to satellites. There are different types of platforms and based on its altitude above earth surface. Three types of platforms are used to mount the remote sensors –

1. Ground based Platform
2. Air - borne Platform, and
3. Space-borne Platform

Remote sensing platforms

- There are three main categories of remote sensing platforms

Commonest platforms

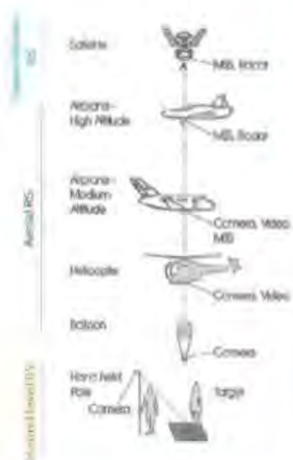
Spaceborne
- Satellite
- Shuttle

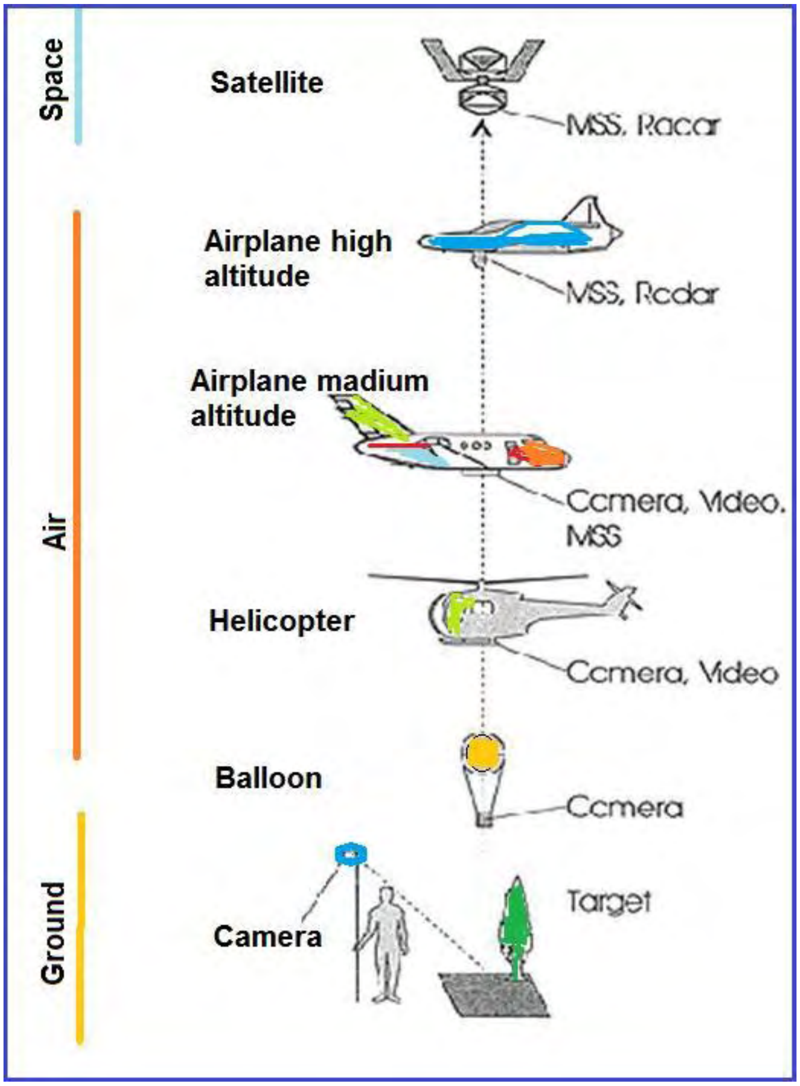
Airborne
- Aeroplane
- Helicopter
- Hot air balloon
- Air ship
- Tethered balloon

Ground-based
- Hand-held
- Raised platform

Remote Sensing Platforms

- Ground level remote sensing
  - Very close to the ground (e.g., Hand held camera)
  - Used to develop and calibrate sensors for different features on the Earth's surface
- Aerial remote sensing
  - Low altitude aerial remote sensing
  - High altitude aerial remote sensing
- Space-borne remote sensing
  - Space shuttles
  - Polar orbiting satellites
  - Geo-stationary satellites





1. Ground based Platforms:

Ground based platforms are used to record detailed information about the objects or features of the earth's surface. These are developed for the scientific understanding on the signal-object and signal-sensor interactions. Ground observation includes both the laboratory and field study, used for both in designing sensors and identification and characterization of land features. Ground observation platforms include – handheld platform, cherry picker, towers, portable masts and vehicles etc. Portable handheld photographic cameras and spectroradiometers are largely used in laboratory and field experiments as a reference data and ground truth verification.

Wide varieties of ground-based platforms are used in remote sensing. Some of the common ones are hand held devices, tripods, towers and cranes. To study properties of a single plant or a small patch of grass, ground based platform is used. Ground based platforms (hand-held or mounted on a tripod) are also used for sensor calibration, quality control and for the development of new sensors. For the field investigations, some of the most popular platforms have been used are ‘cherry picker platform, portable masts and towers. The cherry picker platforms can be extended to approx. 15m. They have been used by various laboratories to carry spectral reflectance meters and photographic systems. Portable masts are also available in various forms and can be used to support cameras and sensors for testing. The main problem with these masts is that of stabilizing the platform, particularly in windy conditions. Permanent ground platforms like towers and cranes are used for monitoring atmospheric phenomenon and long-term monitoring of terrestrial features. Towers can be built on site and can be tall enough to project through a forest canopy so that a range of measurements can be taken from the forest floor, through the canopy and from above the canopy

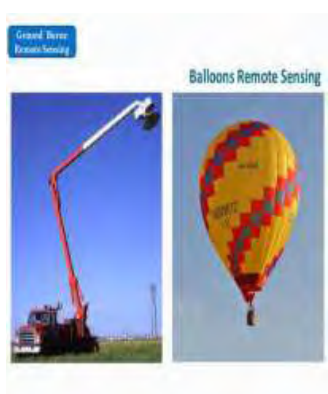
2. Air- borne/ based Platforms:

Airborne platforms were the sole non-ground-based platforms for early remote sensing work. Aircraft remote sensing system may also be referred to as sub-orbital or airborne, or aerial remote sensing system. At present, airplanes are the most common airborne platform. Other airborne observation platforms include balloons, drones (short sky spy) and high altitude sounding rockets. Helicopters are occasionally used.

Balloons:

Balloons are used for remote sensing observation (aerial photography) and nature conservation studies. The first aerial images were acquired with a camera carried aloft by a balloon in 1859. Balloon floats at a constant height of about 30 km. It consists of a rigid circular base plate for supporting the entire sensor system which is protected by an insulating and shock proof light casing. The payload used for Indian balloon experiment of three Hasselblad cameras with different film filter combinations, to provide PAN, infra red black and white and infra red false color images. Flight altitude being high compared to normal aircraft height used for aerial survey, balloon imagery gives larger synoptic views. The balloon is governed by the wind at the floating altitude. Balloons are rarely used today because they are not very stable and the course of flight is not always predictable, although small balloons carrying expendable probes are still used for some meteorological research.

Balloons as platforms are not very expensive like aircrafts. They have a great variety of shapes, sizes and performance capabilities. The balloons have low acceleration, require no power and exhibit low vibrations. There are three main types of balloon systems, viz. free balloons, Tethered balloons and Powered Balloons. Free balloons can reach almost top of the atmosphere; hence, they can provide a platform at intermediate altitude between those of aircraft and spacecraft.



Free floating or anchored balloons have altitude range of 22-40 km and can be used to a limited extent as a platform. It is used for probing the atmosphere and also useful to test the instrument under development. In India, at present, Tata Institute of Fundamental Research, Mumbai, has setup a National balloon facility at Hyderabad. Teethered balloons are connected to the earth station by means of wire shaving high tensional strength nd high flexibility.

Drone

Drone is a miniature remotely piloted aircraft. It is designed to fulfill requirements for a low cost platform, with long endurance, moderate payload capacity and capability to operate without a runway or small runway. Drone includes equipment of photography, infrared detection, radar observation and TV surveillance. It uses satellite communication link. An onboard computer controls the payload and stores data from different sensors and instruments. The payload computer utilizes a GSM/GPRS (where available) or independent satellite downlink, and can be monitored its position and payload status from anywhere in the world connected to the internet.

Drone was developed in Britain during World War-II, is the short sky spy which was originally conceived as a military reconnaissance. Now it plays important role in remote sensing. The unique advantage is that it could be accurately located above the area for which data was required and capable to provide both night and day data.

