

M.A. GEOGRAPHY SEMESTER II (CBCS)

GEOGRAPHY PAPER - 202 GEOINFORMATICS

SUBJECT CODE:92149

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March 2022, Print - 1

Published by	 Director, Institute of Distance and Open Learning , University of Mumbai, Vidyanagari, Mumbai - 400 098.
DTP Composed &	: Mumbai University Press,
Printed by	Vidyanagari, Santacruz (E), Mumbai

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M.A GEOGRAPHY Semester II (CBCS) Paper No 202 GEOINFORMATICS

1. Unit – I

- **1.1** Fundamentals of Remote Sensing: Definition and Concept, Process of Remote Sensing, Development of remote sensing Global and Indian
- **1.2** Electromagnetic Spectrum: Definition and Concept, interactions with atmosphere andearth's surface, Atmospheric window, Black body
- **1.3** Spectral Reflectance Curve: Concept, curves for land, water bodies/oceans, vegetation In Optical, IR, Thermal and Microwave bands
- **1.4** Fundamentals of aerial photography: Concept of stereoscopy and photogrammetry, geometric types of aerial photographs, photographic scale, measurements of distance, area and height, relief displacement, stereoscopic parallax, flight planning.
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- **3.3** Spatial Data Models: Vector and Raster, Vector representation (point, line, area and TIN), Concepts of arc, node, vertices and topology.
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- **4.3** Global Positioning System: Segments of satellite-based positioning systems, mainsystems NAVSTAR, GLONASS, Galileo and Indian GPS
- **4.4** Principles of positioning: Positional Accuracies, Relative Positioning, errors and sources

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FUNDAMENTALS OF REMOTE SENSING

Unit Structure

1.0 Objectives

- 1.1 Introduction: Fundamentals of Remote Sensing: Definition and Concept, Process of Remote Sensing, Development of remote sensing – global and Indian
- 1.2 Electromagnetic Spectrum: Definition and Concept, interactions with atmosphere and earth's surface, Atmospheric window, Black body
- 1.3 Spectral Reflectance Curve: Concept, curves for land, water bodies/oceans, vegetation In Optical, IR, Thermal and Microwave bands
- 1.4 Fundamentals of aerial photography: Concept of stereoscopy and photogrammetry, geometric types of aerial photographs, photographic scale, measurements of distance, area and height, relief displacement, stereoscopic parallax, flight planning.

1.0 OBJECTIVES

After the study of this module learners will be able to -

- Understand fundamental concepts in remote sensing and photogrammetry.
- Understand electromagnetic spectrum and its use in remote sensing process.
- Understand the reflectance value of various objects on the earth surface.
- Measure geometry and heights of earth's objects using photogramettry.

1.1 INTRODUCTION: FUNDAMENTALS OF REMOTE SENSING

Spatial Science has brought about revolutionary changes in developing technologies for acquiring and processing spatial information. Various ground based, low to high altitude airborne and space borne platforms have been used to acquire spatial information of repetitive coverage. Remotely sensed data have been put into various applications to solve socio-economic, physiographic and natural issues and also for appropriate Geoinformatics management of resources. It is therefore the need of time to understand fundamental concepts of Remote Sensing and Geographical Information System so as to make best use of these technologies in various fields of knowledge. This chapter aims at describing fundamental concepts and process related to remote sensing, aerial photography and related technologies. Besides, electromagnetic spectrum and its use in remote sensing process have also been discussed in subsections of this chapter.

1.1.1 Remote Sensing: Concept and Definitions

Remote Sensing refers to the process of acquiring information about phenomena, objects or surface of the earth while at a distance from it. Remote Sensing is defined as observing objects on the earth surface without coming into its actual physical contact. The term remote sensing is also attributed to the technology in which aircrafts and spacecrafts (satellites) are used for collecting information about the earth surface.

NASA defines Remote Sensing as "the acquisition and measurement of data/information on some properties of a phenomena, object or material by a recording device not in physical, intimate contact with the features under surveillance, techniques involved amassing knowledge pertinent to environments by measuring force fields, electromagnetic radiation by employing cameras, radiometer and scanners, radio frequency receivers, radar systems and other instruments. Canada Center for Remote Sensing (CCRS) defines Remote Sensing as the science of acquiring information about the earth surface without actually being in contact with it.

Remote sensing is the use of data collected by precision instruments such as cameras, probes, and sensors that are not being operated directly by a technician in the field. Remote sensing is the collection of information about an object without being in direct physical contact with the object. According to 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, objects, and classes on the Earth's land surface, oceans, and atmosphere.

This technology has been developed as spatial science mainly after 1980s in United States of America whereas it has rapidly been developed in India since the beginning of twenty first century. Remote Sensing is unique in the sense that it can be used to collect spatial data (unlike thematic cartography, statistics, Geographical Information System which depend upon spatial information that is readily available) that can be transformed into information into analog and digital image processing techniques using appropriate logical methods like digital image processing (DIP).

1.1.2 Remote Sensing process

Remote Sensing refers to the use of earth orbiting satellites to capture the information about the earth surface and the lower atmosphere. Satellite Remote Sensing is the most commonly used form of remote sensing for several applications. Satellite based sensors are capable of identifying objects on the earth surface depending upon the bandwidth in which it uses to capture the reflected energy from the given object on the earth surface. Detection and discrimination of objects or surface features means detecting and recording of radiant energy reflected or emitted by objects or surae material. Different objects reflect different amount and kinds of energy in different bands of electromagnetic spectrum. This unique property of earth surface objects depends upon their structural, chemical and physical properties, surface roughness, angle of incidence, intensity and wavelength of radiant energy.

There are various platforms of remote Sensing viz. ground based platforms, low altitude airborne platforms, high altitude airborne platforms and space borne platforms. Spatial data can be obtained by capturing the surface information by clicking photograph of the earth surface from certain elevation and can also be captured by putting high quality camera in aircraft or with the help of sensors placed in satellites.



The process of remote Sensing involves insolation form the source of energy (sun incase of passive remote sensing). The energy falls on the objects of the earth surface. Depending upon the inherent propertied of the surface objects certain amount of energy is reflected back from the earth's objects. This reflected energy is captured by the satellite sensors in form of digital numbers (DN). These digital number ranges from 0 to 255 wherein 0 indicate total absorption and zero reflectance (deep waters) where as 255 indicates total reflection and zero absorption (normally in case of fresh snow cover areas). The reflected energy captured by satellite based sensors is then sent to ground based receiving center which further is processed in different softwares with capacity to process and analyze spatial information. Fundamentals of Remote Sensing



Based on the source of illumination, remote Sensing can be classified into two types;



Types of Satellite Remote Sensing

1. Passive Remote Sensing

2. Active Remote Sensing

1. Passive Remote Sensing - Passive <u>remote sensing</u> in the optical regime (visible through thermal) depends on two sources of radiation. In the visible to shortwave infrared, the radiation collected by a remote sensing system originates with the sun. Part of the radiation received by a sensor has been reflected at the earth's surface and part has been scattered by the atmosphere, without ever reaching the earth. In the thermal infrared, <u>thermal radiation</u> is emitted directly by materials on the earth and combines with self-emitted thermal radiation in the atmosphere as it propagates upward. <u>Landsat TM</u>, <u>AVHRR</u>, <u>Spot</u>, <u>MODIS</u>, <u>IKONOS</u>, <u>Quickbird</u> are examples of passive remote sensing sensors.

2. Active Remote Sensing - Active <u>remote sensing</u> requires transmitting coherent <u>EM</u> wave at a target, and the target can vary from celestial objects or pointed toward the ground. The active system has two additional characteristics that the passive does not typically measure: (1) the time it takes for the transmitted EM wave to return (or arrive if the receiver and transmitter are in different locations) to the receiver and (2) the phase information of the returned EM wave. Both active and passive are interested in the polarization in some applications, but radar gains additional information from the Doppler shift. Digital Elevation Models (DEMs) and LIDAR are examples of active remote sensing sensors.

1.1.3 Development of Remote Sensing: Global trends

Remote Sensing was evolved as the ability of human being to observe regions of electromagnetic spectrum beyond the range of human vision. Remote Sensing has evolved from conventional photography, multi spectral and infrared photography, non-photographic sensors and scanners, platforms of remote sensing such as aircraft and satellite, communication, data transmission and computer technology.

The first photograph image created by light was made by Dagurre and Niepce (France) in the year 1839. French photographer Gaspard Felix and Laussedat attempted successfully to take aerial photograph. Soon after, photogrammetry and aerial photo interpretation became the areas of specialization of spatial sciences. American Society of Photogrammetry published its first journal "Photogrammetric Engineering" in the year 1934. During world war II, aerial photographs were expensively used for topographic mapping and military intelligence.

In post world war period, many developments took place in the field of space sciences. It includes development of non-photographic sensors, operating in ultra violet, infra-red thermal and microwave regions of electromagnetic spectrum. In 1957, first artificial satellite "Sputnik I" was launched. The term "Remote Sensing" was first used in 1960s. LANDSAT I launched by NASA in 1972 is considered to be landmark in the history of remote sensing in the world.

1.1.4 Development of Remote Sensing in India

India's <u>remote sensing</u> program was developed with the idea of applying space technologies for the benefit of humankind and the development of the country. The program involved the development of three principal capabilities. The first was to design, build and launch satellites to a sun synchronous orbit. The second was to establish and operate ground stations for spacecraft control, data transfer along with data processing and archival. The third was to use the data obtained for various applications on the ground.

India demonstrated the ability of remote sensing for societal application by detecting coconut root-wilt disease from a helicopter mounted multispectral camera in 1970. This was followed by flying two

Fundamentals of Remote Sensing

Geoinformatics experimental satellites, Bhaskara-1 in 1979 and Bhaskara-2 in 1981. These satellites carried optical and microwave payloads.

India's remote sensing programme under the <u>Indian Space Research</u> <u>Organization</u> (ISRO) started off in 1988 with the IRS-1A, the first of the series of indigenous state-of-art operating remote sensing satellites, which was successfully launched into a polar sun-synchronous orbit on March 17, 1988 from the Soviet Cosmodrome at Baikonur.

It has sensors like LISS-I which had a spatial resolution of 72.5 meters with a swath of 148 km on ground. LISS-II had two separate imaging sensors, LISS-II A and LISS-II B, with spatial resolution of 36.25 meters each and mounted on the spacecraft in such a way to provide a composite swath of 146.98 km on ground. These tools quickly enabled India to map, monitor and manage its natural resources at various spatial resolutions. The operational availability of data products to the user organisations further strengthened the relevance of remote sensing applications and management in the country.

1.2. ELECTROMAGNETIC SPECTRUM

Electromagnetic Spectrum is a dynamic form of energy that spread wave motion at a velocity of $c = 3*10^{10}$ cm/sec. Wave length, wave velocity and frequency are important parameters of wave motion. Electromagnetic energy radiates in accordance with the basic wave theory. This theory describes the electromagnetic energy that travel at the velocity of light.

1.2.1 Electromagentic Spectrum- concept and definitions

Electromagnetic radiation covers a large range of wavelengths. In remote sensing the maximum wavelength of EMR is concerned with the radiation from visible range of EMR (i.e. 0.4 to 0.7 μ m), to radar wavelength region.

Principal divisions of Electromagnetic Spectrum

Division	Wavelength
Gamma rays	10^{-8} to 10^{-11} cm
X-rays	10 ⁻⁶ to 10 ⁻⁸ cm
Ultraviolet light	$4*10^{-5}$ to 10^{-6} cm
Visible light	$7.6*10^{-5}$ to $4*10^{-5}$ cm
Infra-red light	10^{-1} to 10^{-5} cm
Microwave	10^2 to 10^{-1} cm
Radiowaves	10 ²

The Electromagnetic (EM) Spectrum



1.2.2 Insolation and its interaction with atmosphere and earth's surface

The atmosphere is never transparent to electromagnetic radiation. However, at some wavelengths it has good transparency whereas at other wavelengths it is absorbing. It also scatters radiation through the molecules, aerosols and cloud particles, which can affect visibility considerably. Interaction of direct solar radiation and reflected radiation from the earth's object constitute interfere with the process of remote sensing and is called as "Atmospheric Effects". The interaction of EMR with the atmosphere is important to remote sensing for two reasons. First, reflected energy from the earth surface is modified while traversing through the atmosphere. Secondly, the interaction of EMR with the atmosphere can be used to obtain information about atmosphere itself. Solar energy is traversed by various physical processes such as scattering, absorption and refraction.

1.2.3 Atmospheric window

The atmospheric transmission of solar energy occurs across different wavelengths. These specific wavelengths are also called spectral bands. The spectral bands for which the the atmosphere is relatively transparent are known as atmospheric window. The atmospheric windows are present in visible band (0.4 to 0.7μ m) and the infra-red regions of the Electromantic Spectrum. In the visible part solar transmission is mainly affected by ozone absorption and scattering. The region with wavelength greater than 1mm is used for microwave remote sensing. Hence, these atmospheric windows help in remote sensing process and acquisition of spatial information for its varied applications.

1.2.4 Black body

A black body is a body that is a perfect absorber and emitter of radiation. It is defined as a hypothetical object or material that absorbs all radiation incidents upon it and emits the maximum amount of radiation possible at that temperature.

1.3 SPECTRAL REFLECTANCE CURVE: CONCEPT

Of all interactions of solar radiation with the atmosphere, reflection is the most important interaction of solar radiation with the earth surface which is being used extensively in remote sensing. Reflection occurs when a ray of light is redirected as it strikes on a non-transparent surface, normally any object on the earth surface. The intensity of reflection depends upon various factors. Each object on the surface of the earth has unique reflectance value, the range of which is used to identify objects in satellite image.

