

- The art and science of determining the position and shape of the objects from Photography
- The process of reconstructing objects without touching them.
- Non-contact Positioning method.

What is difference between remote sensing & Photogrammetry?

- Photogrammetry deals with the measurements of geometric properties of objects.
- Remote Sensing focuses on determining the material and condition of surfaces based on their radiometric properties.

Principle of Aerial Photography:-

- Aerial Photograph has been defined as the science of taking Photograph from a point in the air for the purpose of making some type of study on the earth surface.
- The net result of an any photographic mission is photographic negative.
- Photographic negatives are the result of favorable and unfavorable factors acting simultaneously

- A good aerial photograph must have certain standard of geometrical accuracy.

Planning of Aerial Photography-

- Aerial photography and its planning generally includes selection and types of aeroplane and camera, brand of gun film and filter combination, which is of great importance in aerial photo interpretation.
- The scale of photography further depends on objectives of the work, which governs the speed of aircraft, and its flying height, also depends on the type of camera lens being used.
- Optimum scale for geological photo interpretation are 1:25000 to 1:40000
- For regional geological surveys a small scale photography of 1:60000 (or) even smaller is suitable.
- For extensive ground coverage satellite imagery are most suitable.
- In aerial photography for more specific and detailed information such as geotechnical studies, mineral exploration, ground water surveys, land-use planning

and town planning, large scale photographs on photographs of scale, $\frac{1}{5000}$ to $\frac{1}{10000}$ are most suitable.

- In such type aerial photographs, low speed aeroplanes (200 to 350 kmph) are used and flying height is normally not more than 8000 to 10000m.
- Low flying speed and heights are one of the most important aspects in obtaining sufficiently large scale photographs with sharp images of objects.
- There should be complete stereographic coverage of terrain i.e. all features of the terrain should occur on atleast 2 photographs for stereoscopic viewing.

Types of Aerial Photographs:-

- Extreme growth in the technology and techniques used for acquiring aerial photographs.
- Aerial Photographs are classified according to

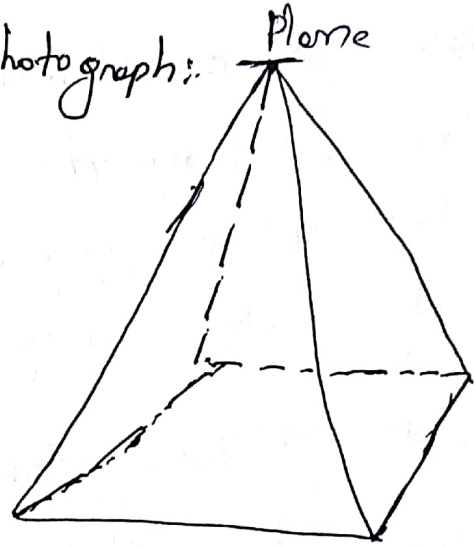
attitude of camera axis, lens system, types of cameras, types of films and filters (or) some special equipment employed in the camera (or) techniques to record some special effect on the film.

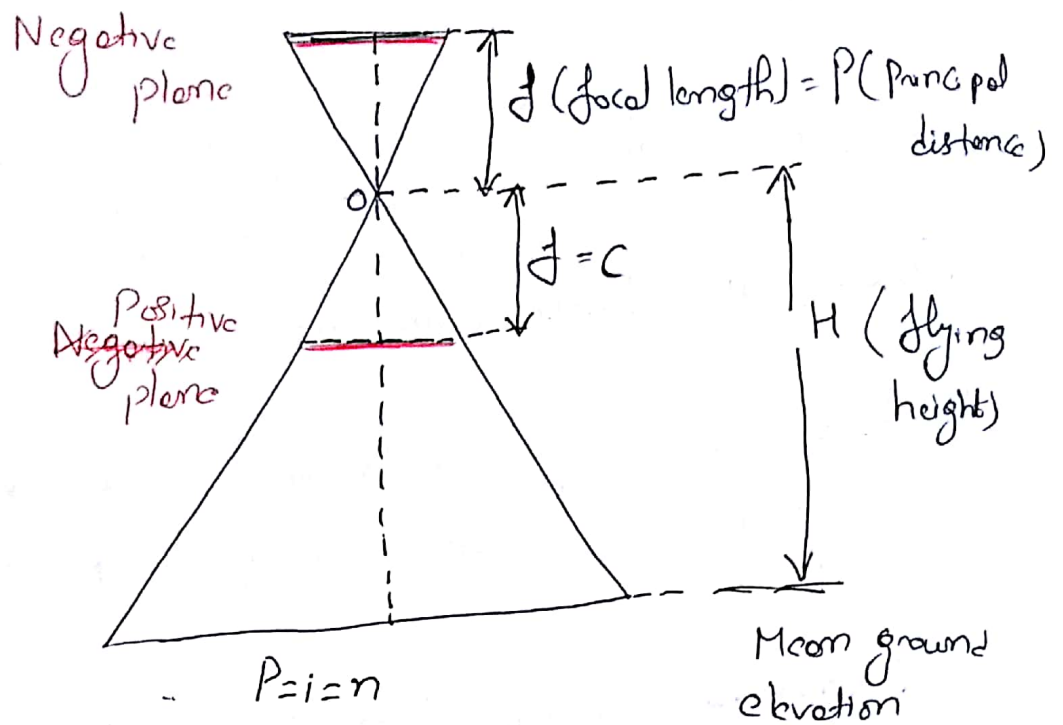
- Classification of techniques is done here according to 3 main criteria which are discussed below:
 - Based on - orientation of camera axis:
 - Vertical photographs
 - low oblique photographs
 - High oblique photographs
 - Based on lens system
 - Single lens photography
 - Three lens photography
 - Four lens photography
 - Nine lens photography
 - Continuous strip photography.
 - According to special Properties of films, filters (or) Photographic equipment:
 - Black and white Photography (Panchromatic)
 - Infrared Photography

- Color Photography
- Color Infrared Photography
- Thermal Infrared Photography
- Radar imagery
- Spectrogonal Photography.

Geometry of Vertical Photograph:

- Tilt < 3 degree
- Scale is approximately constant through out the photo
- Most common format available is 9×9 square inch
- Within limitations a vertical photograph can be used to substitute a map
- $P = i = n$ for a vertical photograph
 P = Principle Point
 i = Isocenter
 n = nodal point
 (vertical)





[Introduction Part :-

Remote Sensing:- Main characteristics

- Physical separation = between sensor and target
- Medium = electromagnetic radiation
- Device = to sample and measure radiation (Sensor)
- Target = is the terrestrial environment
(atmosphere, oceans, land surface)
- Remote Sensing began with aerial photography
- First photographs taken in 1839
- In 1858 Gaspard Felix Toussmachon "Nadar" takes photograph of village of Petit Bicetre in France

from a balloon

Types of Photogrammetry:-

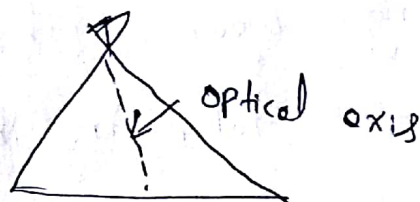
- 1) Aerial :- Series of Photographs of an area of terrain in sequence using a Precision camera.
- 2) Terrrestrial :- Photos taken from a fixed and usually known position (or) near the ground with camera axis horizontal (or) nearly so.
- 3) Close Range :- Camera close to the object being observed. Most often used when direct measurement is impractical.

⇒ Types of Aerial Photographs:-

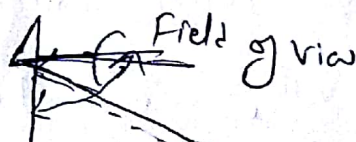
Vertical



Low oblique



High oblique



Scale Measurement.