Aircraft Platform

Aerial platforms are primarily stable wing aircraft. Helicopters are also occasionally used for this purpose. Generally, aircraft are used to collect very detailed images. Helicopters can be for pinpoint locations but it vibrates and lacks stability. Special aircraft with cameras and sensors on vibration less platforms are traditionally used to acquire aerial photographs and images of land surface features. While low altitude aerial photography results in large scale images providing detailed information on the terrain, the high altitude smaller scale images offer advantage to cover a larger study area with low spatial resolution.

The National High Altitude Photography (NHAP) program (1978), coordinated by the US Geological Survey, started to acquire coverage of the United States with a uniform scale and format. Beside aerial photography multi spectral, hyperspectral and microwave imaging is also carried out by aircraft; thereafter multi spectral, hyperspectral and microwave imaging were also initiated.

Aircraft platforms offer an economical method of remote sensing data collection for small to large study areas with cameras, electronic imagers, across- track and along-track scanners, and radar and microwave scanners. AVIRIS hyperspectral imaging is famous aircraft aerial photographic operation of USGS.

Low Altitude Aircraft

It is most widely used and generally operates below 30,000 ft. They have single engine or light twin engine. It is suitable for obtaining image data for small areas having large scale .

It is more stable and operates above 30,000 ft. High altitude aircraft includes jet aircraft with good rate of climb, maximum speed, and high operating ceiling. It acquires imagery for large areas (smaller scale). Examples are NHAP, NAPP, AVIRIS.

Aircraft platform acquire imagery under suitable weather conditions. It controls platform variables such as altitude. Time of coverage can also be controlled. However, it is expensive, less stable than spacecraft and has motion blurring.

Rockets as Platforms:

High altitude sounding rocket platforms are useful in assessing the reliability of the remote sensing techniques as regards their dependence on the distance from the target is concerned. Balloons have a maximum altitude of approximately 37 km, while satellites cannot orbit below 120 km. High altitude sounding rockets can be used to a moderate altitude above terrain. Imageries with moderate synoptic view can be obtained from such rockets for areas of some 500,000 square kilometers per frame. The high altitude sounding rocket is fired from a mobile launcher. During the flight its scanning work is done from a stable altitude, the payload and the spent motor are returned to the ground gently by parachute enabling the recovery of the data. One most important limitations of this system is to ensure that the descending rocket not going to cause damage.

Prior to use of airplanes, aerial photographs were obtained by rocketing a camera into the sky and then retrieving the camera and film. Synoptic imagery can be obtained from rockets for areas of some 500,000 square km. The Skylark earth Resource Rocket is fired from a mobile launcher to altitudes between 90 - 400 kms. With the help of a parachute, the payload and the spent motor are returned to the ground gently thereby enabling speedy recovery of the photographic records. This rocket system has been used in surveys over Australia and Argentina. In 1946, V-2 rockets acquired from Germany after World War II were launched to high altitudes from White Sands, New Mexico. These rockets contained automated still or movie cameras that took picture as the vehicle ascended. The main problem with rockets is that they are one-time observations only. Except for one time qualitative or reconnaissance purposes, rocket platforms are not of much use in regular operational systems.

3. Space-borne/ based Platforms:

In space- borne remote sensing, sensors are mounted on-board a spacecraft (space shuttle or satellite) orbiting the earth. Space-borne or satellite platform are onetime cost effected but relatively lower cost per unit area of coverage, can acquire imagery of entire earth without taking permission. Space-borne imaging ranges from altitude 250 km to 36000 km.

Space-borne remote sensing provides the following advantages: Large area coverage;

Frequent and repetitive coverage of an area of interest

Quantitative measurement of ground features using radiometrically calibrated sensors;

Semi-automated computerised processing and analysis;

Relatively lower cost per unit area of coverage.

Spacecraft as Platform:

Remote sensing is also conducted from the space shuttle or artificial satellites. Artificial satellites are manmade objects, which revolve around another object.

The 1960s saw the primary platform used to carry remotely sensed instruments shifted from airplanes to satellite. Satellite can cover much more land space than planes and can monitor areas on a regular basis.

Beginning with the first television and infrared observation Satellite (tiRoS-1) in 1960, early weather satellites returned rather poor views of cloud patterns and almost indistinct images of the earth's surface. Space photography becomes better and was further extended with the Appolo program. Then in 1973 SKYLAB, the first American space workshop was launched and its astronauts took over 35000 images of the earth with the earth Resource experiment Package (eReP) on board. Later on with LANDSAT and SPOT satellites program, space photography received a higher impetus (Fig. 7).

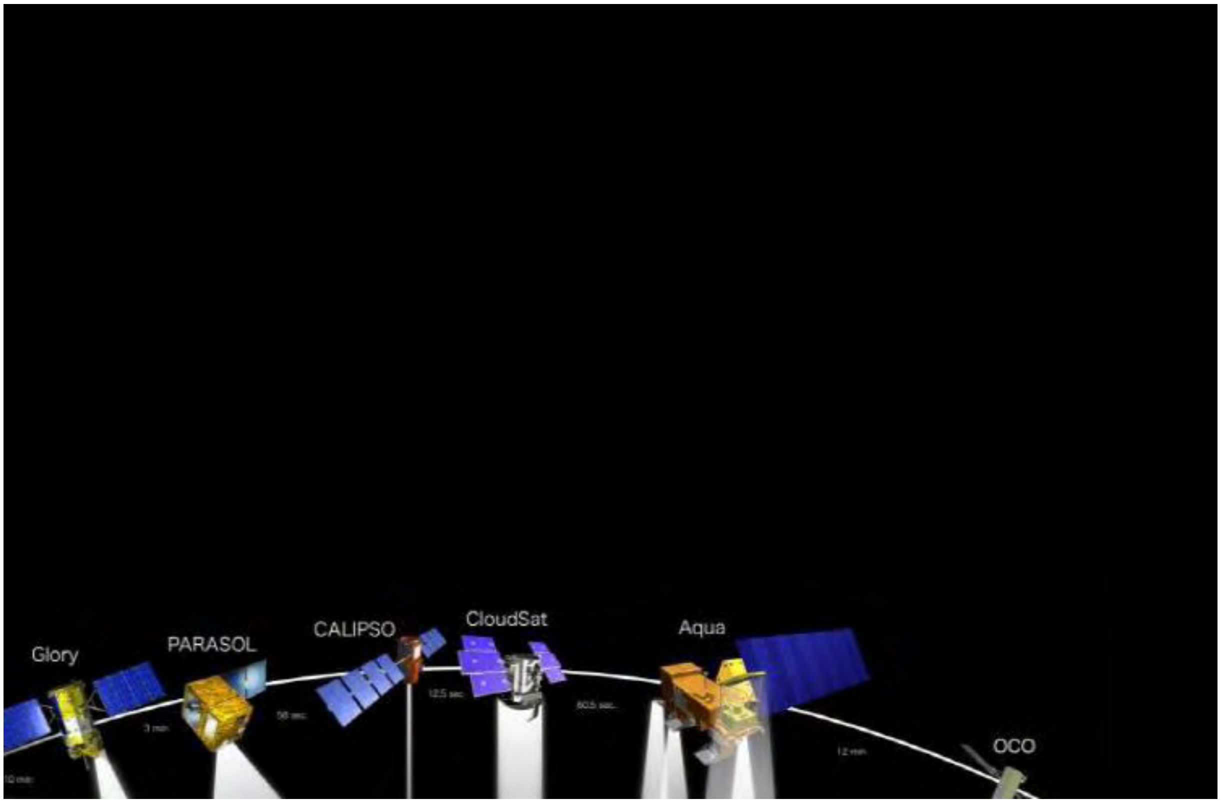


Fig. 7: Spacecraft as platform

There are two types of well recognized satellite platforms- manned satellite platform and unmanned satellite platform.

Manned Satellite Platforms: Manned satellite platforms are used as the last step, for rigorous testing of the remote sensors on board so that they can be finally incorporated in the unmanned satellites. This multi- level remote sensing concept is already presented. Crew in the manned satellites operates the sensors as per the program schedule. Information on a series of NASA's manned satellite programs are given in table 6.1.

Table showing Manned satellite programs of NASA

Program	***Year***	***Crew***	***Sensors used***
Mercury Gemini Apollo Skylab Space Shuttle International Space Station	*1962-1963 1964-1965 1968-1972 1973-1974 1981 2000 Nov 02, 2000 Mar 10, 2001 Aug 12, 2001 Dec 07,2002 June 07,*	*One Two Three Three Three to Seven Variable 1st Station Crew Arrived 2nd Station Crew Arrived 3rd Station Crew Arrived 4th Station Crew Arrived*	*Head-heal Camera Head- held Camera Multispectral Scanner Head-head Camera, LFC, Sir , MOMS Multiple sensors for remote sensing and a range of laboratory equipments for conducting physics-chemical and biological experiments. It is planned to serve as the base for launching smaller unmanned satellites into polar orbits from which remote sensing data can be relayed to earth stations. Crew from the Space station can also go to these polar satellites to repair and refuel them. Space Shuttle to provide transportation of Astronauts and necessary cargo between earth and the Space station*

Source: Panda, 200

Unmanned Satellite Platforms: Landsat series, SPOT series and IRS series of remote sensing satellite, NOAA series of meteorological satellites, the entire constellation of the GPS satellites and the GOES and INSAT series of geostationary environmental, communication, television broadcast, weather and earth observation satellites etc are examples of unmanned satellite category.