Spectral reflectance is the ratio of reflected energy to incident energy as a function of wavelength. Various materials of the earth's surface have different spectral reflectance characteristics. Spectral reflectance is responsible for the color or tone in the photographic image of an object. Trees appear green because they reflect more of green wavelength. To obtain necessary ground truth, the spectral characteristics of each object play important role.

1.3.1 Spectral Reflectance curves for land, water bodies/oceans, vegetation

The spectral reflectance curve refers to the graphical representation of range of reflectance value for various objects on the surface of the earth.

1.3.1.1 Reflectance of Vegetation

Healthy growing vegetation appears to be green because there is selective absorption of chlorophyll bands outside green wave lengths. The absorption is only moderate so that only green light is reflected.



1.3.1.2 Reflectance of water body

Reflectance of water ranges from 5 to 70%. Reflectance is low at lower incidence angle and increases for higher incidence angles. The energy that is reflected by features on the earth's surface over a variety of different wavelengths will give their spectral responses in the remote sensing systems.

1.3.1.3 Reflectance of land

In some rocks, the near absorption bands, the absorption is strong enough for the reflectance to increase. Using different wavelengths, the variation of reflectance or emittance can be used to identify rock formation with minerals.

1.3.2 Optical and Infra Red Thermal

Sensors which operate in this region are;

Aerial camera: 0.38µm to 0.9 µm

Thermal Scanners: 3µm to 5 µm, 8µm to 16 µm

Multispectral scanner: 0.3µm to 1.1 µm

Vidicon / R.B.V.: 0.3µm to 1.1 µm

Microwave bands: 1 mm to 1 meter

1.4 FUNDAMENTALS OF AERIAL PHOTOGRAPHY

Photographs captured from aircraft / aeroplane is called as aerial photograph. Aerial photographs are being used widely for cartographic mapping on various scales and delineation of natural regions. Use of aerial photography has been increased by manifold. Aerial photographs are used for detailed terrain analysis as well as geological studies, forest mapping, soil survey, urban planning etc. Besides qualitative study and interpretations of aerial photographs, the quantitative analysis which involves measurement of linear distances, angle and height of the surface objects under investigation as well as the base map preparation.

1.4.1 Concept of stereoscopy and photogrammetry

Photogrammetry is the science and art of obtaining reliable measurements by means of photographs taken from calibrated camera. Photo interpretation is art of examining photo-images for the purpose of identifying objects and judging their significance.

In order to derive maximum information form aerial photographs, they are normally studied stereoscopically. A pair of photographs taken from two camera stations but covering some common are constitute a stereoscopic pair which when viewed gives three dimensional impression of the surface. It also gives the depth perception to the viewer when observing through stereoscopic images. Lens stereoscope and mirror prism stereoscopes are commonly used stereoscopes for aerial photo interpretation. Lens stereoscope or pocket stereoscope is most commonly used for visual photo interpretation.

1.4.2 Geometric types of aerial photographs

Photographs that are used for mapping and photo-interpretation can be categorized into following types;

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- a. Vertical photographs
- b. Terrestrial Photographs
- c. Oblique Photographs
- a. Vertical photographs: These photographs are taken when axis of aerial camera is vertical or near vertical to the earth surface.
- b. Terrestrial Photographs: These photos are taken from photo theodolites from camera stations on the ground with the axis of camera horizontal.



c. Oblique Photographs: Aerial photographs taken with the optical axis of the aerial camera tilted from the vertical are known as oblique photographs. These photographs cover the area of ground surface but the clarity and details diminishes at the edges of the photographs.

1.4.3 Photographic scale, measurements of distance, area and height:

1.4.3.1 Photographic scale - refers to the ratio between distances of the aerial photograph and the actual ground distance.



Photo Scale = $\frac{Photo \ distance}{Ground \ distance}$ Photo scale = $\frac{(Focal \ length \ of \ the \ camera)f}{(Flying \ Height \ above \ ground \ level)H}$

The scale of the photograph is not uniform if there is irregular terrain. We can determine either the average scale of the photograph as the whole scale of the photograph. In oblique photograph the scale is not constant.

scale of the photograph. In oblique photograph the scale is not constant. Scale of the photograph changes irregularly due to elevation difference of the surface and changes continuously due to inclination of the camera axis.

1.4.3.2 Measurement of distance, area and height

The height difference – The feasibility of finding height difference of objects from the ground / mean sea level is the most important quality of aerial photography. This can be achieved by calculating parallax.

h (height of an object) = d (relief displacement) $*\frac{Flying Height above the datum H}{Ground radial distance r}$

Height of an object based on shadow length:

h = Shadow length L * tan e angle

tan e = Height / Shadow Length

1.4.4 Relief displacement, stereoscopic parallax, flight planning.

Relief displacement is the radial distance between where an object appears in an image to where it actually should be according to a Planimetric coordinate system. The images of ground positions are shifted or displaced due to terrain relief, in the central projection of an aerial photograph.

The measurement of relief displacement depends upon:-

- A. The amount of relief displacement that is d, on a vertical photograph is directly proportional to the difference in the elevation h, between the object whose image is displaced on the datum.
- B. It is directly proportional to the radial distance that is r between displaced image and the principal point.
- C. It is inverse proportional to the altitude H of the camera above the datum.

Relief displacement is expressed mathematically as:

d = hr/H

d = Relief Displacement

h = Height of the object

- r = Radial distance from nadir point
- H = Total altitude of the camera or flying height

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Solution:

H = 25000 feet or $25000 \times 30 = 750000$ cms

h = 30 meters or 30x100 = 3000 cms

r = 6 inches or $6 \ge 2.5 = 15.0$ cms

d =hr/H d

= 3000 x 15.0/ 750000

= 0.06 cms

Sample Questions.

Question 1. Fill in the blanks and complete the statements.

- 1. ______ is the process of obtaining information of the earths' objects without coming into its actual physical contact.
- 2. _____ remote sensing depend upon solar energy for illumination.
- 3. RADAR sensors are used for _____ remote sensing.
- 4. 0.4 to 0.7μ is the wavelength of ______ spectral band.
- 5. The graphical representation of reflectance of various objects is called_____.
- 6. QuickBird sensor is example of ______ remote sensing.
- 7. American Society of Photogrammetry published its first journal titled _______ in the year 1934.
- 8. This reflected energy is captured by the satellite sensors in form of
- 9. French photographer Gaspard Felix and Laussedat attempted successfully to take _____.
- 10. In 1957, first artificial satellite named "_____" was launched.

Question 2. Answer the following question in brief.

- 1. Define Remote Sensing and explain the process of remote sensing.
- 2. Discuss the development of remote sensing technology in India.
- 3. Write a brief note on electromagnetic spectrum.
- 4. What is phtotogrammetry? Explain its process.
- 5. Write a note on measurements in photogrammetry.
- 6. Write a note on relief displacement.



PLATFORMS AND ORBITS

After going through this chapter you will be able to understand the following features

Unit Structure

- 2.1 Objectives
- 2.2 Introduction
- 2.3 Subject Discussion
- 2.4 Platforms and orbits: types of platforms used for remote sensing, types of orbits (geostationary and polar)
- 2.5 Sensing of electromagnetic energy: Measurement of radiance, conversion of radiance to digital number
- 2.6 Resolutions and Sensors: Types of resolutions, Remote Sensors and types based on resolutions and sources of illumination, overview of spaceborne sensors.
- 2.7 Visual Image Interpretation: Image display and color composites, elements of visual image interpretation
- 2.8 Summary
- 2.9 Check your Progress/Exercise
- 2.10 Answers to the self-learning questions
- 2.11 Task
- 2.12 References for further study

2.1 OBJECTIVES

By the end of this unit you will be able to –

- Understand the concept of various remote sensing Platforms and orbits
- Understand about sensing of electromagnetic energy
- Know about Resolutions and Sensors
- Understand the concept of Visual Image Interpretation

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2.2 INTRODUCTION

In this chapter we will study about various remote sensing Platforms and orbits. We learned about the concepts of electromagnetic energy in the previous chapter. In this chapter we shall learn about sensing that energy. We will also try to understand about the various sensors and the concept of resolution. We shall learn about the elements of visual image interpretation and Image display and color composites.

2.3 SUBJECT DISCUSSION

Remote sensing is the process of obtaining information about the earth's surface through measurement and analysis of electromagnetic energy reflected or emitted from terrain using devices called sensors. This process is achieved by launching platforms for sensing, designing the path and orbits, and collecting remotely sensed data, processing the information collected and finally interpreting the results.

2.4 PLATFORMS AND ORBITS: TYPES OF PLATFORMS USED FOR REMOTE SENSING, TYPES OF ORBITS (GEOSTATIONARY AND POLAR)

As we discussed in an earlier chapter, remote sensing is a process of obtaining information about terrain by measurement of the electromagnetic energy(EME) reflected/ emitted from the object using photographic or non-photographic devices. These photographic or non-photographic devices are called sensors from various platforms. These platforms can be terrestrial, aerial or space born.

2.4.1 Terrestrial platforms

These platforms are also known as ground born platforms. These are basically ground observations conducted via field study or laboratory. These devices include handheld platforms like tripods for radiation detector, spectroradiometers , cherry pickers for wider view , buildings and towers, vehicles with Vehicle Video Recorders etc. The data produced by these devices are used in laboratory studies and experiments and for field observations as reference data. This data collected on ground is also used for ground truth verification for the data obtained from satellites.





Figure 2.1- Remote sensing platforms (Image recreated from the reference After Barcegar, 1983 and R. P. Gupta, 1991)

2.4.2 Aerial platforms

Aerial platforms are also known as airborne platforms. These platforms use photographic devices to do remote sensing. These aerial platforms were used to capture earth images at early stages of remote sensing. The technique of capturing photograph was developed by Joseph NicéphoreNiépce. This technique was later on used to capture the earth images with elevated areas, Kites, Pigeons and hot air balloons.

≻ Balloon

The First aerial photograph taken by Gaspard Felix known by the pseudonym Nadar in 1858. After that, balloon photography was used for earth observation and nature conservation research. Hot air balloons float at an average height of 20 to 30 km. Today balloons are only used for Natural conservation or meteorological research as better stable technology is developed for aerial photography.

> Drone

Drone is a new technology developed to capture earth's surface up close. It is an unmanned and automatic vehicle which can be operated remotely. It carries devices such as high resolution cameras to capture images and video. The device can transfer capture data in real time at the receiver's end. It can also carry a device for infrared and radar observation. It is widely used for surveillance for security purposes by administrative and private companies.

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≻ Aircraft

First time an airplane was used for aerial photography was in 1908. World war I and II saw the reconnaissance of aerial photography. After World war II aerial photography became more advanced due to technological warfare. Specially designed aircrafts such as Lockheed- U2, Lockheed F-117, SR 71 developed during this time. Later on, stealth technology was developed which helped in capturing radar, infrared as well as composite images. During the Vietnam war UAV(Unmanned Aerial Vehicle) were used by the American military to survey the unknown territory. Aerial photographs are captured by non-military commercial aircrafts as well. These are mostly single- wing aircrafts with GPS onboard that keep track of the aircrafts location during data collection.

Aerial photography provides detailed spatial information if captured with the low altitude imagery. Along with aerial photography aircrafts can also be used for multi- spectral, thermal and microwave image capturing. The images taken by aircraft are sometimes across- track and sometimes along track scanners.

2.4.3 Space- borne platforms

These platforms are also known as satellite platforms. This imagery system starts with the altitude of 250 km and goes up to 36000 km. Spaceborne platforms are being used for constant imaging and analysis of earth. It is also used as an assistant on weather predictions, mineral and resource exploration, crop management, water and forest management, pollution monitoring etc. Spacecraft launched in Earth orbit can be classified into Earth resource satellites, Meteorological satellites and satellites with Microwave sensors. These satellites can also perform multiple tasks such as collection of earth observation and meteorological data together. Satellites can be also categorized from Viewing parameters. These parameters are revisit interval, observation angle , altitude and resolution. The viewing parameters can be studied after understanding the orbital characteristics of the satellite.

Advantages of space borne platforms:

- Satellite imaging systems can cover a large area, large data can be collected in one mission, thus it is relatively low cost and one time investment.
- As Satellites are longer missions, frequent and repetitive data of the same area can be collected.
- Data can be analyzed with advance commuting, digital processing and quantitative measurement

2.4.4. Types of orbits -geostationary and polar

Satellites always move in the plane called the orbital plane which passes through the centre of earth. (Figure 1.2). The orbit inclination is zero then the orbital plane is the Equatorial plane, If the orbital inclination is between 0^{0} to 180^{0} then it is an Inclined plane and if it is 90^{0} then it is the Polar plane. If the orbit is near to 90^{0} then it is called a Near polar orbital plane. (George Joseph, 2003)



Figure 2.2- Types of orbital planes (Image recreated from the reference George Joseph, 2003)

Orbital characteristics of satellite can be divided into two basic types:

- Geostationary
- Sun-synchronous

> Geostationary

These satellite orbits are also known as geosynchronous equatorial Orbit (GEO). As the name suggests these satellite orbits are stationary with 'Geo' meaning earth. They are stationed at an altitude above 36000 km mostly fixed at one point. This point is near the equator. Communication satellites are mostly placed in this orbit. This orbit is also used by meteorological and navigation satellites. These satellites are inclined at 0° and take a period of 1436 minutes. There are more than 62 geostationary satellites currently orbiting around earth. (Number may vary)

Sun-synchronous orbit

This orbit is also called a helio-synchronous orbit. The satellite will pass through the same location or latitude at the same local solar time. The satellites like Earth observation and imaging, ocean observation, weather, and reconnaissance satellites are designed with Sun-synchronous orbit. The inclination angle of these satellites is at 90[°]. As the satellite moves along with the near polar orbit, solar illumination can be achieved for better imaging. Especially with the multispectral data this proves to be very useful for analysis.