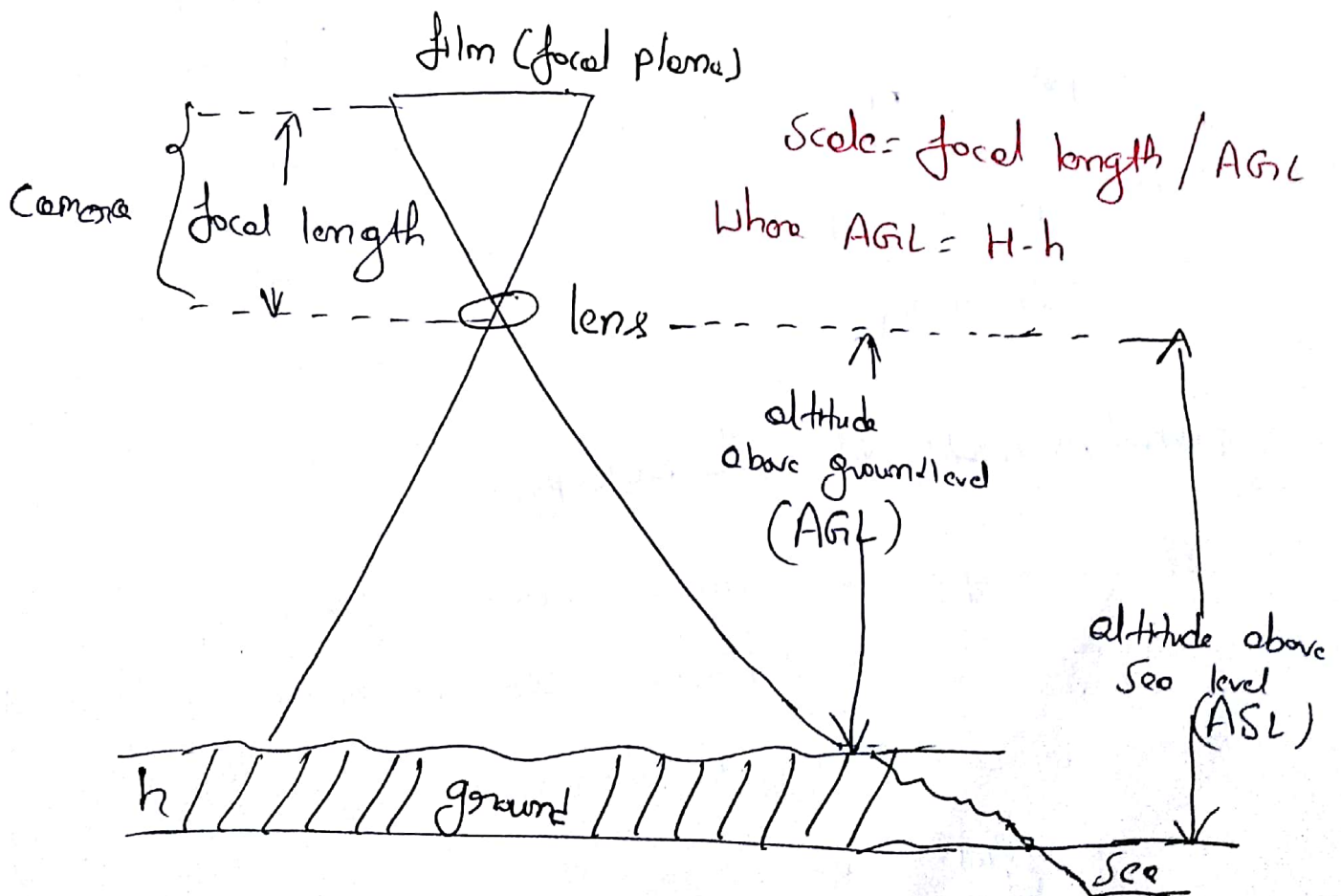
If you know the focal length of camera and height of aircraft above the ground you can calculate the scale of photograph

$$\text{Scale} = f/H-h$$

f = focal length (distance from centre of lens to film surface)

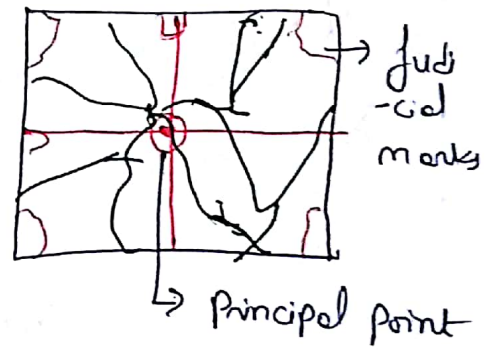
H = flying height of aircraft above sea level

h = height of ground above sea level.



Fiducial Marks:-

- Fiducial Marks is a set of Marks located in the corners or edge centers, or both of an aerial photographic image.
- These marks are exposed within the camera on to the original film and are used to define the frame of reference for spatial measurements on aerial photographs.
- Opposite fiducial marks connected, intersect at approximately the image center (or) Principal point of the aerial photograph.
- The "Principal point" is the geometric center of the photograph.



Fundamentals of Stereoscopy:-

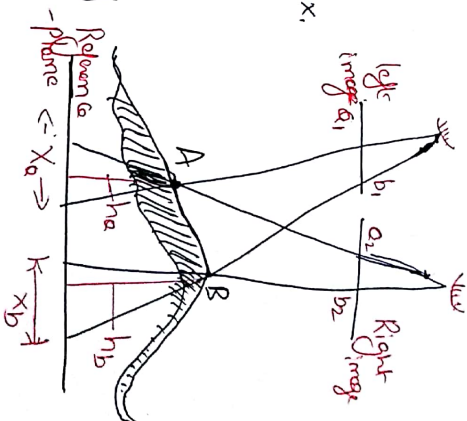
Stereoscopy, sometimes called stereoscopic imaging, is a technique used to enable a three dimensional effect, adding an illusion of depth to a flat image.

- In aerial photography, when two photographs overlap on the same ground area is photographed from two separate positions forms, a "Stereo pair", used for three dimension viewing. Thus obtained a pair of stereoscopic photographs (or) images can be viewed stereoscopically to determine Parallax and Stereo/3D viewing.

Parallax Measurement :-

Parallax:- The displacement of an object caused by a change in the point of observation is called Parallax.

Stereoscopic Parallax:- is caused by taking photographs of the same object but from different points of observation.



Parallax Measurement:-

$$\text{Height of object} = \frac{H \cdot dp}{P + dp}$$

H = height of aircraft above ground

P = absolute Parallax at base of object being measured

$dp =$ differential Parallax

For convenience, the photo base length of a stereo pair is commonly substituted for absolute Stereoscopic Parallax (P).

UNIT-III

GIS:- Geographical information system is a generic term denoting the use of computers to create and depict digital representation of the earth's surface.

Definition:- GIS are decision support computer based systems for collecting, storing and, presenting and analysing geographical spatial information. These systems are spatially referenced databases giving users the potentiality to control queries over space, and usually through time. GIS is much more advanced than Computer Aided Design (CAD).
(or) any other spatial data system. The basic output of GIS (or) spatial data analysis system is a map.

Eg:- A set of states (or) revenue (or) administrative units like Mandals within a country would commonly be ~~represented~~ represented in a GIS as a set of areal objects, or as set of linear objects that form their boundaries.