SENSORS

Remote Sensing sensors are instruments that measures the properties of Electro Magnetic radiation leaving a surface/medium due to scattering or emission

Generally, radiance is the property measured as a function of wavelength but could also include other parameters such as polarization.

Active and Passive sensors

The technology of developing sensors throughout the EM spectrum is not the same.

Technology for developing microwave sensors is quite different from that of optical-Infrared (OIR) sensors.

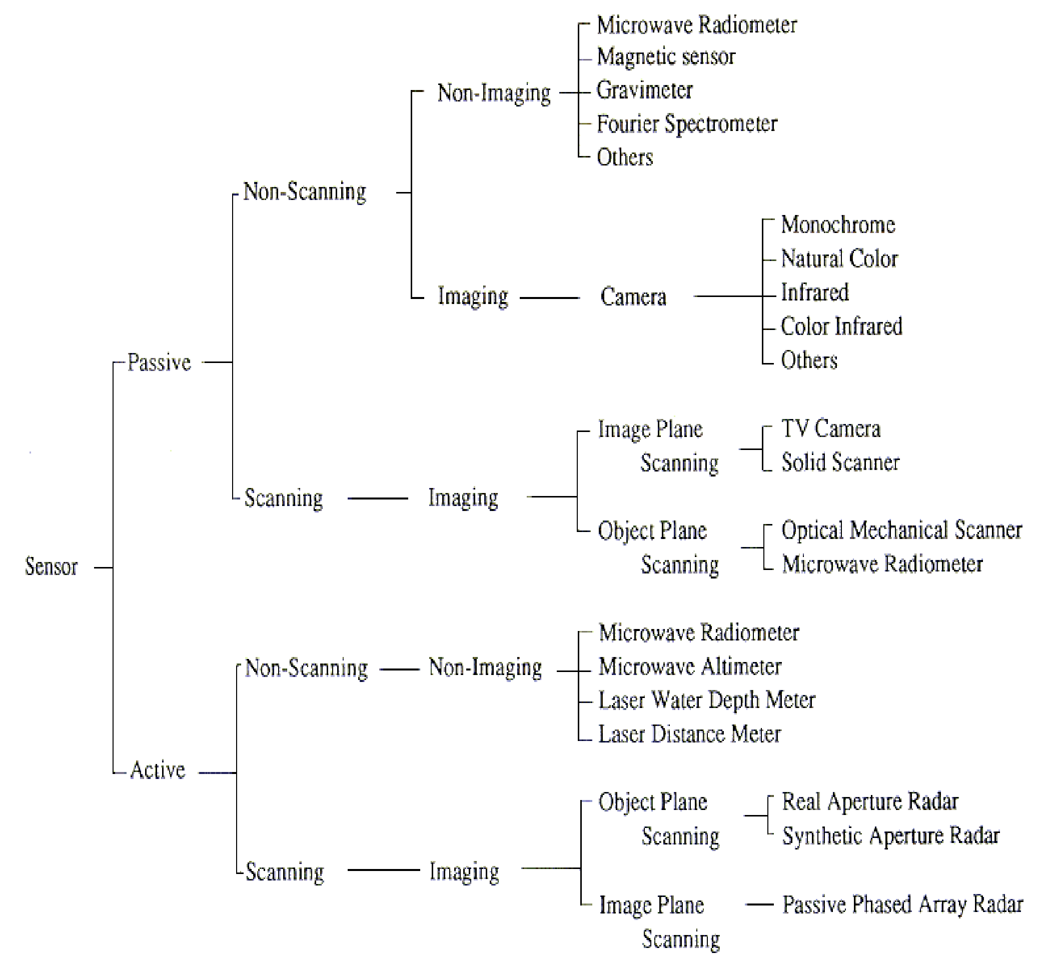
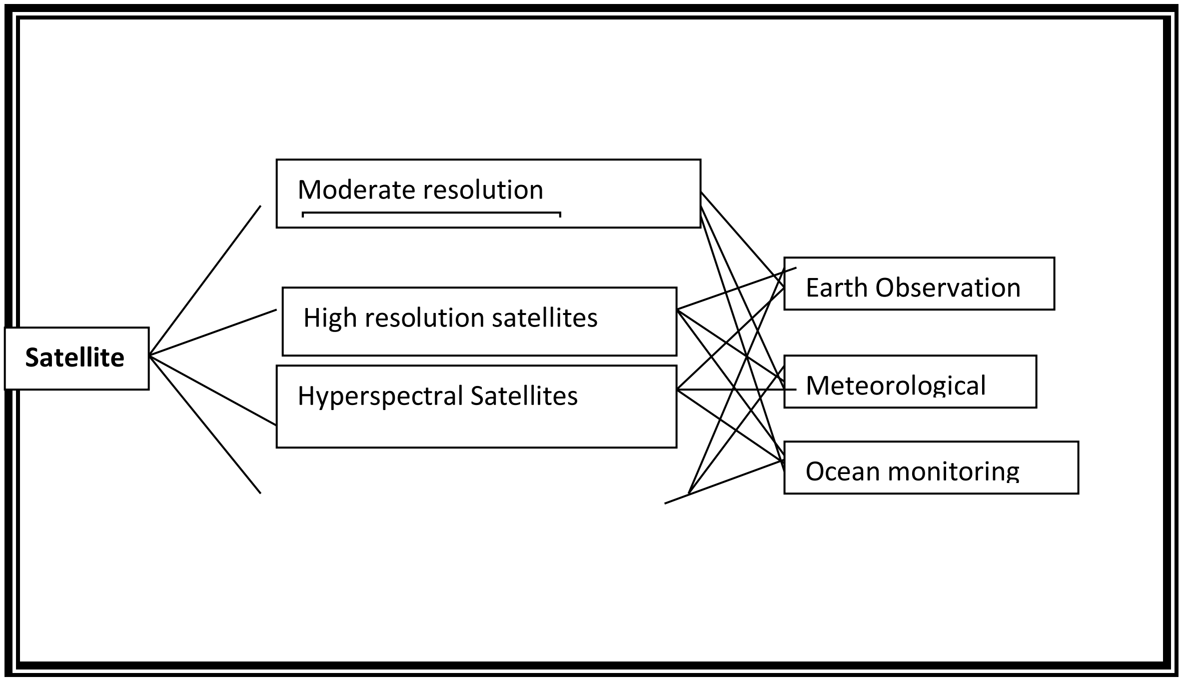


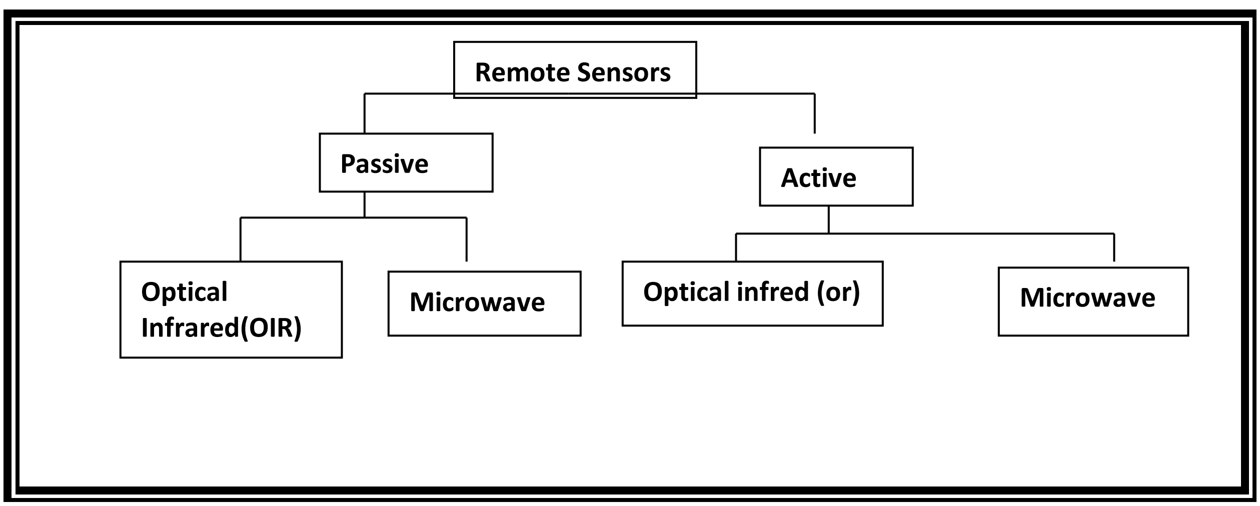
Figure 2.1.1 Classification of Sensor

Understand the basic design characteristics of the sensors an the various trade-offs that determine whether a sensor will be suitable for a given application

U.S. Landsat and French SPOT satellite systems were the first and most robust global monitoring systems to acquire moderate resolution data systematically



Remote Sensors



RS Sensors Characteristics

Classification of sensors is evaluated based on its classification as well as its mapping accuracy requirements

Reasonable assumption:

Instruments ability to detect small differences in the emittance/reflectance of the earth's surface in number of spectral bands for as small an object as possible and as often as possible

What is the optimum set of specifications for remote sensing sensors ?