Geoinformatics Multiple satellites are available for Earth observation and its various applications. The satellites can be categorized by using their resolution.

In case of **spatial resolution** the satellites can be categorized into :

- Low resolution systems- resolution approx. 1 km
- Medium resolution systems- resolution approx. 100 m to 1 km
- High resolution systems resolution approx. 5 m to 100 m
- Very high resolution systems- resolution approx.5 m

In case of spectral data acquisition the satellites can be categorized into :

- Optical and thermal image
- Panchromatic (gray-scale) image
- Multispectral image
- Super spectral image
- Hyperspectral image
- Synthetic aperture radar (SAR) image
- Single frequency
- Multiple frequency
- Single polarization
- Multiple polarization

(Dr. S. C. Liew, Centre for Remote Imaging, Sensing and Processing, National University of Singapore)

2.5 SENSING OF ELECTROMAGNETIC ENERGY: MEASUREMENT OF RADIANCE, CONVERSION OF RADIANCE TO DIGITAL NUMBER

Remote sensing data especially multispectral data can be converted into visual data. This visualization or imagery can be interpreted for basic features on the ground; but when it comes to detailed analysis of the data, radiometric measurement becomes important. The unit of electromagnetic radiation is the rate of transfer of energy in Watt. This unit is recorded at a sensor, per square meter on the ground. This also records measurement of per unit wavelength. (GEOG 472: Remote Sensing: Digital Image Processing and Analysis). This energy is called radiance.

In the previous chapter we understand the concept of radiance in detail. Radiance is nothing but the amount of radiation received by a remote sensing device from a unit of area. This radiation received by the device is captured in a digital unit called pixels.



Figure 2.3- Radiance captured by pixels (Image recreated from Dr. S. C. Liew, Centre for Remote Imaging, Sensing and Processing, National University of Singapore)

As we can observe in figure 2.3 an image is a recreation of the real scene on earth. This representation. The real scene is captured in a twodimensional array called pixels. These pixels carry information about the location of the real scene and its intensity or radiance value. The pixels are formed with row and column coordinates. (Figure 2.4) These row and column coordinates are corresponding with geographical coordinates i.e. Longitude and latitude.



Figure 2.4-Two-dimensional array called pixels

Geoinformatics

The radiance value captured by the pixel is recorded as DN or Digital number. This data is stored in binary digits or bits . (Table 2.1)

bit Digital number	Range	Remark
7-bit	0 to 127	
8- bit	0 to 255	
9- bit	0 to 511	Lowest DN value - No.
10- bit	0 to 1023	reflectance
11- bit	0 to 2047	Highest DN value= Highest reflectance
12 bit	0 to 4095	

Table 2.1 Bit Digital Number

A digital number (DN) is measurement of sensitivity received by a lightsensitive cell installed in a sensor. The more energy or light from the reflectance will be stored with a larger DN. The reflectance received by each object is differently stored in each pixel as discussed in table 2.1. There are several pathways how this electromagnetic energy or light from the sun reaches the sensor (Schott, 1997).

The most common ways are:

- Direct reflected light: Light received by sun which reflected back to atmosphere directly captured by sensor
- Skylight: Sunlight scattered by the atmosphere, and then reflected by the earth which is captured by sensor
- Air light: Scattered sunlight by the atmosphere directly captured by sensor without interaction with the earth

Steps are required to convert these received DNs to absolute radiance values or surface reflectance. These steps are called spectral preprocessing chains.



Figure 2.5- Spectral preprocessing chains-Conversion of various DN values to Land surface reflectance

The process which can be observed in above figure 2.5 is a simple representation of the conversion process; the actual process is much more complex with mathematical calculations. Every sensor has a different equation to convert these digital numbers as spectral specifications of each sensor are different.

For example

LANDSAT

Conversion to TOA Radiance *

Landsat Level-1 data can be converted to TOA spectral radiance using the radiance rescaling factors in the MTL file:

Lλ=MLQcal+AL

where:

- > $L\lambda$ = TOA spectral radiance (Watts/(m2 * srad * μ m))
- ML =Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)
- AL=Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)
- > **Qcal**= Quantized and calibrated standard product pixel values (DN)

*Formula taken from USGS

After this calculation of DN values to DN reflectance values, the two dimensional data array is processed into a visual image. For this conversion reflectance is measured discussed in table 1.1. In the data set Geoinformatics lowest DN value represents more absorption of solar radiation and less reflectance whereas highest DN value represents more reluctance and less absorption. Thus the data is converted according to the DNs of reflectance. As can be observed in figure 2.6 each pixel is carrying a DN value. If one uses the gray scale given according to the reflectance where 0 represents no reflectance and 32 presents high reflectance, it can create a visual image.



Figure 2.6- SConversion of DN values to reflectance (recreated image)

It is important to note that each sensor processes these values differently thus we have different outcomes of the same scene. The real scene and its representation may not change drastically but smaller details may. Resolution of each sensor also contributes to the calculations of the DN values as low resolution data's reflection values will be different from high resolution data's reflection values. Therefore understanding resolution, sensors and their specification becomes crucial to understand remote sensing data.

2.6 RESOLUTIONS AND **SENSORS:** TYPES OF **RESOLUTIONS. REMOTE** SENSORS AND **TYPES** AND **SOURCES** BASED ON RESOLUTIONS OF ILLUMINATION, **OVERVIEW** OF **SPACEBORNE SENSORS.**

2.6.1 Resolution

Resolution can be defined as the ability of pixels to capture the maximum information of the ground. Resolution means how much detail is captured by the digital image of that area. Every sensor has a different resolution.

The image resolution can be categorized as

- Spatial resolution
- Spectral resolution

• Temporal resolution

• Radiometric resolution

Spatial resolution -

Spatial resolution refers to the capacity of pixels holding spatial area and its details. It is measured with the distance. The spatial resolution depends upon altitude of the remote sensing platform.



Figure 2.7 - Spatial resolution (Images from Google Earth)

As one can observe in figure 2.7 the spatial resolution changes as the scale of the image changes. Scene A is covering a large area but if we zoom in each pixel will carry very less amount of information. However, as we progress towards scene B and C the coverage area is lesser but each pixel carries a lot of information. In scene C we can even see man made features like buildings and transport lines. Spatial resolution depends on the Instantaneous Field of View (IFOV) and by the swath width.



Figure 2.8 - Swath and Instantaneous Field of View (IFOV)

Geoinformatics Swath width refers to complete coverage of the digital image of the real scene which is determined by the field of view of the sensor. As the sensor is sensing through the swath width, Instantaneous Field of View (IFOV) captures information in pixels. (Figure 2.7) If the vehicle carrying sensor goes to higher altitude the swath and field of view increases. This results in pixels collecting lesser information. Based on the quality of images the spectral resolution can be categorized into coarse or low and smooth or high resolution. The high-resolution sensors are mostly used for micro region studies i.e. Large scale maps with smaller area, wherein low-resolution images are used for national and global studies.

Spectral resolution

Spectral resolution deals with electromagnetic radiation in optical remote sensing. We studied in an earlier unit about spectral reflectance curves and spectral bands. All features on the earth surface have different spectral signatures. This spectral signature is captured by each of the spectral bands. For example, vegetation. (Figure 2.8) The optical range where reflectance is less than 20 % is due to chlorophyll absorption. In the Near infrared due to reflection of cell structure reflectance goes upto 40%. After that the presence of water contents, again lower down the reflectance.



Figure 2.9 - Spectral reflectance curve- Vegetation

As we can observe in Figure 2.8, Each spectral band reflects differently for the vegetation feature. Thus, spectral resolution is important to obtain specific data if you need to study specific features.

Temporal resolution

As we studied the advantages of remote sensing data, it has constant observation of earth. From the early aerial photographs to modern high resolution data, earth is being observed throughout the time. Modern satellite missions are designed with the time interval. It is pre-designed for when the satellite position will be covering the location of the earth again. This temporal interval is known as temporal resolution. The temporal intervals are calculated with the number of days. For e.g.IRS -1 A returns to the same position to cover the same location on the earth in 22 days. So we can say that IRS-1A has 22 days temporal resolution. Temporal resolution is also called the frequency of occurrence of the satellite Platforms and orbits vehicle.

Radiometric resolution

The radiometric resolution of an imaging system determines its ability to discriminate very slight differences in energy. (nrcan.gc.ca). Coarse radiometric resolution may not be able to differentiate the range of reflectance. For example in Table 1.1 8 bit data only have a range of 0 to 255 where in 11 bit data have 0 to 2047 range. This means 8 bit data can dissect the reflectance only in 256 values wherein 11 bit data can dissect it into 2048 values. Higher radiometric resolution can detect differences in reflected energy with precision.

2.6.2 Sensors

Sensor is a device which is designed to detect electromagnetic radiation. This radiation may be reflected or maybe emitted from an object. Sensor records this transmission of the EMR and stores it for analysis.

The sensors can be classified on the basis of Energy source, Output, Spectral region and number of bands used.

> Energy source

Sensors can be categorized on the basis of energy source. There are two types of sensors in this category: **Active and passive sensors.**

Active sensor uses own energyas a source for illumination.



Figure 2.10 - Active remote sensing

Active sensors are operable at any time and any season as they are not dependent on sun's illumination. They also provide a wide range of wavelengths, especially large wavelengths such as microwaves.

Passive sensor uses radiation from other objects a source for illumination. They mostly depend on the energy available naturally.

Geoinformatics

Therefore, they have limitations of time and seasons to capture optical wavelengths. The illumination emitted by the sun is reflected back to the sensor. Sensor records and stores it. (Figure 2.11) Most earth observation satellites have passive sensors to capture the optical spectral range.



Figure 2.11 - Passive remote sensing

> Output types

Imaging and non-imaging sensors

Imaging sensors produces data which can be converted into visualized data. This data is spatial in nature, which has Digital numbers(DN). These numbers later on can be converted into spatial data. (Figure 2.5) On the other hand non- imaging data is point data which produces a single value. This single value is acquired from a single point which is observed. These are target sensors.

> Spectral region

These sensor categories are based on the spectral band. (Table 2.2)

Sensor type	Spectral Range
Optical	0.3 µm- 3µm
Thermal	3 μm- 1mm
Microwave	1 mm- 1m

Table 2.2 Sensors categorized based on the spectral band

> Number of bands

Sensors can also be categorized based on the number of spectral bands they can capture and process. For example, Panchromatic sensors - These sensors can cover all the visible spectrum with gray scale. Multispectral sensors on the other hand can capture visible, thermal as well as microwave spectrum at a time. One can also produce Multispectral images and create false color or true color composite images for better understanding of features. If we extend the spectrum with narrow intervals we need to use Hyperspectral sensors. This type of sensor can focus on minute details of the spectrum and produce high definition images.

2.6.3 Scanning systems

As we are studying sensors we need to understand the concept of various scanning systems as well. Resolution and image quality as well as digital image process are dependent upon these scanning systems. There are two basic scanning motions of a sensor:

Across track (whiskbroom) scanning sensor



A. CROSS-TRACK SCANNER.

(Image source: Canada Centre for Remote Sensing)

Figure 2.12 Across track (whiskbroom) scanning sensor

In this arrangement, scanning lines are perpendicular to the direction of movement of the sensor platform. The sensor is usually an opticalmechanical device which operates by use of a rotating or oscillating mirror, focusing radiation from different points on the target surface into the detector as it spins. (School of Geography, University of Southampton)

Along track (Push broom) scanning sensor



Figure 2.13 Along track (Push broom) scanning sensor

This is an alternative configuration; whereby scanning lines are oriented parallel to the direction of motion of the sensor platform. Instead of a mirror there is an array of small sensitive detectors stacked side by side, each of which is a charge-coupled device (CCD). Each element in this detector array records data from a unique ground resolution element, hence multiple observations are recorded at the same time. Different sensors in the array may record radiation in different wavebands relating to the same GRE. (School of Geography, University of Southampton)

2.6.4 Major Remote Sensing Systems

LANDSAT

Landsat is an Earth-observing satellite mission. This mission was jointly launched by NASA and the US Geological Survey (USGS). NASA launched the first Landsat satellite on 23 July 1972. After the launch LANDSAT became a pioneer in earth observation and paved the way for many space agencies. Landsat was originally called the Earth Resources Technology Satellite (ERTS). The most recent launch (Landsat 7) was on 15 April 1999.

Landsat 1 to 3 = Landsat Multispectral Scanner (MSS)

Landsat 4 and 5 = MSS and Thematic Mapper (TM) instruments

Landsat 7 = Enhanced Thematic Mapper Plus (ETM+) scanner

Landsat 8 = Operational Land Imager (OLI) and the Thermal Infrared Platforms and orbits Sensor (TIRS)

(USGS)

Landsat 1–3 MSS	Landsat 4–5 MSS	Wavelength (micrometers)	Resolution (meters)
Band 4 – Green	Band 1 – Green	0.5 – 0.6	60*
Band 5 – Red	Band 2 – Red	0.6 - 0.7	60*
Band 6 – Near Infrared (NIR)	Band 3 – NIR	0.7 – 0.8	60*
Band 7 – NIR	Band 4 – NIR	0.8 – 1.1	60*

Table 2.3 LANDSAT resolution specifications (USGS)

SPOT

SPOT -Système Pour l'Observation de la Terre are imaging satellites launched by France with support from Sweden and Belgium. There have been 5 SPOT satellites in total. All the SPOT satellites are near-polar and sun-synchronous orbits. The revisit period is a 26 days.