GIS Architecture (Subsystem nature of GIS):

GIS can be understood as the subsystem nature within the framework of a main system. According GIS has the following generic subsystems:

- (i) A data input subsystem which is also called data capture subsystem
- (ii) A data storage and retrieval subsystem
- (iii) A data manipulation and analysis subsystem
- (iv) A reporting subsystem

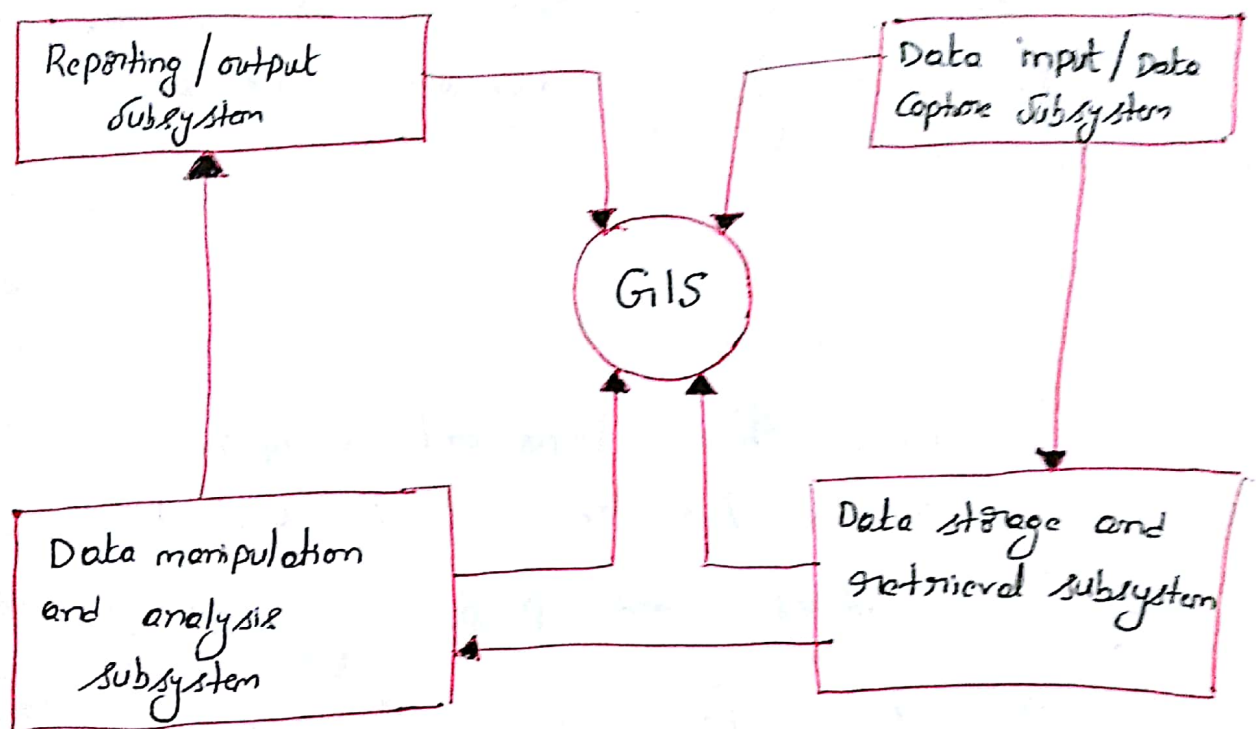


Fig: Subsystem nature of GIS

- Each of subsystem has been described in terms of the functions that the respective subsystem performs.
- Data input / capture subsystem provides operational functions for acquiring data.
- Data storage and retrieval subsystem stores and retrieves the data elements.

The
→ A Manipulation and data Analysis subsystem handles the transformation of data from one form to another and derivation of information from the data.

→ The fourth subsystem output/reporting subsystem provides a way for the user to see the data in the form of diagrams, maps and tables.

Components of a GIS:-

GIS have three important components, namely, computer hardware, sets of application software modules, and proper organisational set-up. These three components need to be in balance if the system is to function satisfactorily. Systems are available that use dedicated and expensive work stations, with monitors and digitising tables built in.

In all cases, there are number of elements that are essential for effective GIS operations. These include

- (1) the presence of Processor with sufficient power to run the software

(ii) Sufficient memory for the storage of large volumes of data.

(iii) a good quality, high resolution color graphics screen &

(iv) data input & output devices, like digitisers, Scanners, keyboards, Printers & plotters.

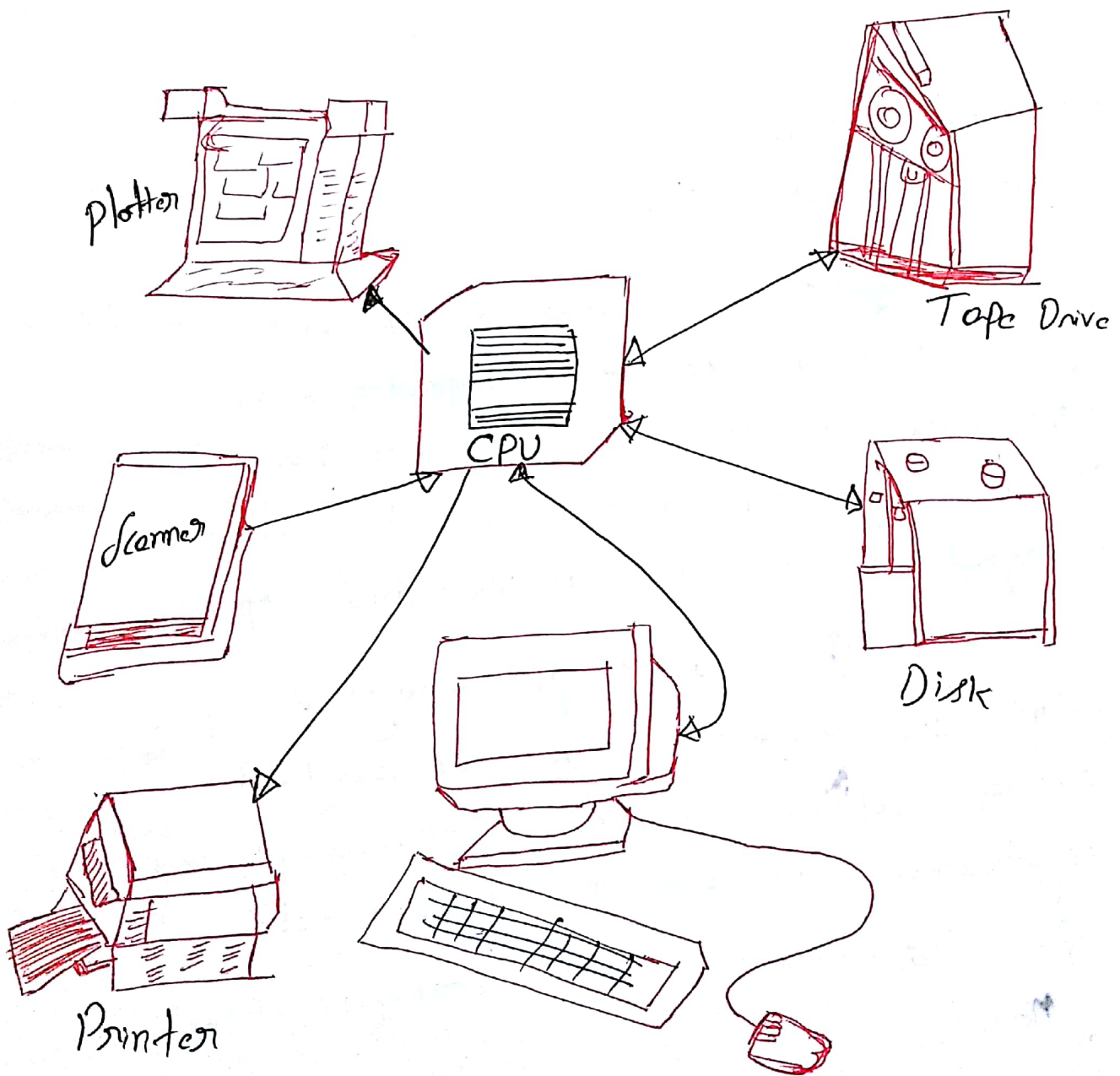


Fig: Hardware components of GIS

The general hardware components of GIS include control processing unit which is linked to mass storage units such as hard disk drives, and tape drives, Peripherals such as digitiser (or scanner), Printer (or) plotter and Visual display unit.

Functional elements

Fundamental operations of GIS

The fundamental classes of operations performed by a GIS have been characterized as "map algebra" in which context primitive operations of map analysis can be seen as analogous to traditional mathematical operations.