Even if we identify an ideal set of parameters, the realization of a combination of these parametric values (i.e., Spatial resolution, Number of spectral bands, spectral bandwidth, signal-to-noise ration, etc.) is a complex problem due to strong correlation among these parameters.

Sensors parameter under 4 domains:

1. Spatial
2. Spectral
3. Radiometric
4. Temporal

Resolution

So far, you've read that remote sensing systems measure electromagnetic radiation, and that they record measurements in the form of raster image data. The resolution of remotely sensed image data varies in several ways. As you recall, resolution is the least detectable difference in a measurement. In this context, three of the most important kinds are spatial resolution, radiometric resolution and spectral resolution.

Spatial resolution refers to the coarseness or fineness of a raster grid. The grid cells in high resolution data, such as those produced by digital aerial imaging or by the Ikonos satellite, correspond to ground areas as small or smaller than one square meter. Remotely sensed data whose grid cells range from 15 to 80 meters on a side, such as the Landsat ETM+ and MSS sensors, are considered medium resolution. The cells in low resolution data, such as those produced by NOAA's AVHRR sensor, are measured in kilometers. (You'll learn more about all these sensors later in this chapter.)

The higher the spatial resolution of a digital image, the more detail it contains. Detail is valuable for some applications, but it is also costly. Consider, for example, that an 8-bit image of the entire Earth whose spatial resolution is one meter could fill 78,400 CD-ROM disks, a stack over 250 feet high (assuming that the data were not compressed). Although data compression techniques reduce storage requirements greatly, the storage and processing costs associated with high resolution satellite data often make medium and low resolution data preferable for analyses of extensive areas.

A second aspect of resolution is **radiometric resolution**, the measure of a sensor's ability to discriminate small differences in the magnitude of radiation within the ground area that corresponds to a single raster cell. The greater the bit depth (number of data bits per pixel) of the images that a sensor records, the higher its radiometric resolution. The AVHRR sensor, for example, stores 2^{10} bits per pixel, as opposed to the 2^8 bits that the Landsat sensors record. Thus, although its spatial resolution is very coarse (~4 km), the Advanced Very High Resolution Radiometer takes its name from its high radiometric resolution.

Temporal resolution

Remote sensed data represents a snap shot in time. Temporal resolution is the time between two subsequent data acquisitions for an area. This is also known as the “return time” or "revisit time". The temporal resolution depends primarily on the platform, for example, satellites usually have set return times and while sensors mounted on aircraft or unmanned aircraft systems (UAS), have variable return times. For satellites, the return time depends on the orbital characteristics (low vs high orbit), the swath width and whether or not there is an ability to point the sensor. Landsat has a return time of approximately 16 days, while other sensors like MODIS have nearly daily return times.

Finally, there is **spectral resolution**, the ability of a sensor to detect small differences in wavelength. For example, panchromatic film is sensitive to a broad range of wavelengths. An object that reflects a lot of energy in the green portion of the visible band would be indistinguishable in a panchromatic photo from an object that reflected the same amount of energy in the red band, for instance. A sensing system with higher spectral resolution would make it easier to tell the two objects apart.

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UNIT III: Introduction to GIS - Definition - Advantages of GIS - Components of GIS-Data Capture – Data Storage – Data base management system - Data Retrieval, Analysis and Display.

INTRODUCTION TO GIS – HISTORY AND DEVELOPMENT

1. A geographic information system is a system designed to **capture, store, manipulate, analyze, manage,** and **present** all types of geographic data. A GIS can be thought of as a system that provides **spatial data entry, management**, and **retrieval, analysis**, and **visualization** functions.

2. Keeping long tradition of map making as background, G.I.S. has been developed during mid **20th century** with the development of **computer science**. The data analysis of geographic locations was being done by computers in government organizations and universities in **U.S.A.** during **1950s** and **1960s**

3. The first true operational G.I.S. was developed by Dr. Roger Tomlinson, Department of Forestry and Rural Development, Canada. It was called as Canada Geographic Information System **(CGIS)** and was used to store analyse and manipulate land related data. ***Dr. Roger Tomlison was also known as the 'Father of G.I.S'.***

4. In 1964, a laboratory of Computer Graphics and Spatial Analysis was established at the Harvard Graduate School of Design by Howard T. Fisher. This organization developed a number of important theoretical concepts of spatial data handling and in 1970s it distributed seminal software code and system such as '***SYMAP'***, **'*GRID'*** and '***ODYSSEY***'.

5. This inspired subsequent commercial development. By early 1980s, M & S Computing (later Intergraph) and ***Environmental Systems Research Institute*** (**ESRI**) emerged as commercial vendors of G.I.S. software.

6. ESRI released ARC/ Info and ARC View software in 1981 and 1992 respectively. By the end of 20th Century, the development of ARC View enabled viewing G.I.S. data through internet and eliminated many of the hardware and licensing expenses of software packages.

7. Since then a number of organisations and universities have been doing research in the field of G.I.S. and developing user friendly softwares . Now there is a growing number of free, open source G.I.S. packages which run in a wide range of operating systems and perform specific tasks.

ADVANTAGES OF GIS

1. GIS explores both geographical and thematic components of data in a **holistic way**. It allows handling and exploration of **large volumes of data**.

2. It allows **integration of data** from widely disparate sources. It allows analysis of data to explicitly incorporate location.

3. GIS would then integrate software, hardware and also data in order to **capture, analyse, manage** and so **display all forms of information** being geographically referenced.

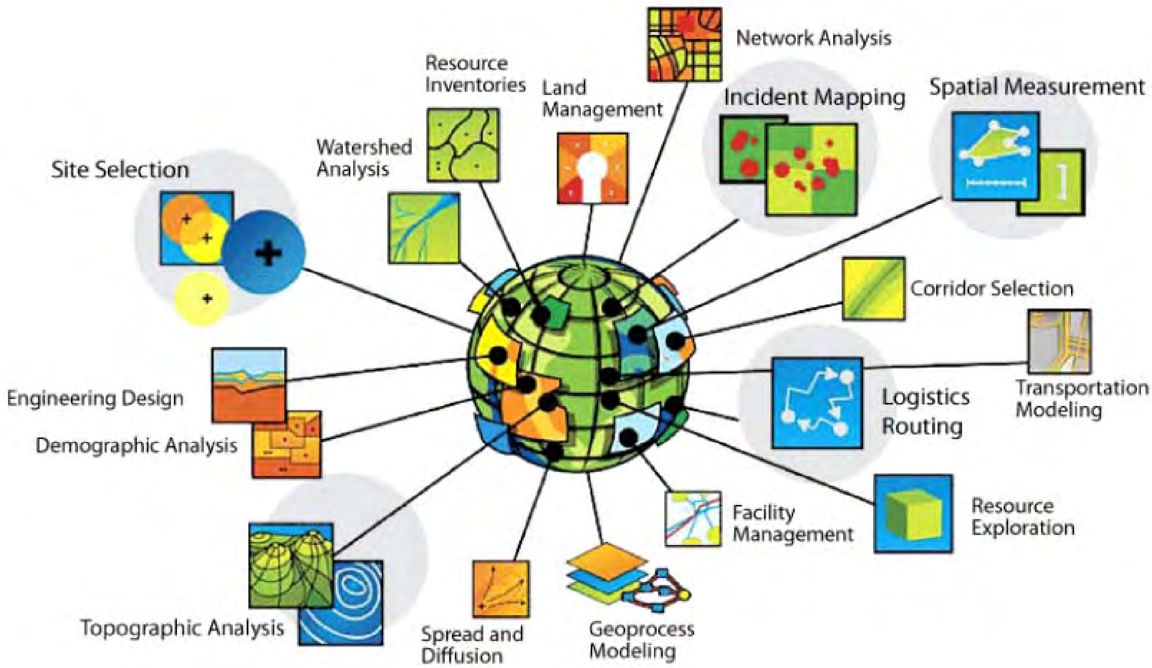
4. GIS would also allow viewing, questioning, understanding, visualizing and interpreting the data into numbers of ways which will **reveal relationships, trends and patterns** in the form of globes, maps, charts and reports.