SPOT 1 launched February 22, 1986 = panchromatic and 20 meter multispectral Sensor

SPOT 2 launched January 22, 1990

SPOT 3 launched September 26, 1993

SPOT 4 launched March 24, 1998

SPOT 5 launched May 4, 2002 with 2.5 m, 5 m and 10 m resolution.

SPOT 6 launched September 9, 2012

SPOT 7 (Azersky) launched on June 30, 2014

Image resolution for SPOT 6 and 7

- Panchromatic: 1.5 m
- Color merge: 1.5 m
- Multi-spectral: 6 m

Geoinformatics IKONOS

The IKONOS satellite sensor was successfully launched as the first commercially available high-resolution satellite sensor on September 24, 1999, at Vandenberg Air Force Base, California, USA.

The IKONOS satellite sensor is a high-resolution satellite operated by MAXAR Technologies Inc.

- Launch Date =24 September 1999 at Vandenberg Air Force Base, California, USA
- Operational Life =Over 7 years
- Orbit =98.1 degree, sun synchronous
- Speed on Orbit = 7.5 kilometers per second
- Speed Over the Ground =6.8 kilometers per second
- Revolutions Around the Earth =14.7, every 24 hours
- Altitude = 681 kilometers
- Image Swath =11.3 kilometers at nadir; 13.8 kilometers at 26° offnadir
- Equator Crossing Time =Nominally 10:30 AM solar time
- Revisit Time= Approximately 3 days at 40° latitude
- Dynamic Range =11-bits per pixel
- Image Bands = Panchromatic, blue, green, red, near IR

The resolution of IKONOS included:

- 3.2m multispectral
- Near-Infrared (NIR) 0.80-meter
- Panchromatic resolution at nadir

Its applications include both urban and rural mapping of natural resources and natural disasters, tax mapping, agriculture and forestry analysis, mining, engineering, construction, and change detection. It can yield relevant data for nearly all aspects of environmental study. IKONOS images have also been procured by Satellite Imaging Corporation for use in the media and motion picture industries, providing aerial views and satellite photos for many areas around the world. Its high-resolution data makes an integral contribution to homeland security, coastal monitoring and facilitates 3D Digital Terrain Models (DTMs) and Digital Elevation Models (DEMs). (satimagingcorp.com)
India embarked on satellite launch vehicle development in the early 1970s. ISRO in 1979 and 1981, respectively began the development of an indigenous IRS (Indian Remote Sensing Satellite) program. India today has two very capable launch systems namely PSLV (Polar Satellite Launch Vehicle) and GSLV (Geosynchronous Satellite Launch Vehicle). In 1995, IRS imagery was made available to a larger international community on a commercial basis. The initial program of Earth-surface imaging was extended by the addition of sensors for complementary environmental applications. This started with the IRS-P3 satellite which is flying MOS (Multispectral Optoelectronic Scanner) for the measurement of ocean color. The IRS-P4 mission is dedicated to ocean monitoring.

The first generation satellites IRS-1A and 1B were designed, developed and launched successfully during 1988 and 1991 with multispectral cameras with spatial resolutions of 72.5 m and 36 m, respectively. The second generation remote sensing satellites IRS-1C and -1D with improved spatial resolutions have been developed and successfully launched in 1995 and 1997, respectively. IRS-1C/1D data has been used for cartographic and town planning applications. (ESA 2000 - 2022)

Parameter	LISS-I	LISS-II A/B
Focal length	162.2 mm	324.4 mm
FOV, IFOV	9.4°, 80 μrad	4.7°+ 4.7°, 40 μrad
Spectral bands (µm)	0.46 - 0.52 (blue)	0.46 - 0.52 (blue)
	0.52 - 0.59 (green)	0.52 - 0.59 (green)
	0.62 - 0.68 (red)	0.62 - 0.68 (red)
	0.77 - 0.86 (NIR)	0.77 - 0.86 (NIR)
Ground resolution	72.5 m (each band)	36.25 m (each band)
Swath width	148 km 2 x 74 km	
Radiometric resolution	7 bit	7 bit

Table 2.4 IRS -LISS resolution specifications (Information taken from eoportal.org)

IRS

2.7 VISUAL IMAGE INTERPRETATION: IMAGE DISPLAY AND COLOR COMPOSITES, ELEMENTS OF VISUAL IMAGE INTERPRETATION

2.7.1 Image display and color composites

Image display tool in digital image processing is used for displaying digital data into a visual image. Image can be defined as a twodimensional function. They are arranged in rows and columns. If it is spatial data the geographical coordinates represent rows and columns of the image. Following are the basic types of images:

- 1. Binary this image contains only two values 0 and 1 0 refers to black and 1 refers to white on the image. This image is Monochromatic.
- 2. 8 bit color format as we studied earlier 8 bit format has 256 different shades of colors. In this grey shade image where 0 refers to black and 255 stands refers to white and 127 refers to grey
- 3. 16 bit color format- This format has 65,536 different colors in it. An image in this format is divided into RGB format.

Color composition in Image

A multispectral image consists of several spectral bands of data together. For better understanding of the data, proper visual display plays a vital role. When one combines three or more bands together it is called a color **composite image**. Every band from the spectrum has a reflectance value. This reflectance value is passed through either same or different color filters to create the color composite image three primary colors filters are used. These colors are Blue, Green and Red from the visible spectrum. Sometimes these primary colors are also complemented by complementary color filters Yellow, Magenta and Cyan respectively. (Table 2.5) Various combinations of these colors produce a range of colors. (Figure 2.14) Creating these combinations is called a color composite.

Primary colors		Complementary colors	
Blue		Yellow	
Green		Magenta	
Red		Cyan	

Table 2.5 Primary ar	d Complementary col	ors (J. Jenson, 2006)
----------------------	---------------------	------------------------

Platforms and orbits



Figure 2.14 Primary and Complementary colors (Image recreated from pngitem.com)

These composites can be further divided into True color composite and False color Composite.

• **True Color Composite-** This composition of image is achieved using true color filters i.g. Red, Blue and Green. These images are closer to the human eye and features are easy to understand.

• False Color Composite(FCC)- This composition of image is achieved using different color filters on different bands. With this technique some of the features like vegetation are easy to identify. For example

- Red band passes through- NIR filter
- Green band passes through Red filter
- Blue band passes through Green filter

Please note in this color scheme NIR filter is used. We have observed in figure 2.9 vegetation reflectance is very high at the NIR range in the spectrum. Thus using FCC we can get a clear picture of vegetation in the image. If we observe the Figure 2.15 the use of FCC enhanced the vegetation feature. One can have multiple combinations with the filters to extract information needed for specific study.



Figure 2.15 True and FCC (Images from Google Earth and IRS 1 D)

Geoinformatics **2.7.2 Elements of visual image interpretation**

Interpretation of any image is a science as well as art. Science is included with development of technology and exploring the concepts like radiance which we learned earlier in chapter. Art of interpretation comes with how the interpreter associates the feature in the image using his knowledge. In recent years digital image processing and resolution of images made image interpretation less complicated. Yet as a student of geoinformatics one needs to understand the basics of image interpretation. One needs following informationfor optical image interpretation:

- Radiometric information such as brightness, intensity
- Spectral information as color or tone
- Textural information
- Geometric information as size and shape
- Contextual information as association

1. Color or tone

If the image is panchromatic then the tone element is used for interpretation wherein color composite image color is used as an element of interpretation. Tone of the image represents reflectance of the image brighter the feature whiter the tone. (Figure 2.16)



Figure 2.16 Color or Tone (Image from Google Earth)

2. Texture

Texture means the tonal arrangement in an image. Texture can be described as fine, medium, coarse etc. (Figure 2.17)



Figure 2.17 Texture (Image from Google Earth)

3. Shape

Shape is an outline of a feature. There are many shapes which can be easily identified like the Delta region, Sand dunes, ox-bow lake etc. Many man-made objects also have specific shapes such as stadiums, runways etc. (Figure 2.18)



Figure 2.18 Shape (Image from Google Earth)

4. Shadow

If the image is taken by a low- sun angle then shadow appears in the image, especially if the feature is elevated. Shadow can be useful to determine the elevation of the feature and sometimes identify it. (Figure 2.19)





5. Pattern

Pattern means an arrangement of lines, shapes, colors, etc. to form a design. There are many patterns that can be observed on earth's surface such as drainage patterns, streets, agricultural fields etc. The patterns can be linear, radical, rectangular, circular etc. (Figure 2.20)





6. Association

Some features can be identified with their association. For example salt pans near the coast line, ox bow lake near rivers etc. (Figure 2.21)



Figure 2. 21 Association (Image from Google Earth)

The above elements of image interpretation are used to make observations on real scene. These observations are based on the knowledge of the interpreter as well. One needs to consider and integrate all the elements together to interpret remote sensing data. This process is known as convergence of evidence. The approach of convergence of evidence is very important for accurate geographical and geological interpretations. (R. P. Gupta, 1991)

2.8 SUMMERY

Remote sensing means data acquisition of EM radiation from various platforms. We understand that Remote sensing data provides excellent geometric, spatial, spectral, radiological and temporal information about earth. With continuous monitoring and analysis, improved technology provides vital information about earth and its systems. In this Unit we tried to understand various platforms for collecting this information. Then we discussed the orbital paths of each device. We also try to understand the concept of radiance. Calculating radiance and later converting it into digital values is a complex process and it changes with each sensor. Only after understanding the sensor and its specifications, one can understand the remote sensing image better. Therefore we learned about various sensors and later discussed the various elements of image interpretation such as color, shape, pattern, association etc.

2.9 CHECK YOUR PROGRESS/EXERCISE

1. Answer True or False

- i. The data collected on ground is also used for ground truth verification.
- ii. Primary colors are complemented by complementary color filters Yellow, Magenta and Cyan.
- iii. The most recent launch (Landsat 7) was on 15 April 2009.
- iv. Active sensor uses sun's energy as a source for illumination.
- v. The temporal intervals are calculated with the number of days.

2. Fill in the blanks.

- i. _____platforms are also known as airborne platforms.
- ii. The First time an airplane was used for aerial photography was in_____.
- iii. The images taken by aircraft are across- track and ______track scanners.
- iv. If the orbit is near to ______ then it is called a Near polar orbital plane.
- v. _____ orbit is also called a helio-synchronous orbit.

3. Answer the following Questions (Multiple Choice)

i. The radiance value captured by the pixel is recorded as _____.

- a. Digital Number
- b. Digital Code
- c. Digital Signature
- d. Digital Mark

ii. 11- bit data ranges from 0 to _____.

- a. 127
- b. 255
- c. 1023
- d. 2047

iii. Spatial resolution is measured with the _____.

- a. EMR
- b. distance
- c. time
- d. digital number
- iv. As the sensor is sensing through area, _____ captures information in pixels.
- a. Instantaneous Field of View
- b. Field of View
- c. Swath
- d. Pathway

v. Across track scanning sensor is also known as _____ Platforms and orbits sensor.

- a. whiskbroom
- b. push broom
- c. along track
- d. with track

4. Answer the following questions.

- i. Discuss the various Remote sensing Platforms.
- ii. Discuss the types of orbits with a neat diagram.
- iii. Explain the convergence of radiance to digital numbers.
- iv. Discuss the various Types of resolutions.
- v. Explain the types of sensors in detail.
- vi. Explain the concept of color composite.

vii. Discuss the various elements of visual image interpretation.

2.10 ANSWERS TO THE SELF-LEARNING QUESTIONS.

1. Answer True or False

- i. True
- ii. True
- iii. False
- iv. False
- v. True

2. Fill in the blanks.

- i. Aerial
- ii. 1908
- iii. Along
- iv. 90⁰
- v. Sun-synchronous

3. Answer the following Questions (Multiple Choice)

- i. Digital number
- ii. 2047
- iii. Distance
- iv. Instantaneous Field of View
- v. whiskbroom

2.11 TASK

• Write a detailed article on various satellite missions in the world.

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FUNDAMENTALS OF DATABASES

Unit Structure

3.0 Objectives

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 - 3.1.2 Data Storage
 - 3.1.3 Basic file structure
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3.0 OBJECTIVES

At the end of the modules learners will be able to-

- Understand the conceptual background of GIS
- Differential Vector and Raster data models
- Understand the concept of nodes, vertex, arc and topology
- Understand difference between geographic and projected coordinate system.
- Understand the importance and applications of different map projectins.

3.1 FUNDAMENTALS OF DATABASE

3.1.1 Concept of Database

Database is a collection of logically related data designed to meet the information needs of users. A database is a collection of records stored in a computer in a systematic way so that it is consulted by a computer program to answer questions / queries. Geographical Information System involves spatial entities linked with the attribute information to it. Different GIS software has varying capabilities in handling spatial and attributes data. Some GIS software efficiently handles attribute data whereas some are effective in handling spatial data. Spatial and attribute entities are characterized by data and data are characterized by metadata.

Databases are used in all disciplines in which an efficient data handling is needed, especially if those data are large. The data that are used in GIS are usually rather large, and the improvements in data acquisition have caused geographical data to be now more precise and consequently, larger.