The classes of 'analytical operation' are divided into reclassification, overlay, distance / connectivity measurement and neighbourhood characterisation of the data.

These operations can be identified as follows:

- (i) Reclassification operations transform the attribute information associated with

a single map coverage.

(i) Overlay operations involve the combination of two or more maps according to boolean conditions and may result in the delineation of new boundaries

(ii) Distance and connectivity measurement include both simple measurement of interzones of increasing transport cost away from specified locations, and

(iv) Neighbourhood characterisation involves the values to a location both summary and mean measures of a variable, and include smoothing and enhancement filters. Sequences on such manipulation operations have become known as "cartographic modelling".

Theoretical Framework for GIS:-

This discussion is based on an analysis of the way in which data are transformed and held as a digital model of the external world.

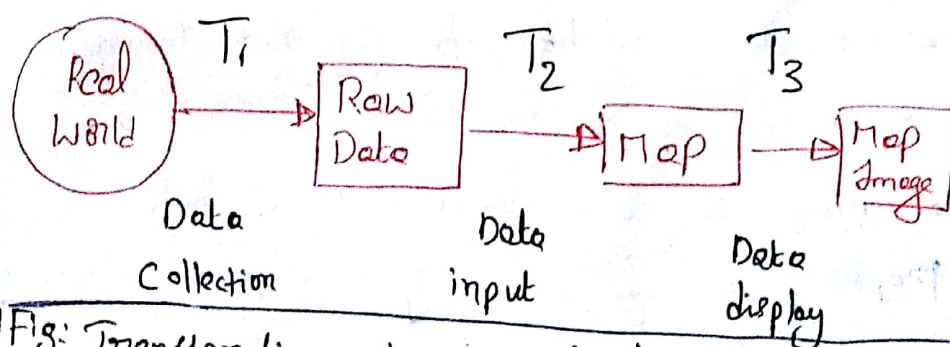


Fig: Transformation stages in the traditional cartographic process

The ground work for this approach has been laid by cartographers seeking to understand the relationship between the world and map as a model.

We have seen how digital map is related to analog map, and we must now modify and extend the existing theoretical structure to replace the paper map with a digital map sitting within a GIS. The process of analog map production may be modelled as series of transformations between the real world, raw data, the map & the map image.

In the first transformation (T_1) data are selected from the real world, as for example surveying measurements or census data. These are then input for the GIS in some form (T_2) to provide the basis for its digital map representation of the real world. Within the system, a vast range of manipulation operations are available to further transform the data and store the results (T_3), and these may be communicated as tabulated or graphic images by means of hardcopy or screen (T_4).

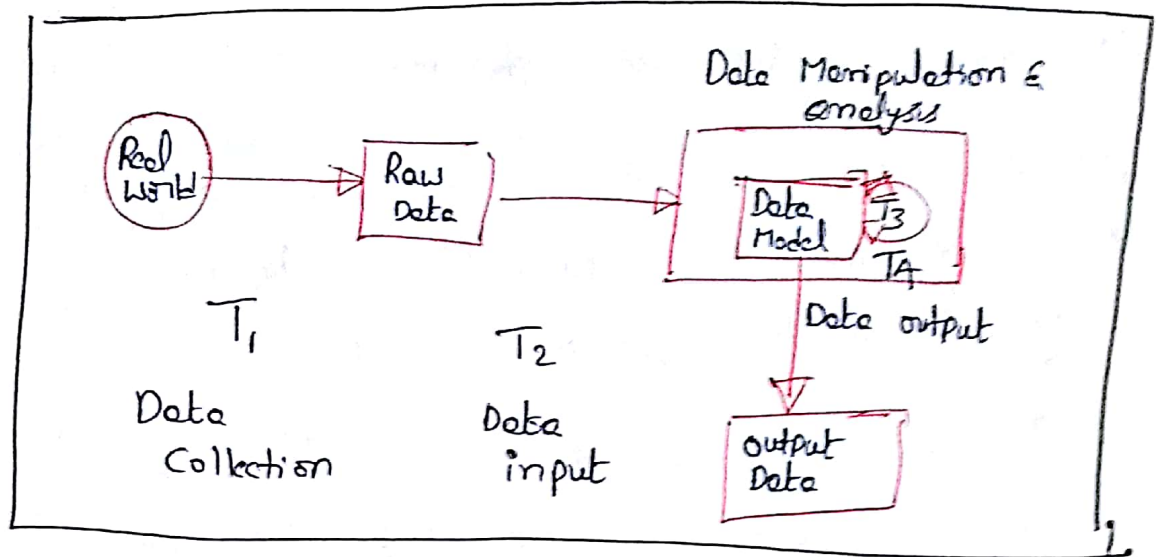


Fig: Transformation based view of GIS operation

⇒ Map Projections Parameters:

There are five map projection parameters that are going to be discussed. They are

- Standard points and lines
- Projection aspect
- Central Meridian
- Latitude of origin
- Light source location

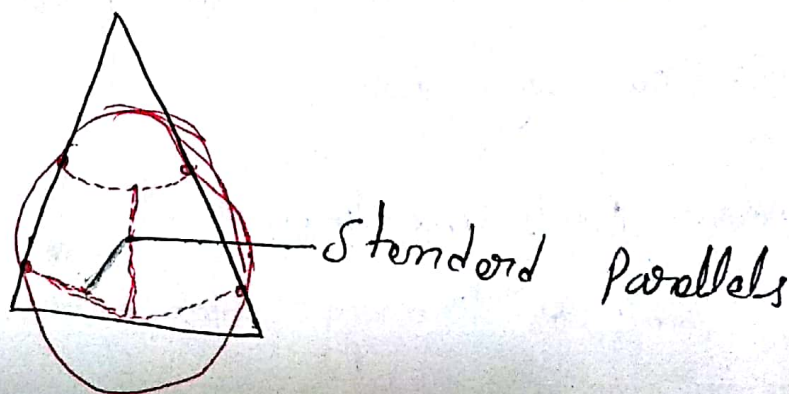
Now start with a standard points and lines and work our way down

① Standard Points and lines:

Def: Points or lines of intersection between the

developable surface and spheroid.

- * Standard point and line is defined as a point or line of intersection between the developable surface and the spheroid or ellipsoid.
- * In the case of "secant intersection", there will be two standard lines that would define where the developable surface intersects with the spheroid.
- * If the developable surface happens to intersect the spheroid with a long line of latitude, it is known as a "Standard Parallel".
- * Additionally if a standard line falls on a line of longitude exactly, it is known as "Standard Meridian".
- * When defining a Map projection, you must define standard points and lines. It is not uncommon to have map ~~as~~ projection follow a standard parallel (or) standard Meridian.



* In this illustration, one is named aspect, and with second intersection, the second intersection lines follow parallels, therefore they are both known as "standard parallels".

Why are standard points & lines important? :-

* The reason why standard points & lines are important, because the corresponding places (or) along the standard points to lines will have no scale distortion

* That means, that where the developable surface intersects with the spheroid, there is little to no distortion on our flat map.

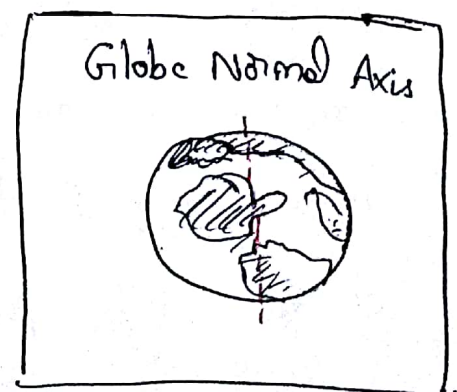
* Now, the further away from the standard points (or) lines, the greater the distortion or deformation that will occur on the map.

* Second intersection between the developable surface and spheroid can help to minimize distortion over a large area by providing more control than a tangent intersection at a single point or line.