5. GIS has led to a **better decision making**. It has enhanced our ability to make better decisions about the location of places. Examples include real estate site selection, zoning, planning, conservation, route selection and natural resource extraction. People are starting to realize the significance of GIS in making correct decision about the location of an intended project.

6. GIS has promoted cost savings mechanism and measures resulting in **greater efficiency**. By implementing GIS, customer service efficiency can also be increased by reducing the number of return visits to the same site and scheduled appointments more efficiently.

7. Handling, compiling and distribution of information have been made easy by GIS. Government and many other large corporations use GIS information products to communicate and share data. These products provide a framework for creating a blueprint for action, understanding it and prescribing the action. GIS is fast becoming an **enterprise for information systems**. Geography is emerging as a new way to organize and manage information. GIS is transforming the way organizations manage their assets, serve their clients, make decisions and communicate.

8. Geographic information system is a powerful tool that has been successfully implemented to help address a number of significant issues. As more and more professionals begin to adopt and integrate the program the number of benefits is likely to continue to rise including the connectivity between government, transport system, health sectors and managerial posts professionals with communities they serve which are perhaps the most important connection to be made.



Source: http://mappa.com.bd/services/gis-mapping/

RECENT TREND

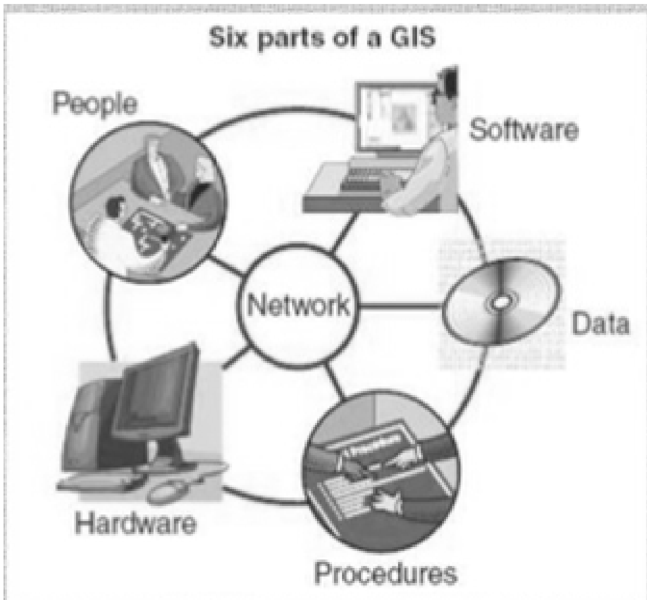
1. **Service-based GIS**: This means the GIS professional connects with consumers directly through web-based applications that provide easy-to-access visualizations. GIS also has huge implications for the enterprise user at a business or a city organization, where departments have enormous amounts of geographic data.

2. **Big Data Analytics:** The ability to access the vast amounts of data - integration of big data operations into spatial analysis- Enterprise users can now build their own imagery and raster analytics workflows for fast, multi-CPU, parallel processing of massive imagery collections.

3. **Real Time GIS:** Everything from smart phones to crowd sourced social media feeds is being used to integrate real-time data from the Internet of Things (IoT) directly into a GIS layer stack, where the data is analyzed, visualized, and reintegrated into online applications for use by either professionals within the enterprise or by consumers and citizens.

4. **Mobility:** iPhones or Android devices can be used to collect geospatial data or explore it visually, anywhere and at any time. Professionals in the field can use these apps for data collection or as observational data, which they can then bring directly into an enterprise services environment in the cloud. Field information is immediately input and analyzed.

COMPONENTS OF GIS



The major components of GIS is

◦ **Hardware,**

◦ **Software,**

◦ **Data,**

◦ **People,**

◦ **Procedure**

◦ **Network**

1. Hardware

- The computer or Central Processing Unit is the general hardware component of the GIS.
- It is attached to a disk drive storage unit, used for storing data and program.
- Devices like digitizer, scanner are used for converting the data, which is available in the form of maps and documents, into digital form and send them to computer.
- Display device or a plotter is used which presents the result of the data processing.

2. The GIS software

- Includes the programs and the user interface for driving the hardware.
- GIS software is essential to generate, store, analyze, manipulate and display geographic information or data.
- Good GIS software requires user friendliness, functionalities, compatibilities, updatability, documentation, cost effectiveness.
- The basic functions GIS software should offer can be grouped into data capture, data management and data analysis.

Some Leading software

ESRI): **ArcInfo, Arc View. Arc GIS**. Autodesk: **AutoCAD Map,** International Institute for Aerospace Survey and Earth Sciences: **ILWIS,** MapInfo Corporation: **MapInfo,** PCI Geomatics: **PA MAP**

3. GIS DATA

Types of Data

A) **Spatial Data** :Spatial data describes the absolute and relative location of geographic feature. It relate to the geometry of a spatial feature.

B) **Attribute Data:** Attribute data describes characteristics of spatial features. attribute data are often referred to as tabular data. It gives information about the spatial features.

Format of Data

A) RASTER data: type consists of rows and columns of cells, with each cell storing a single value.

B) The vector data model uses points and their x-, y- coordinates to construct spatial features of points, lines and areas. Vector based features are treated as discrete objects over the space.

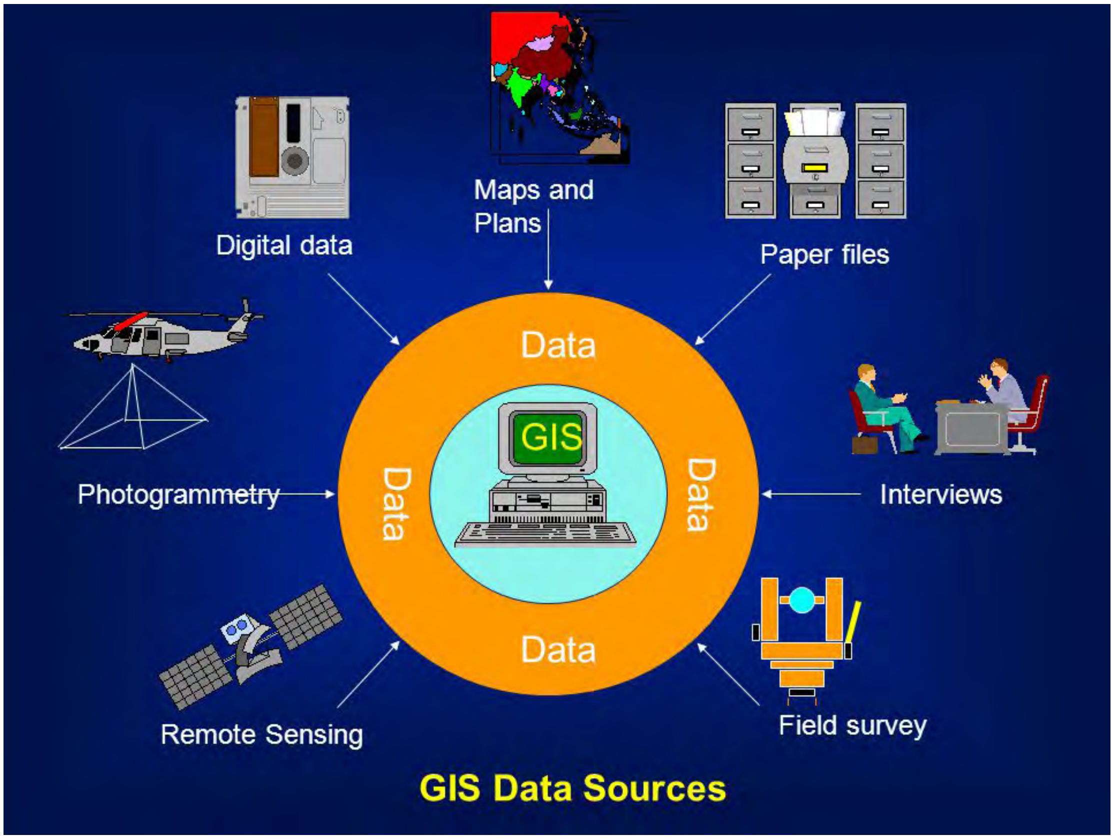
C) TIN/ DEM: 3 dimensional special GIS data format

Geometry of Data

A) **Points Entities: -** Points defines discrete location of geographic feature like well, tree, utilities etc.,

B) Line Entities: - Line entities can be defined as all features built up of straight-line segments – road, river and any network : pipe lines etc.,

C) **Area Entities:** - Areas of polygons can be represented in various ways in a vector Database - Areas are closed figures that represent shape and location of homogeneous feature such as states, soil types,landuse, wate body etc.,



4. **Procedure & Method:**

Procedure, more related to the management, aspect of GIS, is referred to lines of reporting, control points, and other mechanism for ensuring the high quality of GIS.