3.1.2 Data storage

А database is а systematically stored and organized collection of data. Databases provide а better way of handling and using data. The attribute data linked to corresponding the spatial entities are



stored in the table called "attribute table). As shown in the following figure, the attribute table is attached to the spatial database. Attribute table consists of records and each record is made up of number of fields. Fields describe a single aspect of each member of table. A record contains all the information about a single member of class. e.g. in a attribute table of ward wise population of the city, each ward will be a member in a table whereas its population, ward number, literacy, population density etc. forms its record. The columns in an attribute table are called as fields.

3.1.3 Basic file structures

The data storage system in GIS platform requires having structured data management so that data can be accessed and cross-referenced easily and quickly. Following are some forms of basic file structures use in database management system in GIS environment.

- 1. Simple sequential file
- 2. Ordered sequential file
- 3. Indexed file
- 4. Databases

1. Simple sequential file / Simple list

This is the simplest form of database. It consists of simple list of all the records. Each new record is added to the database and placed at the end of the file. It is easy to add data into such system but retrieval of data is quite inefficient and time consuming.

2. Ordered Sequential File

In ordered sequential file the records are arranged in an alphabetical order which enable users to reduce time and efforts made for searching a desired entry. The ordered sequential files are accesses binary search procedure.

3. Indexed files

Indexed files can access to the original data files much faster than simple sequential file and ordered sequential files. Index file is a computer file which is associated with one or more data files and it allows records in data file to be accessed by key values rather than search by record to record. Hence, indexed file present rapid access to the database. In this type of file, new records do not have to be placed at specific position. It may be simply added but the index must be updated.

4. Database

A database consists of interrelated data in many files. The effective database helps to retrieve data efficiently as compared to sequential and indexed files. There are various methods of data organization in the database management system (DBMS). Based on the method of data retrieval the data base models are classified into many types.

3.1.4 Types of database

- 1. Object oriented data models
- a. Entity Relationship models
- b. Object oriented models
- 2. Record-based data models
- a. Hierarchical model
- b. Network model
- c. Relational Model

3. Physical data Models

3.1.5 Advantages of database

Databases not only have the advantage of being able to work with large datasets, but also other advantages such as managing multiple users or providing efficient access and indexing. For this reasons, they are a fundamental element in any software context, including GIS. Some of the advantages of using a database instead of a traditional approach for storing data are:

- 1. More independence. Data are independent from both the users and the software.
- 2. More availability. Databases facilitate the access to data from different contexts and applications, making them more useful for a larger number of users.
- 3. Carbonization of data becomes easier.
- 4. Less redundancy. There is a smaller volume of data and faster access.
- 5. More efficiency in data capture, encoding and input.
- 6. This has a direct influence on the results that are obtained from the exploitation of database.
- 7. More coherence. Better management leads to better data which produces results with a higher quality.
- 8. More efficiency. Accessing the data is easier and more effective.
- 9. More informative value. It is easier to extract the information that is contained in the data, since one of the goals of a database is to increase the value of data as source of information.
- 10. Users also enjoy advantages when using a database, such as the following:
- a. Easier access. The user of the database just has to worry about using the data.
- b. A solid infrastructure to do it is available and tools needed for it.
- c. Easier data reutilization. Data is easier to share when using a database.
- d. In short, we can say that the main characteristic of a database is the centralization of data that it implies which results in a better data access, management and organization.

3.1.6 Scale of measurement

Stevens' Scales of Measurement or level of measurement is a system for classifying attribute data into four categories; nominal, ordinal, interval, and ratio scale.

1. Nominal Level

Nominal data distinguishes between types or class of data, but they do not have numbers associated with them unless the numbers are used as a numerical identification. Nominal data are observations that have been placed in sets of mutually exclusive and collectively exhaustive categories. These data sets contain names or color but have no particular order or hierarchy. An example of using numerical identification for nominal data would be zip codes or phone numbers, because they lack a set order or hierarchy.

2. Ordinal Scale

Ordinal data are categorical data that have a natural ranking or order. For example, temperature can be classified as "hot", "warm", "lukewarm", "chilly", or "cold," with an inherent order. Another example is the ordinal numbers: 1st, 2nd, 3rd, 4th, etc.

3. Interval Scale

Interval data is quantitative or numerical data that is measured on a physical scale without a true origin; that is, the value 0 does not represent the absence of the property. One example is temperature measured in degrees Fahrenheit, because 0 degrees does not mean the absence of any temperature. The degree of difference between two values can be measured through subtraction, thus measuring the interval between the values. For example, if the temperature one day is 20°F and the next day is 40°F, it is meaningful to say that it is 20°F warmer.

4. Ratio Scale

Ratio data is quantitative data in which ratios between two values have definite meaning (eg, 2 is half of 4 and twice as many as 1), and unlike Interval data will have a meaningful zero. The normal numbers (0, 1, 2, 3, etc) is a common ratio data set. A common geographic example of ratio data is density (i.e. population, ethnicity, etc.).

3.1.7 Entity-Relationship Model

Entity relationship model was developed to provide overall view of organization of data. This data modeling provides a geographical notation for representing such data models in the form of entity relationship diagram. There are number of conventions for entity-relationship diagrams. A entity represents a discrete object. Entities can be thought of as nouns e.g. a computer, an employee, a song, a house etc. A relationship captures how one or more entities are related with each other. Relationships can be thought of verbs e,g, an own is relationship between company and computer, a perform is relationship between artist and song etc.

3.1.8 SQL

SQL is the abbreviation for Structured Query Language. Many different versions of SQL exist but it is the current industry standard query language for requesting information fom the database. The adoption of SQL as standard was done ny American National Standards Institute in 1986 and International Organization for Standardization (ISO) in 1987. Oracle Corporation's PL/SQL or Sybase, IBM's SQL PL and Microsoft's Transact-SQL are some of the extensions of SQL. SQL is designed for specific, limited purpose – querying data contained in a relational

Geoinformatics database. SQL is a programming language because it has a grammar, syntax, programmatic purpose and intent. SQL in short is a tool for organizing, managing and retrieving data from computer database. The language has evolved beyond its original purpose to support RDBMS. SQL is essentially a programming language for relational database. SQL can control all DBMS functioning such as;

- 1. Data definition
- 2. Data retrieval
- 3. Data manipulation
- 4. Access control
- 5. Data sharing
- 6. Data integrity

3.2 GEOGRAPHIC INFORMATION SYSTEM: DEFINITION, CONCEPT, COMPONENTS, FUNCTIONS AND APPLICATIONS.

3.2.1 Introduction

Remotely sensed data many often needs to be processed and analyzed for deriving meaningful spatial information required by the users for solving various environmental problems, planning purposes and decision making. Geographical Information System is capable of integrating spatial information derived from various sources and of processing huge amount of spatial and attribute data for various applications. Geographical Information system play significant role in all walks of life, starting from and administrators where they planners are concerned about developmental activities for a particular regions to a common user to meet his own needs like finding a shortest path to reach the destination. Geographical Information Science has moved into the mainstream of technology and is being treated as a corporate resource that needs computing platform and capability to support huge spatial data.

The Geographical Information System (GIS) is mainly a combination of two disciplines; Geography and Information System. The study of Geography involves the scientific description of physical and cultural elements in spatial context and interactions therein. Information system refers to the system involving electronic records consisting of input source documents, processing of electronic data, records on electronic media and output records along with related documentations. In simple words, the information system is an interactive combination of computer hardware, software, communication devices, procedures and users who need information to perform analysis and to make appropriate decisions.

The Geographical Information System is a computer based information system which is used to process, analyze and evaluate geospatial or geographical data digitally. Geospatial refers to the distribution of any entity in geographical sense which can be located by geographic coordinate system. In fact, every object on the planet earth can be georeferenced. Geo-referencing is attributed to location of a feature defined

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by geographic coordinate referencing system. The GIS is a specific form of information system applied to geographical data. GIS uses geographically referenced data as well as non-spatial (attribute) data and performs range of operations which supports spatial analysis. This section aims at describing concept, components, functions and applications of Geographical Information System in detail.

3.2.2 Geographic Information System: Definitions

Geographical Information System (GIS) aims to work with spatial data referenced by geographical coordinate system. GIS is not only a spatial database system but it is also capable to perform various operations with the spatial and attribute (non-spatial) data. There is no universally accepted definition for GIS. In fact, GIS has been defined in many ways by many people.

One of the ways GIS has been defined as "a systematic integration of computer hardware, software and spatial data for capturing storing, displaying, updating, manipulating and analyzing in order to solve complex management problems."

Geographical Information System is also defined as "an information system that is used to input, store, retrieve, manipulate, analyze and output geographically referenced data or geographical data in order to support decision making for planning and management of land use, natural resources, environment, transportation, urban facilities and other administrative records."

"GIS is a computer assisted system for capture, storage, retrieval, analysis and display of spatial data within a particular organization" - Clarke (1986).

According to Aronoff (1989), GIS is a computer based system that provides the following four sets of capabilities to handle geo-referenced data;

- 1) Input
- 2) Data Management (Data storage and retrieval)
- 3) Manipulation and Analysis and
- 4) Output.

Berry (1986) defined GIS as an "an internally referenced, automated spatial information system."

According to Redlands (1990), "A GIS is an organized collection of computer hardware, software, geographic data and personnel designed to effectively capture, store, update, manipulate, analyze and display all forms of geographically referenced information."

The definitions of GIS discussed above cover various subjects and activities associated with spatial information or geographical information. It is also termed as Spatial Information System which deals with the spatial information not just the geographical but also the objects in the world space. Following technical terms are interchangeably used to describe spatial data handling system.

- 1) Geographic / Geographical Information System (GIS)
- 2) Geo-information System
- 3) Spatial Information System (SIS)
- 4) Land Information System (LIS)
- 5) Multi-purpose cadastre

According to Trigal (2015), a GIS is a set of tools made up of hardware, software, data and users, which allow us to capture, store, manage and analyze digital information, as well as make graphs and maps, and represent alphanumeric data.

Geographical Information Systems are widely used in variety of subjects / disciplines as tools for data handling and spatial analysis in geographical environment.

3.2.3 Components of Geographical Information System

Geographical Information System is an integration of technology, informatics, geo-spatial information and user with the purpose to capture, analyze, store, edit, and visualize geo-referenced data. GIS essentially constitute five key components including hardware, software, procedure, data and users.



Fig. 3. 1 Components of Geographical Information System (GIS)

1. Hardware

It includes the computer hardware system on which various GIS softwares can be installed and analysis can be performed. The GIS can be run on range of computer systems from personal computers (PC) to super computers like Param. The ability of GIS software for data input, data processing, output, storage and retrieval of data depend largely upon the capacity of computer hardware system. Hardware requirements for efficient GIS analysis include computers, digitizers, graphics card, color printers, external storage devices, scanner etc.

2. Software

GIS software is the set of functions and tools required to store, analyze, retrieve and display the output geo-spatial information. Arc/Info, ILWIS (Integrated Land and Water Information System), Quantum GIS, MapInfo, Geomatica, ArcView, AutoDesk Map are some of the widely used GIS software. Web based GIS is also popularly used web application software

since recent times. Department of Space is one of the leading organizations in developing GIS based software and applications. The choice of GIS software depends upon the nature of spatial analysis to be done. The effectiveness of GIS software largely depends upon userfriendliness, functionalities, compatibility with different operating systems, changeable software versions, documentation and cost effectiveness.

3. Procedure

Besides hardware and software, computer system with GIS also includes various procedures designed for data capturing, storage, retrieval, analysis, modeling and display the geospatial information. The operating procedures are normally unique to each organization. However, well designed spatial data processing procedures improves the efficiency of GIS.

4. Data

The core of GIS, lives in the data. A detailed knowledge of the data we use, its quality, its source, its reliability and accuracy is extremely important to understand GIS environment.

Data, in context of GIS refers to the geo-spatial / geographical data. Digitized maps, aerial photographs, satellite images, statistical data etc. are important sources of geospatial data. Different kinds of geo-spatial data can be can be brought to a GIS platform and can be integrated by applying common geo-reference. There are two types of data used for geo-spatial analysis;

1) Spatial data / geographical data and 2) Non-spatial data / attribute data

The accuracy and reliability of the data determines the reliability of the results derived from spatial data analysis in GIS platform.

5. Users

The role of user in GIS analysis is important. Skilled and competent personnel are required for geo-spatial analysis in GIS environment. The definitions of GIS discussed in the earlier section focus on hardware, software, procedures and analysis tools. However, these components of GIS cannot perform spatial analysis in isolation unless these are used by competent users. Techno savvy personnel are needed for planning, implementation and analysis in GIS platform as well as to make appropriate decisions based on the derived results.

3.2.4 Functions of Geographical Information System

Geographical Information System performs various functions. Some of the important functions of GIS are listed below.



- 1) Identification of objects and their geographical location
- 2) Spatial modeling
- 3) Digital Mapping
- 4) Spatial Database
- 5) Spatial Analysis

1) Identification of objects and their geographical location

GIS is primarily used as a tool for decision making in spatial context. For instance, if we want to find out a safe place for human habitation in flood prone areas so as to reduce the amount of risk caused by floods using GIS analysis, one can identify suitable sites for human habitation and can also frame policies for prevention of such hazards.GIS is capable of handling multi-temporal as well as multi resolution geo-spatial data which can also help to analyze natural as well as anthropogenic changes taking place in a particular geographical region over a given period of time.

Geo- referenced spatial data is the most powerful feature of GIS. Identification of a place or a point with its accurate geographic location is of immense importance because accuracy and reliability of GIS output largely depend upon the accuracy of location. Various physical and manmade objects observed on the earth surface can be geo-referenced in GIS environment. In fact, geo-referencing is the prerequisite for different GIS operations. Geo-referencing in GIS is carried out by applying various projections.