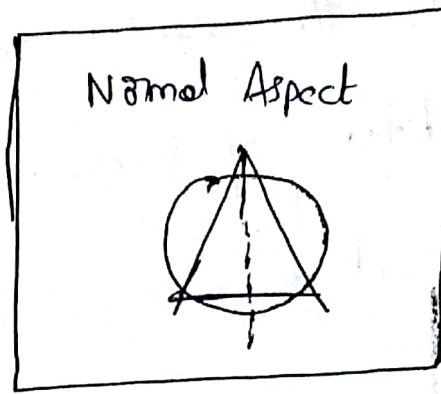
- * Therefore the placement of standard points & lines is one of the most important parameters to consider when defining a map projection.

(2) Projection Aspect:-

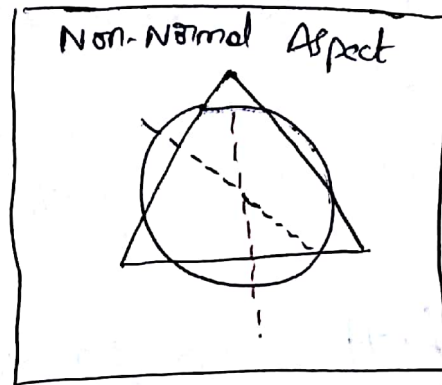
- * A Projection Aspect is the position of the projected graticule relative to ordinary position of the geographic grid on earth. [Graticule - a network of lines representing meridians and parallels on map]
- * What that means is that if the developable surface's vertical axis coincides with vertical axis of the earth, then this defines a "normal aspect".
- * If the vertical axis of the developable surface differs from the vertical axis of the earth, then this would be an abnormal aspect.
- * This illustration displays the normal axis of the globe, which runs from the north pole through the center of the Earth to the south pole.



* This illustration shows a cone developable surface at a secant intersection with the earth.



* As the vertical axis of the cone, which is displayed as a blue line, coincides with the vertical axis of the earth, which is displayed as a red dotted line, this is considered a normal aspect.



* This illustration shows a non-aspect. Note that the vertical axis of the cone does not coincide with the vertical axis of the earth thus creating a non-aspect.

③ Central Meridian :-

* The central meridian defines the center point of the projection. It means that this is the meridian, or longitude line that displays in the center of the map.

* Essentially, this allows you to rotate the earth about the vertical axis to determine what portion the earth you want to have.

in the centre of the map

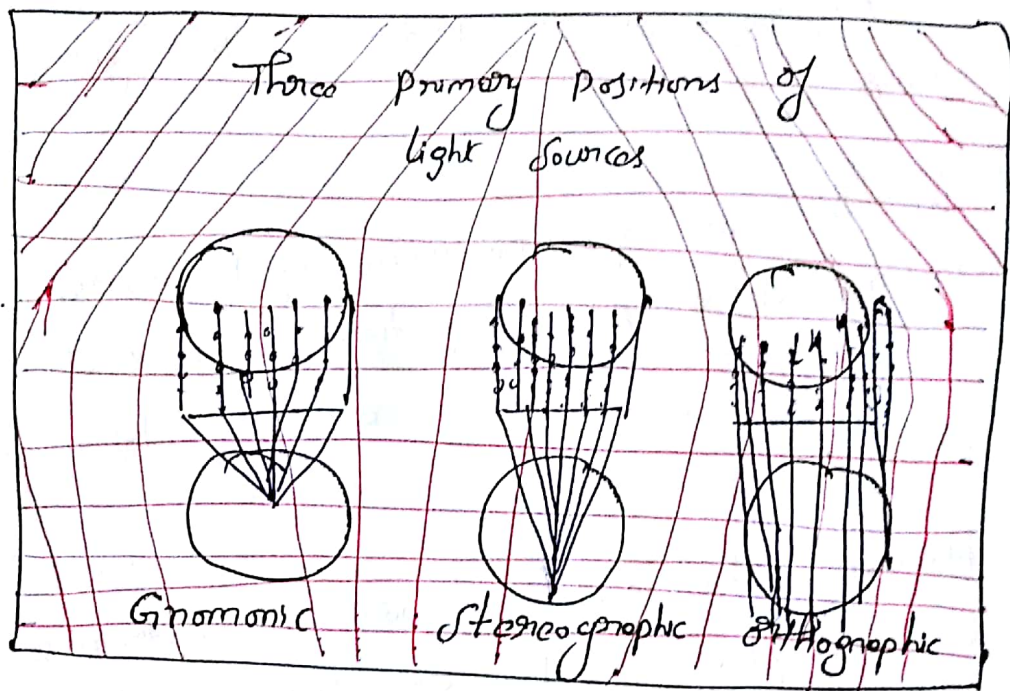
④ Latitude of origin:

- * Latitude of origin is a latitude that defines the centre of the projection.
- * It means that this is the latitude that will be in the center of the map projection.
- * Changing the latitude of origin moves the projection about the horizontal axis to determine which portion of the earth will be shown in the middle of the map.

⑤ Light Source Location:

- * The light source location map projection ^{parameter} is the location of the hypothetical light source in the reference to the globe being projected.
- * Remember that there are three parts of the map projection:
 - (1) Ellipsoid
 - (2) The light source &
 - (3) The developable surface.
- * The light source is what projects the surface of the earth on to the developable surface.

- * There are three primary positions in which we can place the light source.



- * The three primary positions of my sources are gnomonic, stereographic and orthographic.
- * In gnomonic light source position, the light source is placed at the centre, or the core of the earth.
- * The light is then projected through the earth's surface and projects the landmasses on to the developable surface.
- * In this illustration, the earth is the bottom circle, the lines are the light source, and the solid white line is the developable surface.

* The top circle and the dotted lines represent where the earth will be compressed, (or) stretched, based on the position of the light source.

* In the case of gnomonic light source, looking at a polar projection, locations at the centre of the earth are held closer to true,

* However, the locations towards the extremities, are elongated as they are stretched out to meet the developable surface.

* In Stereographic Projection, the light sources placed at the opposite side of the earth from where the developable surface has its secant (or) tangent intersection

* In this case, there is a less severe differential between where the earth is compressed and elongated, but no location is clearly free from distortion.

* In orthographic position, the light is placed at a theoretical infinite distance from Earth opposite from the point of intersection (or) tangency.

* This allows formidable distortion in the center of the projection, however significant compression at the extremities of the map.

Together, these five map projections properties allows us to selectively display, and distort the earth to create a map that is suitable for our needs.

What does map distortion mean?

A map projection is a systematic transformation of latitudes and longitudes of locations from the surface of a sphere or an ellipsoid into locations on a plane. Maps cannot be created without map projections. All map projections necessarily distort the surface in some fashion.

What causes distortion in maps?

A map projection is mathematical formula

used to transfer all (or) part of the curved surface of the earth on to the flat surface of the map. The process of flattening the earth causes distortions in one (or) more of the following spatial properties: Distance, Area.

⇒ Geospatial data:- Spatial vs Attributes:

- 1) GIS data is the key component of a GIS and has two general types: a) spatial and b) Attribute data.
- 2) Spatial data are used to provide the visual representation of geographic space and is stored as raster and vector types.
- 3) Hence, this data is a combination of location data and a value data to render a map, for example.
- 4) Attribute data are descriptions, measurements, and/or classifications of geographic features in map.
- 5) Attribute data can be classified into four levels of measurement: nominal, ordinal, interval and ratio.

- 6) The nominal level is the lowest level of measurement for distinguishing features quantitatively using type or class.
(eg: tree species)
- 7) Ordinal data are ranked in to hierarchies but doesnot show any magnitude of difference
(eg: city hierarchy)
- 8) The interval measurement indicates the distance between the ranks of measured elements, but a starting point is arbitrarily assigned (eg: celsius temperature)
- 9) Ratio measurements, the highest level of measurements, includes an absolute starting point. Data of this category include property value and distance

Sources of Spatial and Attribute data

• Spatial data can be obtained from Satellite images (or) Scanned maps and similar resources.