The procedures used to input, analyze, and query data determine the quality and validity of the final product.

The well-designed implementation plan and business rules are unique to each organization.

5 **People:**

GIS technology is of limited value without the people who manage the system and develop plans for applying it to real world problems.

GIS users range from **technical specialists** who design and maintain the system to those who use it to help them perform their everyday work.

6) NETWORK

Network allows rapid communication and sharing digital information. The internet has proven very popular as a vehicle for delivering GIS applications.

GIS DATA CAPTURE / ACQUISITION / INPUTS / SOURCES

GIS data capture is a technique in which the information on various map attributes, facilities, assets, and organizational data are digitized and organized on a target GIS system in appropriate layers. GIS Data capture can be divided into:

1) **Primary GIS Data Capture Techniques:**

- The primary GIS data capture techniques use **remote sensing** and **surveying technologies** to capture the data using either raster data capture or vector data capture.

- The raster GIS data capture technique involves capturing of attributes and other data without physical contact. This is usually done with the help of satellite imaging techniques such as aerial photography.
- This type of GIS data capture is advantageous as there is a consistency in the data generated, and the whole process can be regularly and systematically multiplied to get accuracy of the data in a cost effective manner.

- The vector GIS data capture technique includes capturing of data-sets through physical surveying techniques such as **Deferential Global Positioning System (DGPS)** and Electronic Total Station **(ETS).** Although this technique is the most effective process to have the accurate data on the target GIS system, it is more time consuming and expensive.

2) **Secondary GIS Data Capture Techniques:**

The secondary GIS data capture technique use technologies such as scanning, manual digitizing, vectorization, photogrammetry, and COGO feature construction to capture data by the following methods:

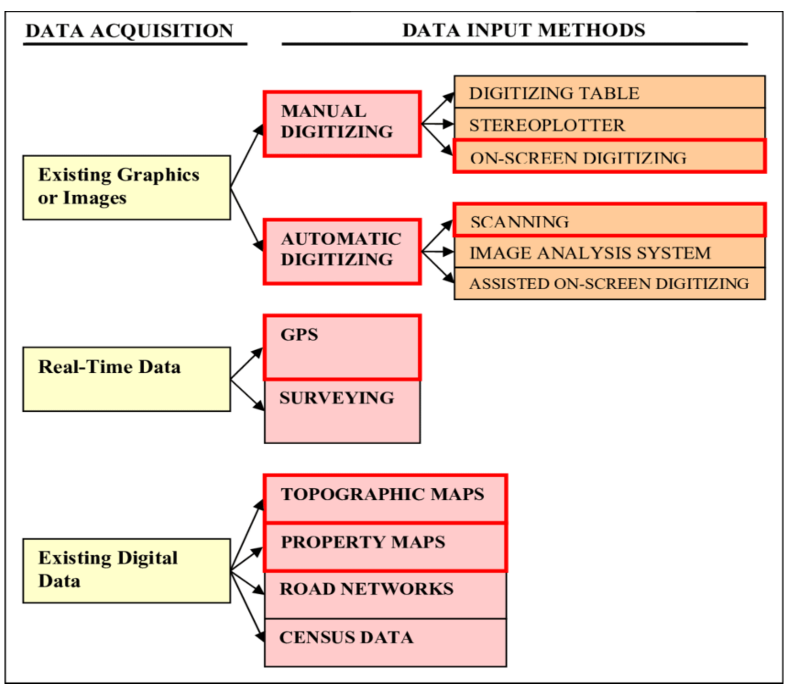
- Scanning the raster data for GIS Data Capture involves the use of high resolution scanners that generate highly accurate raster images from the hard copies which can be geo-referenced and digitized to get the vector output. Digitizing is the process of converting data from analog to digital format.

- Manual digitizing is done directly over the raster by the use of a digitizing tablet, which is a manual pointing device that creates an identical vector map on the computer screen, digitizing the vertices, points, line data, etc. A digitizing table has a built-in electronic mesh, which can sense the position of the cursor. To transmit the x-, y-coordinates of a point to the connected computer, the operator simply clicks on a button on the cursor after lining up the cursor's cross hair with the point.GIS packages typically have a built-in digitizing module for manual digitizing

- Heads-up / **On-screen digitizing** is an alternative to manual digitizing and scanning for limited digitizing work such as editing or updating an existing map. Digitizing on the **computer monitor** using a **data source in the background** digitizing is a part of GIS Data Capture and is similar to the manual digitization, but in heads-up digitization, the raster scanned data is imported and laid below the vector data to be traced on the computer screen itself.

- Automatic raster to vector conversion is a great example of advancement of the technology, the technology uses special software using intelligent algorithms that have been developed to recognize the patterns of the points, lines and polygon features and capture them automatically to generate vector GIS data.

- Photogrammetry involves digital stereo-plotters that are used to capture the vector data from the Ariel photographs, pictures and images. This is comparatively the most effective method of accurate GIS data capture, but is one of the costliest methods too.



https://www.researchgate.net/

DATA STORAGE

Bits

- Computers use a ***binary system*** for storing numbers. In a binary system, the only figures are 1 and 0.
- Computers function on two basic elements, on and off.
- The smallest processing unit is called a ***bit*** (short for Binary digit). Each bit can have one of 2 values: "on" (indicated by the value 1) and "off" (indicated by the value 0).
- Bits are grouped together in sets of eight, called *bytes*.
- The way numerical data is stored in a computer depends on the architechture of the computer: this depends on the type of computer ("personal" or mainframe) and the age. The number of bits that the computer uses as the basic unit to store data is called the ***word size***. For example, the following sizes are commonly used:
    - 16-bit (2-bytes) "personal computers" (previous generation)
    - 32-bit (4-bytes) "personal computers" (current generation)
    - 64-bit (8-bytes) mainframes

<u>Efficient Use of Data Storage Capacity</u>

- Spatial accuracy is important in GIS, so it is inevitable that large storage demands are made for storing spatial data. Most GIS software allow the user little (or no) choice on how spatial data, such as UTM co-ordinates or decimal degrees, are stored.
- For non-spatial data, such as cell values in the raster model or polygon or line attribute code in the vector model, design is important, and most GIS software is flexible in storage types for this data.
- The raster model for GIS data, typically requires more storage than the vector model, due to the large number of cell values that must be stored, so design issues are more important with this model.
- Design of data storage is important for two reasons:
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    - Users of GIS inevitably find that requirements for data storage expand at least as rapidly as the capacity of available storage devices, so efficient use of available apace is essential.
    - When data is processed it must be read from the storage device and after processing be re-written. Reading and writing data, is usually the slowest part of data processing. If poor design has resulted in the use of unnecessarily large amounts of storage, processing time will be slowed, by the reading and writing of redundant storage bytes.

i. **Numbers:** Can be one of four numeric data types:
   1. short integers-numbers without decimals (e.g. 2, 3, 4; range -32,768 to 32,767)
   2. long integers-numbers without decimals (e.g. 12,345,678; range 2,147,483,648 to 2,147,483,647)
   3. single-precision floating-point numbers (often referred to as floats; decimal-based numbers, e.g. 3.456; range = Approximately -3.4E38 to 1.2E38),
   4. double-precision floating-point numbers (commonly called doubles; range = Approximately -2.2E308 to 1.8E308).
   5. Number Field Definitions
      a. "Precision" = field length (number of characters in field)
         i. Single Float: precision = 1-6
         ii. Double Float: precision = 7+

      b. "Scale" = No. of decimal places
         i. Short integer scale = 0
         ii. Long integer scale = 0
         iii. Single Precision Float = 1-6
         iv. Double Precision Float 0+

ii. **Text (strings):** Any set of alphanumeric characters of a certain length.
iii. **Date:** Holds date and time data.

e. Field Definitions
   i. When creating new fields in a database, one must define the field type:
      1. Field name (column title)
      2. Width – number of spaces reserved for the field (precision)
      3. Data type (numeric or string)
      4. Number of decimal digits (scale)

DATABASE AND MANAGEMENT SYSTEMS

Basic GIS functions

Data management:
- Data registration & verification
- Data entry & import
- Data storage operations