2) Spatial modeling

GIS also helps to perform spatial modeling. Spatial modeling represents some part of the real world which have certain common characteristics with real world. Hence, GIS based spatial modeling also helps in theory and model building which can be applied universally to analyze various geographical phenomena. The most popular form of model in GIS environment is map. Several GIS based models help in estimation / simulations of various geo-environmental phenomena.

3) Digital Mapping

Maps are the best known conventional models of the real world. GIS has made revolutionary changes in mapping the real world. At the advent of Geographical Information System, the traditional analogue cartography have been changed to digital cartography where dynamic maps are prepared which can further analyzed and edited digitally. GIS is proved to be a powerful tool not only for digital mapping but also various spatial data layers can be extracted, combined, separated and compared in GIS environment. Network analysis, hazard zonation mapping, computations using raster calculators, buffer analysis, density mapping, resource mapping etc can easily be performed to analyze spatial data in GIS environment. One of the important capabilities of GIS is that it can analyze both spatial and non-spatial data and can also extract desired information from the dataset. Hence, production of dynamic digital maps is an important function of GIS.

4) Spatial Database

GIS is beyond conventional mapping software. GIS tools produce output maps combined with its database. Database refers to the repository for storing large amount of data which allows concurrent use, support data integration, offers query facility to data filter and retrieval. GIS database include spatial data and non-spatial data tied with it. GIS database is also named as spatial or geo-database is an integral part of GIS that provide foundation of spatial analysis in GIS environment. Therefore, the success of spatial analysis is largely determined by quality and accuracy of geodatabase.

5) Spatial Analysis

GIS is a powerful tool for data capturing, integration of spatial and nonspatial information, creating dynamic maps, integrating geo-spatial data derived from various sources, relating various data layers to analyze and solve complicated problems and frame development strategies. Spatial analysis of geographical phenomena is of vital importance in GIS applications. Various GIS tools help in carrying out complex analyses and also retrieval of spatial and non-spatial data as and when required. Mapping and analyzing geographical phenomena is not new, but GIS platform can perform these operations much faster with highest possible level of accuracy than manual methods.

3.2.5 GIS Applications

GIS applications refer to as the the specific purpose or a problem to which GIS operations are dealing with. In simple words, GIS applications are the fields or problems which can be analyzed and solved using various GIS tools and operations. It is important to understand various applications of GIS in order to understand its advantages and importance for solving various issues related to natural and anthropogenic phenomena. GIS have been used for variety of purposes. In fact, development in GIS over the years has led to emergence of various areas where it has been applied. Major areas of GIS application are discussed below.

- 1. Facility management
- 2. Environmental and natural resource management

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- 3. Street Network
- 4. Planning and engineering
- 5. Land Information System

1. Facility Management

A wide variety utilities and facilities can be planned, managed and monitored using GIS. Tele-communication network, electric and gas utilities operating in private as well as public sector can be analyzed in GIS environment and utility data based ca be prepared and updated as and when required. Digital maps of these utility services can be prepared along with their attribute information which will be helpful for maintenance and management of utility services. Identifying location of poles, monitoring the layout of pipelines, identifying suitable location for transformer etc. is easily possible with various tools of GIS. Besides, planning of facilities and transmission lines can be done to minimize economic, social and environmental cost. GIS can also be helpful in tracking energy usage and planning future utility infrastructure development.

2. Environmental and natural resource management

GIS is most widely used in natural resource management and environmental management. In agricultural sector, crop suitability analysis, cropping pattern, crop diversification, agricultural land use mapping and mapping of irrigated and dry land farming areas, monitoring of crop growth etc. is possible with various GIS tools. In mining sector, GIS is used for mapping of existing mining areas and also finding out potential mineral deposits. Industrial sector also uses GIS for creating database regarding location of raw material, potential markets, industrial land use, identification suitable location for particular industry etc.

GIS is extensively used in natural resource management. Fundamental natural resources like land, water, forest can be mapped and analyzed using various GIS operations. Land capability classification, land use land cover mapping, change detection analysis, land suitability analysis, water resource mapping, watershed management, soil degradation mapping, soil characterization and classification, soil erosion mapping, forest mapping, mapping and classifications of forests, monitoring forest hazards like forest fire, mapping rate of deforestation, forest health mapping etc. are major applications of GIS in natural resource management.

Environmental management is one of the key areas of GIS applications. GIS can be used to solve complex environmental problems with accurate spatial analysis and planning. Natural hazard zonation mapping, risk mapping, monitoring and simulating flood and other natural hazard, identification of potential affected areas by natural disasters, natural disaster mitigation, mapping pollution areas, monitoring of pollution level, analysis of various determinants of pollution, early warning system for tsunami, environmental impact assessment etc. are major areas where GIS can play a great role not just by spatial data modeling but also for providing sustainable solutions to various environmental problems.

GIS is now being extensively used for developing navigation system for road, railways and other transportation services. Vehicle tracking system, locating houses and streets, identification of site location and finding out shortest route, road and railway network analysis, road and railway network planning, traffic suitability mapping etc. are carried out using various GIS operations and tools. Since there is a dire need to handle multiple format data and spatial data layers, GIS can help to find out effective solutions to problems associated with transportation network particularly in transportation planning.

4. Planning and engineering

GIS has been proved to be most effective tool for spatial planning particularly urban planning. Urban planning needs to include balanced land use planning, critical consideration of utility services and potential problems associated with urban planning. Large scale land use planning (often known as regional planning) is carried out much effectively in GIS environment. Planning of major communication routes (highways) and planning for development of basic infrastructure facilities is done using GIS. Major uses of digital topographic data are in large-scale civil engineering designs such as cut and fill operations for highway construction. Large and medium scale engineering models (particularly those related to civil engineering) can be constructed using GIS.

5. Land Information System

The Land Information System and Land Related Information System are often used in this sector, reflecting the relative importance of survey data and the emphasis on retrieval rather than on analysis. The functions needed in a LIS are well short of those in a full GIS. In many cases, geocoding of parcels is needed to allow spatial forms of retrieval: digitizing of the outlines of parcels is useful for cartographic applications. It is unlikely that many municipalities will advance to the state of creating a full urban GIS by integrating data on transport and utility and developing applications in urban development and planning. Automated cartography and retrieval will remain the major concerns of such systems in future. There will be a steady movement towards GIS capabilities as urban planners and managers demand greater analytic capabilities.

Apart from the applications of GIS discussed above, it has diverse application areas developed since recent times. Some of the important applications of GIS are listed below.

- Population census analysis
- Insurance assessment
- Hazard Mapping
- Agricultural development
- Land evaluation analysis
- Wasteland mapping
- Soil mapping

- Ground water potential mapping
- Glacial processes
- Hydrological modeling
- Automated photogrammetry
- Tax mapping
- Geodetic mapping
- Event mapping (accidents, crime, fire, facility failure)

3.3 SPATIAL DATA MODELS

Spatial data comprises the geographical information about the earth surface and its features. Geographical Information System provide methods for representing spatial data which allow user to adopt conceptual models of spatial information such as object based models, network models and field models. Data models describe the way in which spatial data is represented in a geographical information system or database management system. There are two broad categories of spatial data models;

- i. Vector data model
- ii. Raster data model

Cartographic map model and geo relational are two important models or approaches which are widely used to represent spatial data in GIS framework. The cartographic map model is usually based on raster representation of space whereas geo-relational model is based on vector representation of space. Vector data model represents earth's objects or processes using point, line, polygon and surfaces. Raster data model represents on the surface in grid or cells. Let us try to understand the basic concepts, characteristics of data structures, advantages and disadvantages of spatial data models in detail.

3.3.1 Vector data model and Rater data model

The spatial data models used in GIS environment play significant role in representation of earth surface reality to perform various spatial analyses and modeling. This section helps to describe the concepts and characteristics of both Vector data models and Raster data models.

3.3.1.1 Vector Data Model

Vector data model uses point, line and polygon as spatial entities to describe features on the earth surface. Point feature indicate the location of a particular discrete place on the earth surface along with the information (population, no. of schools, number of households, production etc) attributed to that place. Line feature is used to describe linear objects on the earth surface such as river channel, road network, power lines, railway lines etc. Polygon features on the other hand are used to represent large area such as forests, land use, agricultural fields, land cover, soil type, geological formations etc. Vector models tries to represent objects or features on the earth surface Fundamentals of Database and their dimensions (direction, length, shape) with best possible precision. The vector data structure is represented as pair of co-ordinates (X,Y) denoting geographical location of a feature or object. Point feature has (X,Y) location whereas line feature store sequence of first and last point. Sequentially connected multiple lines are known as polylines. Polygon feature is represented by closed sequence of points where last point and first point are equal.

Vector data models are ideal for representing discrete objects. However, they can also be used for representing continuous field data such as elevation above the mean sea level. Contour lines, iso-lines, mass points, TIN (Triangulated Irregular Network) records values at point location which are connected by lines to form irregular mesh of triangles to represent the terrain surface.

3.3.1.2 Raster Data Model

Vector format, reality In the is represented as points, lines and polygon to indicate objects of the earth surface. Raster format on the other hand represents the earth objects by grid of cells/pixels. The Vector format is based on discrete objects and the raster format is based on continuous field view of reality (photographs, imageries, etc). A raster based GIS locate and stores spatial data cells or pixel format. Individual pixel is represented at its corner by a unique reference coordinate (cell address). Each cell also has attribute data assigned to it.





The raster data formats represent point, line and polygon features in different ways. A point feature in raster data format is indicated as one

single pixel. Line feature is represented as series of pixels whereas area is shown as group of pixels as given in the adjacent figure (source: <u>https://desktop.arcgis.com/</u>).



The raster data resolution is dependent on the pixel or grid cell size which is also called as 'spatial resolution'. The cell size should be small enough to capture the required detail of the desired object on the earth but large enough so computer storage and analysis can be performed efficiently. More features, smaller features, or a greater detail in the extents of features can be represented by a raster with a smaller cell size (source: <u>https://desktop.arcgis.com/</u>). Smaller cell sizes result in larger raster datasets to represent an entire surface; therefore, there is a need for greater storage space, which often results in longer processing time.



The spatial resolution of raster data formats are used in the image given below. The image shown to the left is lower than the spatial resolution of the data used in the image on the right. This means the cell size of the data in the left image is larger than that of the data in the right image; however, the scale at which each is displayed is the same.

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Scale 1:20.000

Cell size: 15.24 cm

Scale 1:20,000 Cell size: 15 m

(source: https://desktop.arcgis.com/)

Spatial data captured from remote sensing imageries, aerial photographs etc. Such imageries of the earth's surface can be easily stored in raster data format. In this format, the various features are identified by superimposing the imageries over a rectangular grid of the earth's surface which they represent. Raster data format facilitates simple scalar operations on the spatial data which a vector format does not permit. Using Raster calculator, various spatial computations may be carried out easily in GIS environment. Raster data requires to be converted to vector format before topology can be built and spatial operations can be carried out. The raster format also requires more storage space on the computer than the vector format. Most standard GIS software has the facility to transform maps from raster formats to vector formats.

3.3.2 Vector representation

This is generally used for capturing data from analogue maps. It is based on th observation that any map consists of 3 basic kinds of features –

(i) point features,

(ii) line features and

(iii) polygon or area features

(iv) Triangulated Irregular Network (TIN)

(i) Point features,

Points do not have length, width or area. They are described completely by their coordinates and are used to represent discrete locational information on the map to identify locations of features such as, cities, towns, well locations, rain gauge stations, soil sampling points, etc.





(ii) Line features

A line consists of a set of ordered points. It has length, but no width or area. Therefore it is used to represent features such as roads, streams or canals which have too narrow a width to be displayed on the map at its specified scale.

(iii) Polygon or area features

A polygon or area is formed when a set of ordered lines form closed figure whose boundary is represented by the lines. Polygons are used to represent area features such as land parcels, lakes. districts. agroecological zones, etc. A polygon usually encloses an area that may be considered homogeneous with respect to some attribute. For example, in a soil map, each polygon will represent an area with a homogeneous soil type.



(iv)Triangulated Irregular Network

Triangulated Irregular Network (TIN) is used to represent points elevation which continuously represent changing elevation surfaces. TIN records elevation values at point locations which are connected with lines to form irregular mesh of triangles. The face of such triangle terrain represents surface. However, it should be noted



that the terrain surface represented by TIN cannot show raster like continuity.

A vector based system displays graphical data as points, lines or curves, or areas with attributes. Cartesian coordinates (X,Y) or geographical coordinates (latitude, longitude) define points in a vector system.

Data is captured from a map in the form of known x-y coordinates by first digitizing the features on the map into a series of nodes (dots) and digitizing the points one by one directly after placing the map on a digitizer. The points on the map are captured directly as point coordinates. Line features are captured as a series of ordered points sequentially. Polygon features are also captured as an ordered list of points by making the beginning and end points/nodes of the digitization the same for the area, the shape or area is closed and defined. The process of digitizing from a digitizer is both time consuming and painstaking. Alternately, the map can be scanned and the scanned image digitized on-screen with appropriate software tools. The latter process is relatively simpler, more accurate and is often preferred.

Digitization is usually done feature by feature. For example, all point features are on a map (say cities, towns, etc.) are digitized in one layer. Similarly all line features (eg. Roads, rivers, drainage network, canal network, etc.) are digitized as a separate layer. Polygon features (soils, districts, agro-ecological zones, etc.) are also digitized as separate feature.