- This data can then be digitised into vector data (or) maintained as raster graphic data.
- Essentially, any format of geographical image with location (or) co-ordinate points can be used as spatial data.
 - ⇒ Attribute data can be obtained from a number of sources (or) data can be captured specifically for your application.
- Some popular sources of attribute data are from town planning and managing departments, policing and fire departments, environmental groups, online media.

UNIT-IV

Vector Data Model

- Vector data structures allow the representation of geographic space in an intuitive way reminiscent of the familiar analog map.
- The geographic space can be represented by the spatial location of items (or) attributes which are stored in another file for later access.
- It shows how the different entity, namely, points, lines, and areas can be defined by coordinate geometry.
- Like the raster spatial data model, there are many potential vector data models that can be used to store the geometric representation of entities in the computer.
- A point is the simplest spatial entity that can be represented in the vector world with topology.
- A point requires to be topologically correct with respect to a geographical reference system which locates it with respect to other spatial entities.

Simplest form of Vector data

- The simplest vector data structure that can be used to reproduce a geographical image in the computer is a file containing (x, y) coordinate pairs that represent the location of individual point features
- The limitations of simple vector data structures start emerging when more complex spatial entities are considered.
- There are several ways in which vector data structures can be put together into a vector data model by which the relationships between variables in a single coverage (or) among variables in different coverages can be defined.
- The two basic types of vector data models are
 - (1) Spaghetti model
 - (2) Topological Model

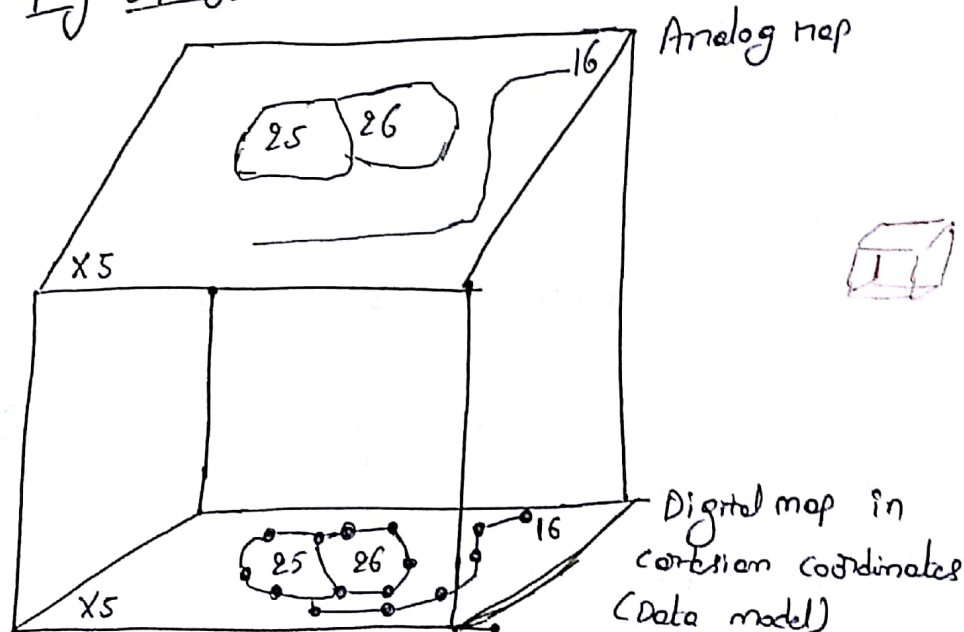
⇒ Spaghetti Model: The simplest vector data structure that can be used to reproduce

a geographical image in the computer is a file containing (x,y) coordinate pairs that represent the location of individual point features.

- The below figure is essentially a one-for-one translation of the graphical image (or) a map which is also termed as the conceptual model
- Let us consider a conceptual model in which an analog map covering each graphic object is shown in following figure.
- Each graphic object can be represented with a piece of spaghetti.
- Each piece of spaghetti acts as a single entity.
- Each entity is a single, logical record in the computer, coded as variable length strings of (x,y) coordinate pairs.
- These two adjacent Let us assume that two polygons lie adjacent to each other in a thematic coverage.
- These two adjacent polygons must have separate pieces of spaghetti for adjacent sides.

- That is, no, two adjacent polygons share the same string of spaghetti
- Each side of polygon is uniquely defined by its own set of lines and coordinate pairs
- In this model of representing vector data, all the spaghetti are recorded separately for polygons. But in the computer they should have same coordinates.

Fig: Spaghetti Vector Data Model



Data Structure

Feature	Number	location
Point	5	X,Y (Single pair)
line	16	(String of x,y coordinate pairs)
Polygon	25	(closed loop of x,y coordinate pairs where first and last pair are same)
	26	(closed loop sharing coordinates with adjacent polygons to form a data structure)

- The spaghetti model is relatively efficient as a method of cartographic display and is still used quite often in computer aided cartography, when analysis is not the primary objective.
- The characteristic feature of spaghetti model is recording of the coordinates of all the points associated with all the polygons.
- However this model would not address any information about the linkage between lines.
- Linkages would be implied only when the lines are displayed on the computer screen.
- In the way, a series of polygons created using either the simple data structure (or) a point by point approach may appear connected on the screen.
- Therefore the spaghetti model does not consider the topology.
- But any vector model would be called a perfect vector GIS model, if and only if it has the functional capabilities of spatial database management.

- For the representation of line networks and adjacent island polygons, a set of instructions is required to inform the computer where one polygon (or) line is with respect to its neighbours.

Topological Models:

- The topological data model incorporates solutions to some of the frequently used operations in advanced GIS analytical techniques.
- This is done by explicitly recording adjacency information in to log the basic logical entity in topological data structures, beginning and ending.
- When it contacts (or) intersects another line, (or) when there is a change in the direction of line.
- Each line then has two sets of numbers:

a pair of coordinates, and an associated node number.

- The node is the intersection of two (or) more lines, and its number is used to refer to any line to which it is connected.
- In addition, each line segment called a link has its own identification number that is used as a pointer to indicate the set of nodes that represent its beginning and ending of polygon.
- These links ^{also} have identification codes that relate polygon numbers to see which two polygons are adjacent to each other along its length.
- In fact, the left and right polygon

are also stored explicitly, so that even this tedious step is eliminated.

- Fundamentally, the topological models available in GIS ensure

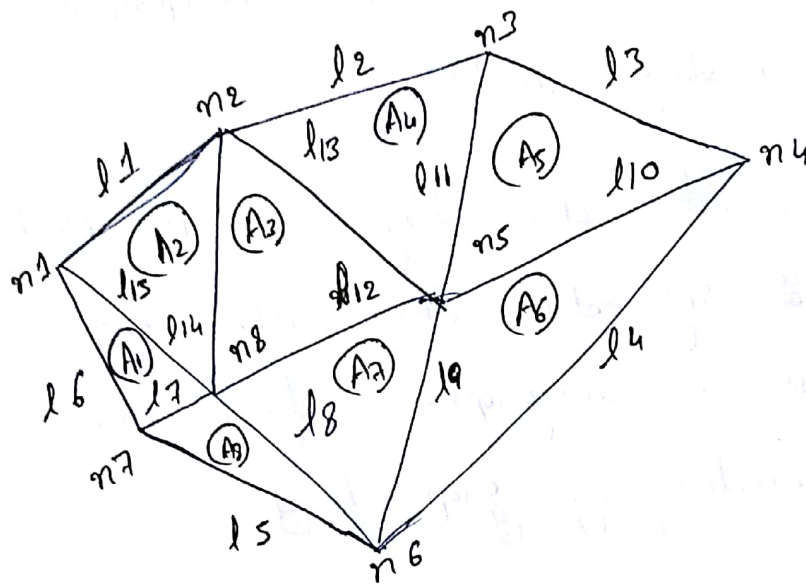
- (a) that no node (b) line segment is duplicated.