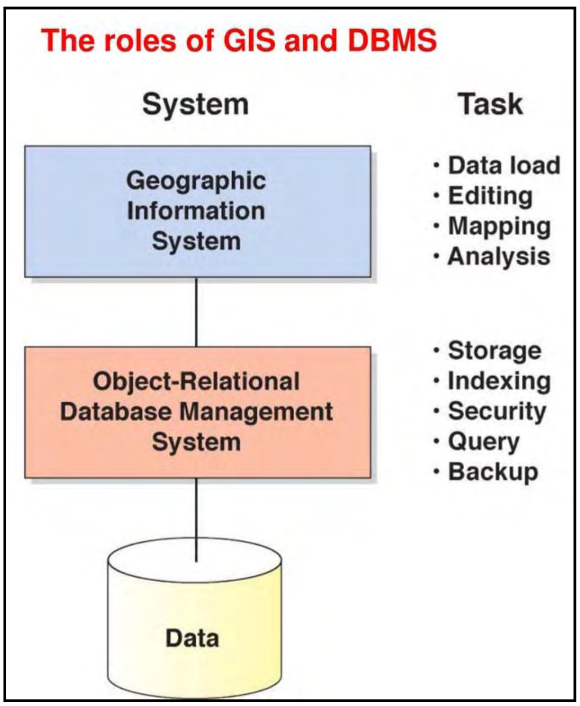
Data manipulation:
- Geometric manipulations
- Editing
- Matching & conflation
- Map projections & coordinate transformations

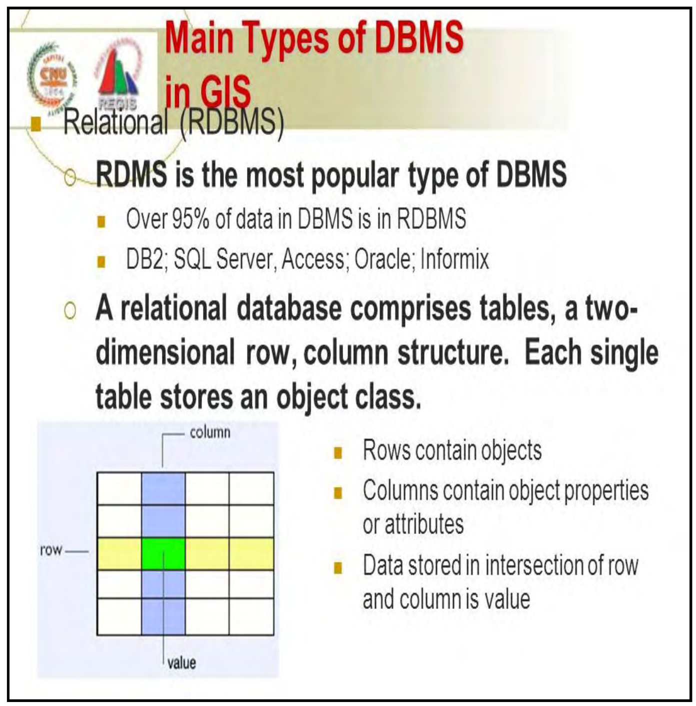
Data analysis:
- Support query operations
- Process attributes
- Topology & network analysis
- Statistical processing
- Terrain operations

Data visualization
- 2D/3D
- Symbology
- Annotation

Digital data are stored in computers as files. Often, data are arrayed in tabular form. For this reason, data files are often called **tables**. A **database** is a collection of tables. Businesses and government agencies that serve large clienteles, such as telecommunications companies, airlines, credit card firms, and banks, rely on extensive databases for their billing, payroll, inventory, and marketing operations.

Database management systems are information systems that people use to store, update, and analyze non-geographic databases. Often, data files are tabular in form, composed of rows and columns. **Rows**, also known as **records**, correspond with individual entities, such as customer accounts. **Columns** correspond with the various **attributes** associated with each entity. The attributes stored in the accounts database of a telecommunications company, for example, might include customer names, telephone numbers, addresses, current charges for local calls, long distance calls, taxes, etc.





Characteristics and Significance of DBMS

1. **Reduce redundancy**
2. **Maintain consistency & integrity**
3. **Data sharing with controlled access for security**
4. **Standards for presentation and storage**
5. **Data independence and reduced program maintenance**

6. **Interface with metadata**
7. **A query language interface**
8. **Transaction processing**
9. **Ability to lock records**
10. **Efficient data recovery after system or power failure**

Advantages of DBMS

1. **Clear picture of logical organization of dataset**
2. **Centralisation of multi-user support and management**
3. **Data independence**
4. **Controlled data redundancy and consistency**
5. **Increased flexibility**
6. **Maintenance of data integrity and quality**
7. **Reduced software development cost**
8. **Independent structures**
9. **Secured sharing of data**

Geographic data are a special case: records correspond with places, not people or accounts. Columns represent the attributes of places. Database management systems are valuable because they provide secure means of storing and updating data. Database administrators can protect files so that only authorized users can make changes. DBMS provide transaction management functions that allow multiple users to edit the database simultaneously. In addition, DBMS also provide sophisticated means to retrieve data that meet user specified criteria. In other words, they enable users to select data in response to particular questions. A question that is addressed to a database through a DBMS is called a **query**. (Some popular database products are MS-Access, SQL Server, Oracle®, Sybase®, Ingres® and IBM)

DATA RETRIEVAL, QUERYING AND DISPLAY

- The ability to query and retrieve data based on some user defined criteria is a necessary feature of the data storage and retrieval subsystem.
- Data retrieval involves the capability to easily select data for graphic or attribute editing, updating, querying, analysis and/or display.
- The ability to retrieve data is based on the unique structure of the DBMS and command interfaces are commonly provided with the software.
- Most GIS software also provides a programming subroutine library, or macro language, so the user can write their own specific data retrieval routines if required.

SPATIAL AND ATTRIBUTE (NON-SPATIAL) QUERRY

Querying is the capability to retrieve data, usually a data subset, based on some user defined formula. These data subsets are often referred to as *logical views*. Often the querying is closely linked to the data manipulation and analysis subsystem.

Many GIS software offerings have attempted to standardize their querying capability by use of a *Standard Query Language (SQL)*. This is especially true with systems that make use of an external relational DBMS. Through the use of SQL, GIS software can interface to a variety of different DBMS packages. This approach provides the user with the flexibility to select their own DBMS.

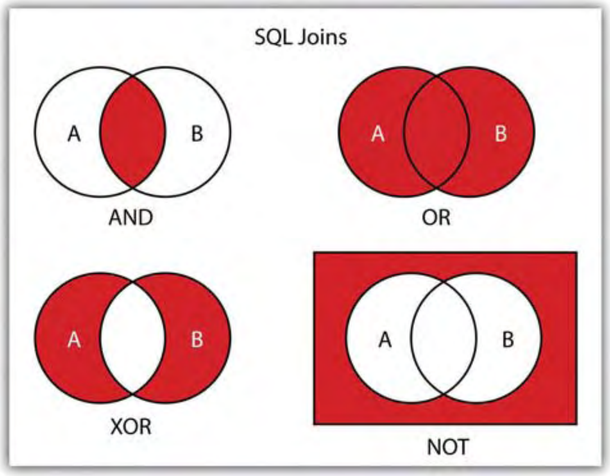
Attribute (Database) queries — use **set algebra** and **Boolean algebra**. Set algebra uses the operators like =, <>, >, >=, <, and <=., whereas an Boolean algebra (logical operators) LIKE, AND,OR, and NOT etc.,. Both of these types of queries focus on the features and attributes that are in the dataset. These selection criteria may be applied individually or in combination.

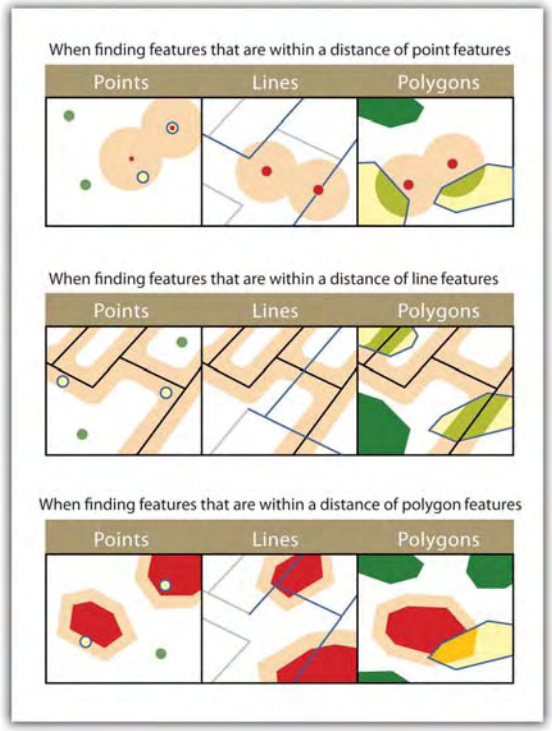
Spatial queries — Answers to spatial queries are derived directly from the location of features on a map. Information about the proximity of one parcel to other parcels or other kinds of features, such as roads, is not contained in an attribute table.