The identification number (ID) is the key field in each data base (points, lines, areas databases) as it can be used to relate the spatial data with the attribute data. Vector systems are capable of very high resolution (<.001 in) and graphical output is similar to hand drawn maps.

3.3.3 Concepts of nodes, vertices, arc and topology in vector data model

A vector based system displays spatial objects like point, line and polygon with defined geographical coordinates. The data captured from a map in the form of known geographical coordinates by digitizing the features on the map. Vector data model include geographical features on the earth surface with known geographical coordinates. The vector data model include following concepts;

- 1. Node
- 2. Arc
- 3. Vertex
- 4. Topology

1. Node

In geo-database, points representing start and endpoint of feature or end point of an arc or intersection point of lines (string). Nodes can also be known as an intersection of more than two lines or string or start and end point of string with node number.



2. Arc

Arcs are lines defined by two nodes to represent features that are linear in nature. Real world linear features can also be shown as multiple sequentially connected segments of lines to create an object. Such multiple lines are collectively known as polyline or arc.



3. Vertex

Vertex refers to one set of ordered x,y coordinate pairs that defines shape of a line or polygon feature. In fact, line or string are constructed with series of vertices.



4. Topology

Topology in GIS, can be defined as a set of objects and object data that defines the relationships between the spatial objects. In simple words, topology refers to the process that defines the relationships between the spatial objects in the vector based data structure. Topology consists of three elements;

- 1. Adjacency
- 2. Containment
- 3. Connections

1. Adjacency: Adjacency describes the geometrical relationships between the area features. Area features or polygons adjacent to each other often share common boundary.



2. **Containment:** Containment is an extension of adjacency when area features can wholly be contained within another area features such as open piece of land in dense forested areas.



3. Connectivity: Connectivity is a geometric property used to describe the linkages between line features such as road network, drainage network etc.



The important characteristic of vector based model is that it enable individual feature to be isolated for carrying out its measurements and also for determining the spatial relationships between the features (point, line and polygon). The adjacency, connectivity and containment are important examples of topological relationships. I vector based spatial model, these relationships are also termed as topological structures.

Topological structure play important role in determining spatial relationships between complex objects in vector data models. Proper connectivity and adjacency is achieved in digitized features. If two polygon features are adjacent to each other, they will share a common boundary. If two linear features (such as roads, river channels, power lines) intersect each other, they will have common intersecting node. Topology thus helps in maintaining integrity in the spatial database.

3.4 COORDINATE REFERENCE SYSTEMS: GEOGRAPHIC AND PROJECTED, MAP PROJECTIONS AND DATUM FOR GIS DATA.

3.4.1 Coordinate System

Coordinate System is an x,y grid upon which GIS data is overlaid which helps in identifying the exact location of a point on the map. There are two important systems in the earth's referencing systems called as Geographical Coordinate System (GCS) and Projected Coordinate System (PCS). Geographical Coordinate System is a reference system for identifying locations on the curved earth surface. However, projected coordinate system is a referencing system to identify location measuring on the flat map (two dimensional).

3.4.1.1 Geographic Coordinate System

Geographical coordinate system is expresses in terms of degree decimal which helps to identify location on the surface of the earth. However,

latitude and longitude locations are not located using uniform measurement unit which is one of the most important disadvantages of geographical coordinate system. Hence GCS is not ideal for measuring distances. Geographical coordinates are based on rectangular coordinate system with origin at the center of the earth. The World Geodetic System, 1984 (WGS84) is he geographical coordinate system which fits well for most of the countries in the world. GPS use WGS84 datum for identifying the location of the



point on the earth's surface. Survey of India use Everest Datum named after India's first Surveyor General George Everest. America uses NAD27 since 1927.

3.4.1.2 Projected Coordinate System

Projected Coordinate System is defined on a flat 2Dsurface Projected coordinate system has constant lengths, angles and areas across two dimensions. Α projected coordinate system is alwavs



based on geographic coordinate system. In PCS, locations are identified by x,y coordinates on a rectangular girds.

3.4.2 Map Projection

Map projection refers to the transformation of spheroid or ellipsoid earth on a flat map. Map projection can be on a flat surface that can be made by cutting such as cylinder or cone. Line where cutting take place does not have any projection distortion.

Advantages of map projection:

- 1. Globes are hard to store and difficult to use for practical demonstration.
- 2. Globe cannot show the entire world at once.
- 3. Projection can be optimized to minimize distortion.
- 4. Computer screens are flat. Projection is useful to visualize the entire world on the screen.
- 5. Projection helps in thematic mapping.

Following are important types of map projections:

- 1. Cylinder projection: Flat surface is wrapped around the earth so that it can touch the equator. This projection proves to be accurate for the regions near equatorial belt.
- 2. Conical projection: Place on the earth so that it can touch the earth surface between equator and the poles. This type of projection is well suited for mid latitudes.
- 3. Plane / Azimuth projection: It touches earth at the poles. It is accurate to map Polar Regions.



Questions:

- A. Fill in the following and complete the sentence.
- 1. A ------ is a systematically stored and organized collection of data.
- 2. In -----, the records are arranged in an alphabetical order.
- 3. In drainage network analysis first, second, third and subsequent order streams are examples of ------ scale.
- 4. SQL stands for -----.
- 5. ----- is a computerized system which is capable of storing, processing and retrieval of spatial data as and when required.
- 6. ----- data model uses point, line and polygon segment as spatial entities to represent features on the earth's surface.
- 7. ----- data models represent earth's objects by pixels or grids.
- 8. WGS84 is the example of ----- coordinate system.
- 9. ----- projection can map polar regions more accurately.
- 10. ----- of the following type of files can arrange records of original data files much faster. (simple list, sequential ordered file, indexed file)
- B. Short Questions.
- 1. Write a note on functions of GIS
- 2. Elaborate various GIS applications.
- 3. Describe different types of data models.
- 4. Distinguish between geographic and projected coordinate systems.
- 5. Write a note on Components of GIS.
- 6. Write a note on SQL.
- 7. Elaborate Entity Relationship Model
- 8. Advantages of database.



VECTOR-BASED SPATIAL ANALYSIS

After going through this chapter, you will be able to understand the following features

Unit Structure

- 4.1 Objectives
- 4.2 Introduction
- 4.3 Subject Discussion
- 4.4. Vector-based spatial analysis: single layer operations (extraction and proximity) and multilayer operations (overlay operations)
- 4.5. Raster-based spatial analysis: Georeferencing, Spatial Interpolation and raster generation, raster reclassification, arithmetic, relational and logical operations
- 4.6. Global Positioning System: Concept, Development, GPS Satellite Navigation System and their Segments, Main Systems – NAVSTAR, GLONASS, Galileo and Indian GPS
- 4.7. Principles of positioning: Positional Accuracies, Relative Positioning, errors and sources
- 4.8. Summary
- 4.9. Check your Progress/Exercise
- 4.10. Answers to the Self-learning Questions
- 4.11. Technical words and their meaning
- 4.12. Task
- 4.13. References for further study

4.1. OBJECTIVES

By the end of this unit, you will be able to

- Learn the various vector-based spatial analysis
- Implement various raster-based spatial analysis tools
- Understand concepts related to Global Positioning System
- Know the various principles of positioning

4.2. INTRODUCTION

The subject of Geoinformatics includes Remote Sensing (RS), Geographical Information System (GIS) and Global Positioning System (GPS). Though the first two technologies are still technical in nature, GPS is now seen in the hands of everyone, attached to almost all vehicles and

Vector-based spatial analysis

every possible device. Today, GPS has come into common usage with the synonym 'navigation', but it has a long history and other technical aspects associated with it which we shall see in the following chapter.

4.3 SUBJECT DISCUSSION

In this fold we will be studying about the vector and raster based spatial analysis in detail and about GPS Satellite Navigation System and their Segments.

4.4. VECTOR-BASED SPATIAL ANALYSIS: SINGLE LAYER OPERATIONS AND MULTILAYER **OPERATIONS**

4.4.1. Single Layer Operations

Buffers are common vector analysis tools used to address problems of proximity in a GIS and can be used on points, lines, or polygons. For instance, determination of no honking zone around a school for a distance of 2kms in all directions.

The dissolve operation combines adjacent polygon features in a single feature dataset based on a single predetermined attribute. The dissolve tool automatically combines all adjacent features with the same attribute values. The dissolved output layer is much easier to visually interpret when the map is classified according to the dissolved field.

The merge operation combines features within a point, line, or polygon layer into a single feature with identical attribute information. This operation is particularly useful when polygons are found to be unintentionally overlapping. Merge will conveniently combine these features into a single entity.

4.4.2. Multilayer Operations

Overlay is a GIS operation that superimposes multiple data sets together for the purpose of identifying relationship between them. An overlay creates a composite map by combining the geometry and attributes of the input data sets. Tools are available in most software for overlaying both Vector and Raster data. Overlay is the operations of comparing variables among multiple coverages. In the overlay operations new spatial data sets are created by merging data from two or more input data layers. Overlay operation is one of the most common and powerful GIS techniques. It analyses the multilayer with common coordinate systems and determines what is on the top layer.

There are three types of overlays are independent of whether a vector or a raster model is used.

Point in Polygon

In the vector model, this overlay determines the points lying inside a specific polygon. In the example, we are looking for all the hotels that are located in the settlement areas. In the resulting layer, the points have the additional information whether or not they are in the settlement area. In the raster model, the points in question are visible through the addition of the two input layers.

• Line in Polygon

The overlay of lines and polygons is more complex. The example shows the calculation of road sections located in the settlement area. In the vector model, the topology changes: the original line is cut into shorter segments by the intersection points. It has to be specified for each segment whether it is inside or outside the segment polygon. In the raster model, a simple addition identifies the interest areas.

• Polygon in Polygon

In the vector model, the most complex case is the intersection of polygons. The result is a data layer with a whole new topology. The overlay of contour lines results in a variety of new intersections and polygons for which the attributes have to be reassigned. In addition, for non-cut areas it has to be checked whether they contain areas of another information layer i.e. whether island polygons were created. Raster overlay is very simple, however. Again, the cell values of the input are calculated.

4.5. RASTER-BASED SPATIAL ANALYSIS: GEOREFERENCING, SPATIAL INTERPOLATION AND RASTER GENERATION, RASTER RECLASSIFICATION, ARITHMETIC, RELATIONAL AND LOGICAL OPERATIONS

4.5.1. Georeferencing

Raster data is obtained from many sources, such as satellite images, aerial cameras, and scanned maps. Modern satellite images and aerial cameras tend to have relatively accurate location information but might need slight adjustments to line up all your GIS data. Scanned maps and historical data usually do not contain spatial reference information. In these cases you will need to use accurate location data to align or georeference your raster data to a map coordinate system. A map coordinate system is defined using a map projection-a method by which the curved surface of the earth is portrayed on a flat surface.

When you georeference your raster data, you define its location using map coordinates and assign the coordinate system of the map frame. Georeferencing raster data allows it to be viewed, queried, and analyzed with your other geographic data. The <u>georeferencing tools</u> on the **Georeference** tab allows you to georeference any raster dataset.

In general, there are four steps to georeference your data:

- 1. Add the raster dataset that you want to align with your projected data
- 2. Use the **Georeference** tab to create control points, to connect your raster to known positions in the map
- 3. Review the control points and the errors
- 4. Save the georeferenced result, when you are satisfied with the alignment

4.5.2. Spatial Interpolation and Raster Generation

Spatial interpolation is the process of using points with known values to estimate values at other unknown points. For example, to make a precipitation (rainfall) map for your country, you will not find enough evenly spread weather stations to cover the entire region. Spatial interpolation can estimate the temperatures at locations without recorded data by using known temperature readings at nearby weather stations. This type of interpolated surface is often called a **statistical surface**. Elevation data, precipitation, snow accumulation, water table and population density are other types of data that can be computed using interpolation.

Because of high cost and limited resources, data collection is usually conducted only in a limited number of selected point locations. In GIS, spatial interpolation of these points can be applied to create a raster surface with estimates made for all raster cells.

In order to generate a continuous map, for example, a digital elevation map from elevation points measured with a GPS device, a suitable interpolation method has to be used to optimally estimate the values at those locations where no samples or measurements were taken. The results of the interpolation analysis can then be used for analyses that cover the whole area and for modelling. Isopleth Map is classic example of spatial interpolation

4.5.3. Raster Reclassification

Reclassification is the process of reassigning a value, a range of values, or a list of values in a raster to new output values. Reclassification of raster dataset is undertaken for the following reasons:

- 1. To set specific values to NoData to exclude them from analysis
- 2. To change values in response to new information or classification schemes
- 3. To replace one set of values with an associated set (for example, to replace values representing soil types with pH values)
- 4. To assign values of preference, priority, sensitivity, or similar criteria to a raster

Reclassification is an important process when you need to combine dissimilar data using a common value scale. For example, to analyse a

Geoinformatics forest, besides forest cover, additional rasters of soil type, slope, aspect, and drainage might also be reclassified on a suitability scale of 1 to 3. These rasters, which originally held values belonging to different measurement scales, could then be added to find the most suitable site for afforestation.

4.5.4. Arithmetic, Relational And Logical Operations

• Arithmetic Operators

The arithmetic operator allows the program to perform general algebraic operations against numeric values.

There are five basic operators present in the world of programming language:

- Addition (symbol "+"): Perform the addition of operands.
- Subtraction (symbol "-"): Performs subtraction of operands.
- **Division (symbol "/"):** Performs division of operands.
- Multiplication (symbol "*"): Performs multiplication on operands.
- Modulus (symbol "%"): Returns reminder after the division of integer.