- (b) that line segments and nodes can be referenced to more than one polygon &

- (c) that all polygons can be adequately represented in following figure shows one possible topological data structure for the vector representation.

- To understand the topological vector data structure, let us consider a network with 8 nodes enclosed as n_1 to n_8 .

- The links joining all these nodes are encoded as l_1 to l_{14} and the polygons created by all these line segments / links are coded as A_1 to A_8



- There are number of topological vector data models.
- out of the available models, three models are very common in use.
- These ~~and~~ three models are
 - GBF / DIME model created by US Department of commerce, Bureau of the census, 1969

(b) TIGER model (Mox, 1986) and

(c) POLYVERT (Pequet, 1984)

→ GBF / DIME Topological Vector model.

- The best known topological model is the Geographical Base File / Dual Independent Map Encoding model.
- These models were designed to incorporate topological information about urban areas for use in demographic analyses and were created by graph theory.
- In case of straight-line segment ends when it either changes direction or intersects another line, and the nodes are identified with codes.
- In addition to the basic topological model, the GBF / DIME model assigns a directional code in the form of a ' from node and

a To node; i.e. a low value node to a high-value node in the sequence.

- An additional useful feature of the GBF/DME system is the creation of the files for both the street address and coordinates for each node and links.
- The disadvantage of such a model is the slowest possible way to search for records in a computer.
- The GBF/DME system is based on the concept of graph theory.
- It does not matter whether the line connecting any two points is curved
(or) Straight.

TIGER Topological Vector model:-

- TIGER stands for Topologically Integrated

Geographic Encoding and Reforming System.

- This model does not depend upon the graph theory designed for use in the 1990 US census)
- In this system, points, lines and areas can be explicitly addressed, and therefore census blocks can be retrieved directly by block number.
- Real-world features such as meandering streams and irregular coastlines are given a graphic portrayal more representative of their true geographic shape.
- Thus TIGER files are more generally used in research which is not related to census.

→ POLYVRT Topological Vector Model:-

- POLYVRT developed by Peucker and Christman (1975) and later implemented at the Harvard Laboratory for Computer Graphics was called the POLYVRT.
- In this method of representing vector data, each type of geographic entity is stored separately.
- These separate objects are then linked in a hierarchical data structure with points relating to lines, which in turn are related to polygons through the use of pointers.
- This structure is also called an n-mode structure and objects in the database are structured hierarchically.

- In this system, points are the elemental base components.
- Arcs are the individual line segments that are defined by a series of x, y coordinate pairs.
- Nodes are at the ends of arcs and form the points of intersection between arcs.
- POLYVRT model has advantage of retrieving selective and specific entity types like points, lines, or polygons based on their codes.
- POLYVRT has the following advantages
 - It allows to store and retrieve specific entity types and identify them based on their codes.

- Since a polygon can be stored with indirect line segments, individual line segments are straight as nodes and with those nodes as coordinate pairs, each entity can be accessed, retrieved, stored, manipulated, and analysed selectively.
- The major drawback of POLYVRT is that it is difficult to detect an incorrect pointer for a given polygon until the polygon has actually been retrieved.

Shape files:

- Advancement of computer technology in terms of database management techniques, speed of processor, and massive storage capacity of

of the devices.

- It leads to the development of a new and non topological structure called the shape file.
- The shape file structure is the file structure that stores the geometry, topographic information, and attribute information of the geographical features in a data set file.
- The geometry and shape of the feature comprise a set of vector coordinates and topology corresponding to their attributes.
- The shape file generally has less processing overhead than its topological counterpart.
- Shape files are usually three separate and distinct type of files.

- main file, index file, and database tables.
- The main file is a direct access, variable record length file that contains the shape as a list of vertices.
- The index file contains character length and offset information for locating the values, and a database table which contains the attributes that describe the shapes.

Compact Vector Data Models:

- There are two schemes of compacting vector data models: Galtoris schemes and Freeman - Huffman chain codes.
- In the Galtoris scheme, we have to apply eight numerical values, one for each of the cardinal compass directions and

=> Comparison of Raster and Vector Models

Raster model	Vector model
Advantages • It is a simple data structure • Overlay operations are easily and efficiently implemented	Advantages • It provides a more compact data structure than the raster model • It provides efficient encoding of topology and network analysis.

Disadvantages	Disadvantages
• The raster data structure is less compact • Topological relationships are more difficult to represent. • The output of graphics is less aesthetically pleasing	• It is more complex data structure than a simple raster • Overlay operations are more difficult to implement. • The representation is high spatial variability is inefficient.

UNIT-V

Raster Data Model & Data Input

⇒ Elements of the Raster Data Model:-

There are three elements in a raster data model. points, line and Area

(i) Raster data represents points by single cells

(ii) Raster data represents lines by sequence of neighboring cells

(iii) Raster data represents areas by collection of contiguous cell.

• In the raster GIS, a range of different methods are used to encode a spatial entity for storage and representation in the computer.

• The following figure shows the most straight forward method of coding raster data