All basic queries have **three parts**: **A SOURCE**, **A Filter**, and A **RELATIONSHIP.**

This is true of both attribute and spatial queries. The source can be **a table or feature class**. The filter can be an **attribute value or a shape or feature**. The relationship between the source and the filter is based on **logical, comparison, or spatial operators** (Intersect, Are Within a Distance Of, Contain, and Are Contained By, etc.,)

RELATIONSHIP.





Non spatial / attribute queries

What is the population of this city?

Show me the roads longer than 1km

(Population and road length must be recorded in the attribute table)

Spatial queries

where is the closest bus stop? (Proximity)

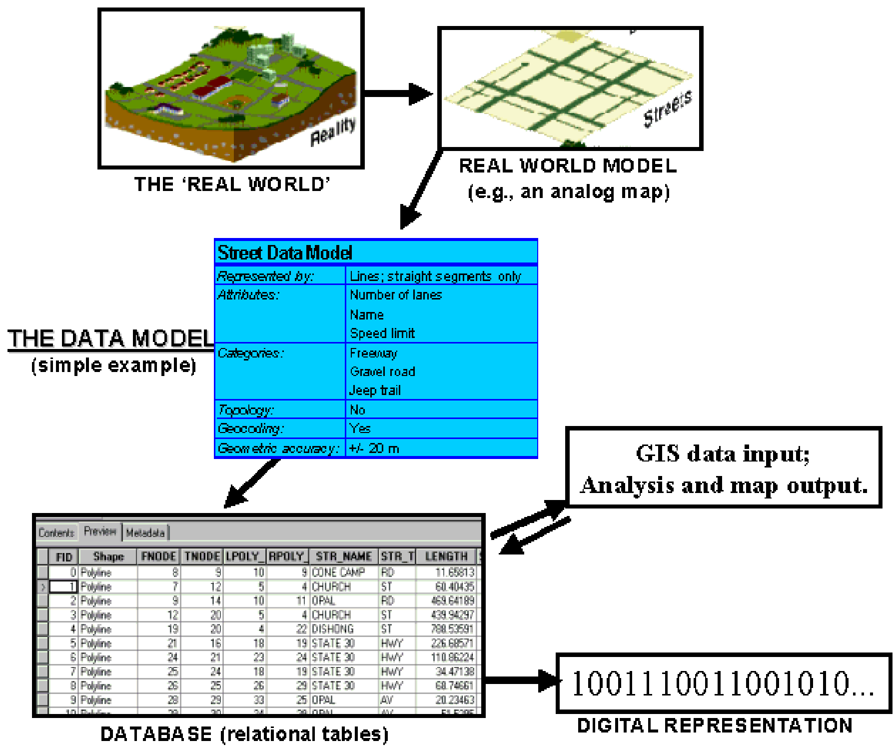
In what region is this city? (Containment)

What are the neighbours of Italy? (Adjacency)

Which regions are crossed by this river? (Intersection)

GIS DISPLAY (Visualization)

Visualizing large amounts of information **interactively** is one of the most attractive and useful capabilities of GIS. High-powered computers can alter any element of the display "**on the fly**," changing not only the look of the graphic image but also its interpretation. This ability to create **multiple perspectives** -- both literally and figuratively -- enhances a viewer's perceptive abilities to understand the phenomenon being studied like never before.



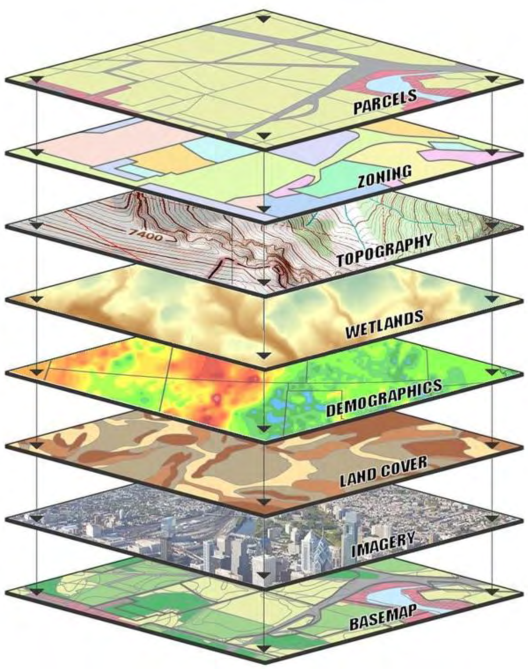
Source: https://dusk.geo.orst.edu/buffgis/Arc9Labs/Lab2/lab2.html

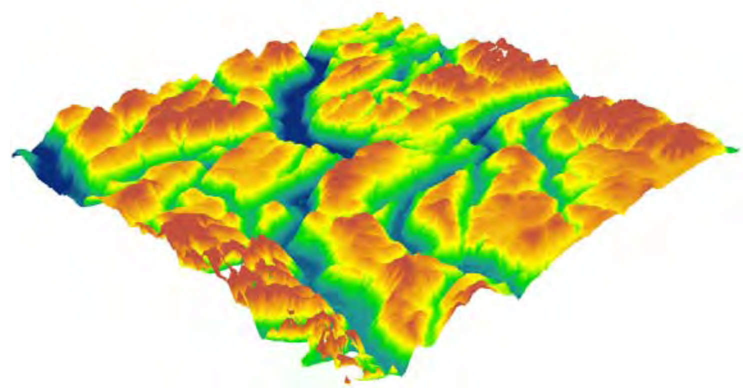
Visualizing data using current computing technology and interactive GIS has many advantages over doing so using traditional paper maps. The following is a partial list, one that grows with each new version of software and each new advance in hardware.

- **GIS is fully interactive**. Adding new fields of data, taking them off, changing the color scheme or form of the map, adding text, moving symbols, and a host of other capabilities give a user tremendous flexibility and power.

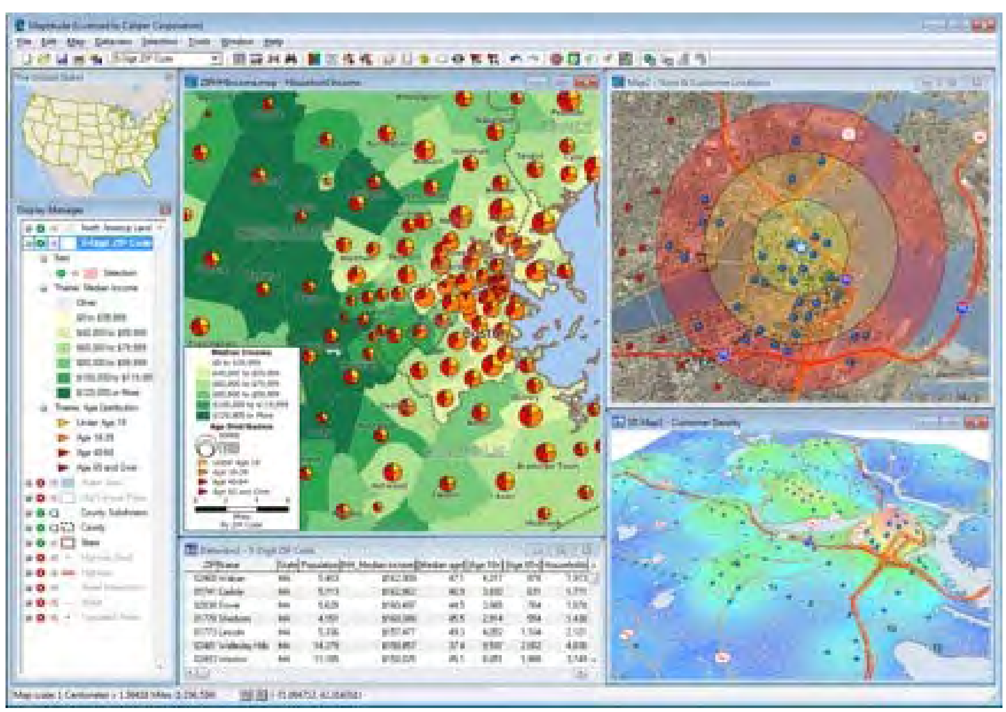
- **GIS displays are zoomable and pannable**. Moving around in the display offers a user new perspectives, greater (or less) detail, and new insight.

• Users can take advantage of computationally intensive functions such as "**draping**" a perspective view over a surface (like a digital elevation model) or creating the impression of three dimensions on a 2D display (the computer screen) using complex rendering and shading algorithms.





Source: https://www.usgs.gov/media/images/gis-data-layers-visualization Source: https://gisgeography.com/free-global-dem-data-sources/



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