• Relational Operators

Any relation between the two operands is validated by using relational operators. Relational operators return Boolean values. If the relation between two operands is successfully validated then it will return "true" and if the validation fails then "false" will be returned.Relational operators are mainly used in decision making or for defining conditions for loops.

The most basic Relational Operators are:

- **Greater than operator:** (denoted by ">"): Validates greater than the relation between operands.
- Less than operator: (denoted by "<"): Validates less than the relation between operands.
- Equals To operator: (denoted by "=="): Validates the equality of two operands.
- Greater than or equals to (denoted by ">="): Validates greater than or equals to the relation between the two operands.
- Less than or equals to (denoted by "<="): Validates less than or equals to the relations between the two operands.
- Not equal: (denoted by "!="): Validates not an equal relationship between the two operands.
- Logical Operators

Logical operators are used for performing logical operations. Logical vector-based spatial analysis operators work with Boolean expressions and return a Boolean value. Logical operators are used with the conditional operators in loops and decision-making statements.

Following are the Logical Operators:

Sr. No.	Name	Symbol	Use
1	Logical AND Operator	"&&"	AND operator returns true when both the values are true. If any of the value is false then it will return false
2	Logical OR Operator	" "	OR operator returns true if any of the condition/operands is true. It will return false when both of the operands are false
3	Logical NOT Operator	۰۰ ۱ .,	NOT operator is used to reverse the logical conclusion of any condition. If the condition is true then it will return false and if the condition is false then it will return true

4.6. GLOBAL POSITIONING SYSTEM: CONCEPT, DEVELOPMENT, GPS SATELLITE NAVIGATION SYSTEM AND THEIR SEGMENTS, MAIN SYSTEMS – NAVSTAR, GLONASS, GALILEO AND INDIAN GPS

4.6.1. Concept

The Global Positioning System (GPS) is a navigation system using satellites, a receiver and algorithms to synchronize location, velocity and time data for air, sea and land travel.

4.6.2. Development

GPS has its origins in the Sputnik era when scientists were able to track the satellite with shifts in its radio signal known as the "Doppler Effect." The United States Navy conducted satellite navigation experiments in the mid 1960's to track US submarines carrying nuclear missiles. With six satellites orbiting the poles, submarines were able to observe the satellite

changes in Doppler and pinpoint the submarine's location within a matter of minutes.

In the early 1970's, the Department of Defense (DoD) wanted to ensure a robust, stable satellite navigation system would be available. Embracing previous ideas from Navy scientists, the DoD decided to use satellites to support their proposed navigation system. DoD then followed through and launched its first Navigation System with Timing and Ranging (NAVSTAR) satellite in 1978. The 24 satellite system became fully operational in 1993.

Today, GPS is a multi-use, space-based radionavigation system owned by the US Government and operated by the United States Air Force to meet national defense, homeland security, civil, commercial, and scientific needs. GPS currently provides two levels of service: Standard Positioning Service (SPS) which uses the coarse acquisition (C/A) code on the L1 frequency, and Precise Positioning Service (PPS) which uses the P(Y) code on both the L1 and L2 frequencies. Access to the PPS is restricted to US Armed Forces, US Federal agencies, and selected allied armed forces and governments. The SPS is available to all users on a continuous, worldwide basis, free of any direct user charges. The specific capabilities provided by SPS are published in the Global Positioning System Performance Standards and Specifications.

4.6.3. GPS Satellite Navigation System and their Segments

GPS is made up of three different components, called segments, that work together to provide location information.

The three segments of GPS are:

- **Space (Satellites)** the satellites circling the Earth, transmitting signals to users on geographical position and time of day.
- **Ground control** the <u>Control Segment</u> is made up of Earth-based monitor stations, master control stations and ground antenna. Control activities include tracking and operating the satellites in space and monitoring transmissions. There are monitoring stations on almost every continent in the world, including North and South America, Africa, Europe, Asia and Australia.
- User equipment GPS receivers and transmitters including items like watches, smartphones and telematic devices.

4.6.4. Main Systems – NAVSTAR, GLONASS, Galileo and Indian GPS

Global Navigation Satellite System (GNSS) constellations refer to a collection of Earth-orbiting satellites that provide positioning, navigation and timing data to GNSS receivers on Earth. There are various GNSS constellations in use around the world which include NAVSTAR GPS developed by the United States, GLONASS developed by Russia,

GALILEO developed by Europe, India's Regional Navigation Satellite Vector-based spatial analysis System (IRNSS or NavIC) and few more.

• NAVSTAR

Navstar is a network of U.S. satellites that provide global positioning system (GPS) services. They are used for navigation by both the military and civilians.

These 24 main GPS satellites orbit Earth every 12 hours, sending a synchronized signal from each individual satellite. Because the satellites are moving in different directions, a user on the ground receives the signals at slightly different times. When at least four satellites get in touch with the receiver, the receiver can calculate where the user is – often to a precision of just a few feet, for civilian use.

GPS signals used to be "degraded" for civilian use, meaning that they were only really precise in military applications. In 2000, however, President Bill Clinton authorized the switch-off of this "selective availability."

• GLONASS (GLObalNAvigation Satellite System)

The other fully operational <u>constellation</u>, GLONASS, is the one developed by the former <u>Soviet Union</u>. Started in 1976, it began to finally achieve its goals in 2001. Since 2001, many new satellites have been launched and the constellation has provided global geo-positioning since 2007. The constellation is currently nominal with 24 satellites in three orbital planes inclined at 64.8°.

• Galileo

Galileo is a global GNSS owned and operated by the European Union. The EU declared the start of Galileo Initial Services in 2016 and plans to complete the system of 24+ satellites by 2020.

• Indian GPS- NavIC (Navigation with Indian Constellation)

This is an independent Indian Satellite based positioning system for critical National applications. The main objective is to provide Reliable Position, Navigation and Timing services over India and its neighbourhood, to provide fairly good accuracy to the user. The IRNSS will provide basically two types of services

- 1. Standard Positioning Service (SPS)
- 2. Restricted Service (RS)

To date, ISRO has built a total of nine satellites in the IRNSS series; of which eight are currently in orbit Three of these satellites are in geostationary orbit (GEO) while the remaining in geosynchronous orbits (GSO) that maintain an inclination of 29° to the equatorial plane. The IRNSS constellation was named as "NavIC" (Navigation with Indian Constellation) by the Honourable Prime Minister, Mr. Narendra Modi and

dedicated to the nation on the occasion of the successful launch of the IRNSS-1G satellite. The eight operational satellites in the IRNSS series, namely IRNSS-1A, 1B, 1C, 1D, 1E, 1F, 1G and 1I were launched on Jul 02, 2013; Apr 04, 2014; Oct 16, 2014; Mar 28, 2015; Jan 20, 2016; Mar 10, 2016, Apr 28, 2016; and Apr 12, 2018 respectively. The PSLV-39 / IRNSS-1H being unsuccessful; the satellite could not reach orbit.

4.7. PRINCIPLES OF POSITIONING: POSITIONAL ACCURACIES, RELATIVE POSITIONING, ERRORS AND SOURCES

4.7.1. Working of the GPS technology:

GPS works through a technique called trilateration/ triangulation. Used to calculate location, velocity and elevation, <u>trilateration</u> collects signals from satellites to produce location information.

Satellites orbiting the earth send signals to be read and interpreted by a GPS device, situated on or near the earth's surface. To calculate location, a GPS device must be able to read the signal from at least four satellites. At any given moment, a GPS device can read the signals from six or more satellites.

Since a GPS device only gives information about the distance from a satellite, a single satellite cannot provide much location information. Satellites do not give off information about angles, so the location of a GPS device could be anywhere on a sphere's surface area.

When a satellite sends a signal, it creates a circle with a radius measured from the GPS device to the satellite.

When we add a second satellite, it creates a second circle, and the location is narrowed down to one of two points where the circles intersect.

With a third satellite, the device's location can finally be determined, as the device is at the intersection of all three circles.

A fourth circle from the fourth satellite is added to double check the location obtained.

4.7.2. Positional Accuracies

Over time, any stationary GNSS/GPS receiver will plot multiple positions for a given point. This happens because of errors caused by variables in the satellites, the surrounding physical environment, and the ionosphere.

Modern geospatial technology has made huge progress in correcting for those errors, but a receiver's real-time accuracy is dependent on its ability to process those corrections.

• Accuracy refers to the radius of the circle of unknown around a true point. The smaller the radius, the higher the accuracy. A receiver with

sub-meter accuracy can plot a position within a sub-meter radius of the Vector-based spatial analysis true point. Both of the images above show sub-meter accuracy.

• **Precision** refers to repeatability or how frequently a receiver can plot a point inside the circle of accuracy and whether or not that circle is centered over the true point. In the first image, the receiver has sub-meter accuracy with 95–98% precision. That is, 95–98% of the time, it will plot a point within one meter of the true point. In the second image, the receiver has sub-meter accuracy with 50% precision, i.e., the points fall within the meter radius 50% of the time.

4.7.3. Relative Positioning

GPS relative positioning, also called differential positioning, employs two GPS receivers simultaneously tracking the same satellites to determine their relative coordinates. Of the two receivers, one is selected as a reference, or base, which remains stationary at a site with precisely known coordinates. The other receiver, known as the rover or remote receiver, has its coordinates unknown. The rover receiver may or may not be stationary, depending on the type of the GPS operation.

A minimum of four common satellites is required for relative positioning. However, tracking more than four common satellites simultaneously would improve the precision of the GPS position solution.

4.7.4. Errors and Sources of errors

<u>GPS device accuracy</u> depends on many variables, such as the number of satellites available, the ionosphere, the urban environment and more.

Some factors that can hinder GPS accuracy include:

- **Physical obstructions:** Arrival time measurements can be skewed by large masses like mountains, buildings, trees and more.
- Atmospheric effects: Ionospheric delays, heavy storm cover and solar storms can all affect GPS devices.
- **Ephemeris:** The orbital model within a satellite could be incorrect or out-of-date, although this is becoming increasingly rare.
- **Numerical miscalculations:** This might be a factor when the device hardware is not designed to specifications.
- Artificial interference: These include GPS jamming devices or spoofs.

Accuracy tends to be higher in open areas with no adjacent tall buildings that can block signals. This effect is known as an urban canyon. When a device is surrounded by large buildings, like in downtown Manhattan or Toronto, the satellite signal is first blocked, and then bounced off a building, where it is finally read by the device. This can result in miscalculations of the satellite distance.

4.8. SUMMARY

Vector layer and raster layer operations are extended ways of analysing remotely sensed or vectorised data. They help to undertake analysis which can be implemented on ground as it is. Hence all geographical analysis can be undertaken most accurately and faster. GPS is a very powerful tool in collecting spatial data and organising it. It is based on satellite system hence gives most accurate locational information.

4.9. CHECK YOUR PROGRESS/EXERCISE

I. True or False

- **a.** Buffers are common vector analysis tools used to address problems of proximity
- **b.** Accuracy refers to the radius of the circle of unknown around a true point. The smaller the radius, the higher the accuracy.
- **c.** A minimum of four common satellites is required for relative positioning
- **d.** Precision refers to repeatability or how frequently a receiver can plot a point inside the circle of accuracy
- e. To date, ISRO has built a total of nine satellites in the IRNSS series

II. Fill in the blanks.

a. The ______ operation combines adjacent polygon features in a single feature dataset based on a single predetermined attribute.

(buffer, dissolve, merge)

b. The ______ operation combines features within a point, line, or polygon layer into a single feature with identical attribute information.

(buffer, dissolve, merge)

c. Used to calculate location, velocity and elevation ______ collects signals from satellites to produce location information.

(precision, accuracy, trilateration)

d. ______validates the equality of two operands

(not, equal to, greater than)

e. _____ performs multiplication on operands

(/,*,=)

III. Multiple Choice Questions.

- 1. In the vector model, this overlay determines the points lying inside a specific polygon
- a. Polygon in polygon
- b. Line in polygon
- c. Point in polygon
- d. Shapes in polygon
- 2. This overlay is more complex.
- a. Polygon in polygon
- b. Line in polygon
- c. Point in polygon
- d. Shapes in polygon
- **3.** The satellites circling the Earth, transmitting signals to users on geographical position and time of day are in this segment.
- a. Space
- b. Ground
- c. Control
- d. User
- 4. _____ is a global GNSS owned and operated by the European Union
- a. NAVSTAR
- b. GLONASS
- c. Galelio
- d. NavIC
- 5. ______ is a global GNSS owned and operated by Russia
- a. NAVSTAR
- b. GLONASS
- c. Galelio
- d. NavIC

4.10. ANSWERS TO THE SELF-LEARNING QUESTIONS

- Ia. True
- Ib. True
- Ic. True
- Id. True
- Ie. True
- IIa. Buffer
- IIb. Dissolve
- IIc. Trilateration
- IId. Equal to
- IIe. *
- IIIa.Polygon in polygon
- IIIb. Line in polygon
- IIIc. Space

IIId.Galelio

IIIe. GLONASS

4.11. TECHNICAL WORDS AND THEIR MEANING

- Remote sensing: Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object.
- GIS: A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map, such as streets, buildings, and vegetation.

4.12. TASK

Make a table with differences between the different GPS constellations.

4.13. REFERENCES FOR FURTHER STUDY

- Ghosh, J. 2015. A Text Book on GPS Surveying. CreateSpace Independent Publishing Platform. ISBN:9781522952749, 1522952748
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