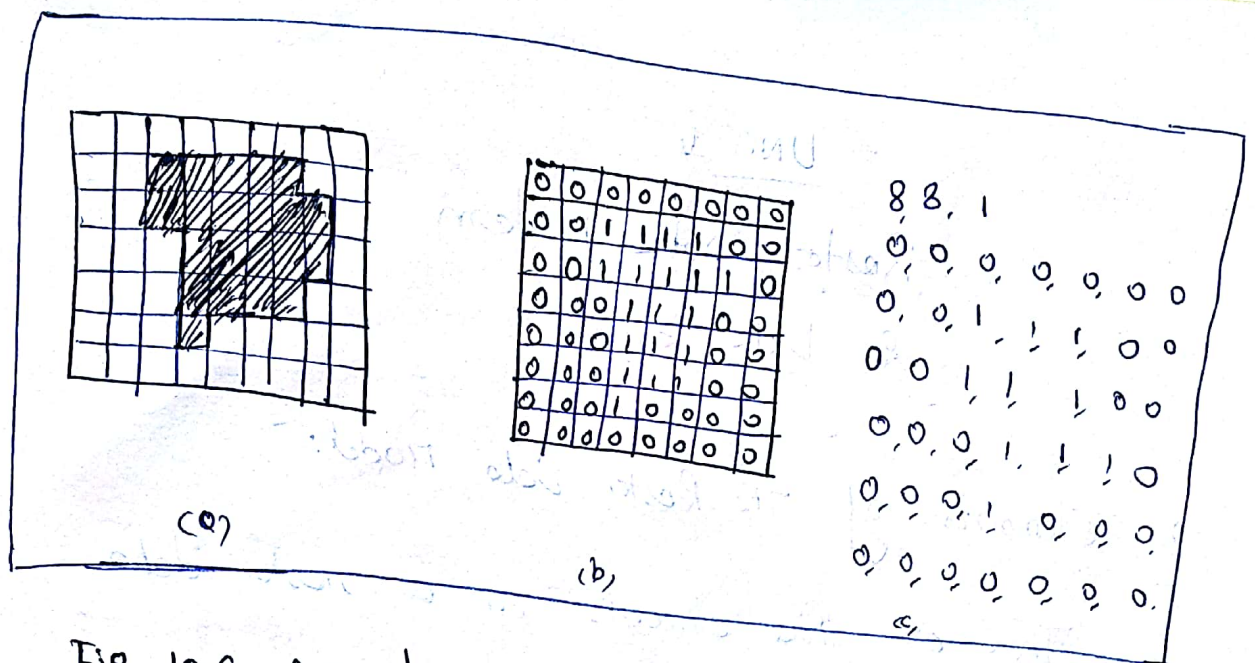


Fig 10-6 A Simple Raster Data Structure

(a) Entity model (b) cell values and (c) file structure

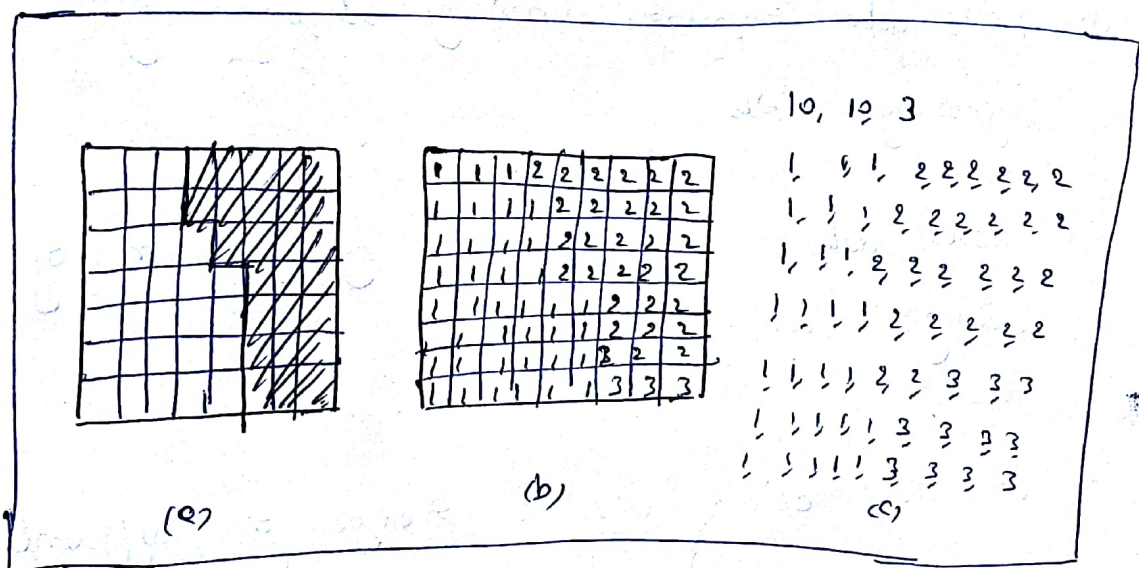


Fig: Coding of features in Raster GIS

- The cells in each line of the image are mirrored by an equivalent row of numbers in the structure.

- The line of the file structure indicates the number of rows, the number of columns and the maximum cell value in the image.
- one of the major problems with the raster data sets is their size, in that a value must be recorded and stored for each cell in an image.
- Thus, a complex image made up of a mosaic of different features such as a soil map with 20 distinct classes requires the same amount of storage space as a simpler raster map showing the location of a single forest.
- To address this problem a range of data compression methods have been developed.
- These include run length encoding, block coding, chain coding and quadtree data structures.
- one of the simplest data structures is a

master (or) cellular organisation of spatial data.

- A set of cells are located by coordinates, and each cell is independently addressed with the value of an attribute.
- The simplest raster data structure consists of an array of grid cells.
- Each grid cell is referenced by an row and column number and it contains a number representing the type of value of the attribute being mapped.
- Raster representation assumes that the geo-graphical space can be treated as though it were a flat cartesian surface.
- Each pixel (or) grid cell is then associated with the square parcel land.
- The resolution (or) scale of raster data is the relation between the cell size in the database and the size of the cell on the ground.

- The use of this type of model mainly related to the volume of data size of memory required.
- Data storage requirements can be considerably reduced by chain codes, run-length codes, quadrees and block codes.

Simple Raster Arrays:

- The horizontal dimension of the simple raster, along the rows of the array, is often oriented parallel to the east-west direction for convenience.
- Positions in the vertical direction, aligning with the columns of the array, are often numbered starting from the top boundary.
- This numbering scheme comes from the computer graphics field, in which displays are often painted on the computer screen (or) printer from the top down.

- Thus, the origin of the raster is frequently the upper left corner.
- Note that this referencing system for cells in a raster is different from more traditional georeferencing systems, such as latitude-longitude in which one specific point on the earth's surface is the origin.
- Often, the distances between cells in the raster are constant in both the row and column directions.
- In other words, the cells in the raster are square.
- In this case, it is natural to store the data on a computer in a two-dimensional array.

Hierarchical Raster Structures:

- Consider a set of digital elevation data values where the fundamental data are

stored on a 50 meter square grid.

Rather than storing this information as a single layer in GIS, we shall store it in several interrelated layers.

- one layer corresponds to the original 50 meter interval raster data.

- A second layer consists of data resampled to a 100 meter interval.

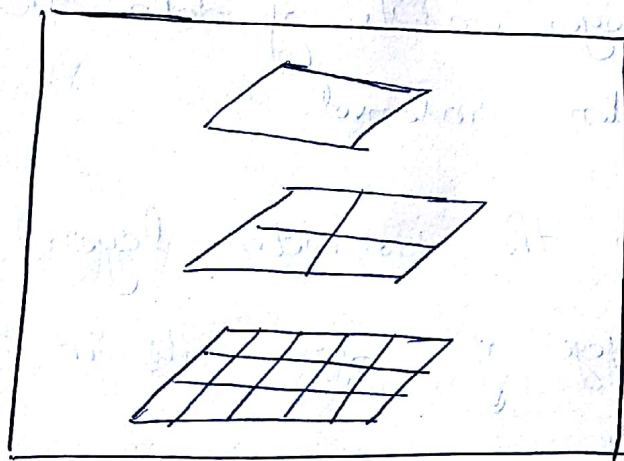
- Each cell in the 100 meter layer is the algebraic average of four cells in the 50 meter layer.

- A third spatial averaging process, decreasing the spatial resolution at each "higher" layer until at the highest layer we might have a single pixel.

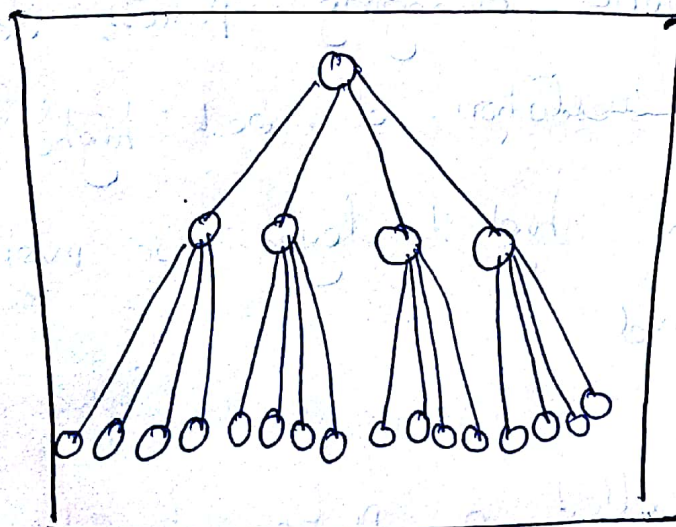
- This is called a pyramidal data structure since we can imagine each of the derived

layers stacked on top of previous layers
in the space of a pyramid.

- If each higher level layer has pixel that are exactly twice as wide as the earlier one, this is called a quadtree structure.



Raster layers of different cell sizes.



Tree representation

Types of Raster GIS models:

- The GRID based GIS spatial data can be stored, manipulated, analysed and referenced basically in any one of the three methods.
- These three models are GRID/LUNAR/MAGI model, IMGRIID model & MAP model.
- All of these models use the grid cell values, their attributes, coverages and corresponding legends.
- These models are developed depending upon the requirements from time to time.
- There are number of ways of forcing a computer to store and reference the individual grid cell values their attributes, coverage names and legends.

GRID model:

- The first and foremost model for the representation of raster data is the GRID model.
- The method of storing, manipulating, and analysing the grid based data was first conceptualised by an attempt to develop GRID model.
- In this method, each grid cell is referenced and addressed individually and is associated with identically positioned grid cells in all other coverages.
- Comparisons between coverages and therefore performed on a single column at a time.
- For example to compare soil attributes in one coverage with Vegetation attributes in a second coverage.

- land use/ land coverage attributes in a third coverage.

- The advantage of this model is that computational comparison of multiple themes (or) coverages for each grid cell location is relatively easy.

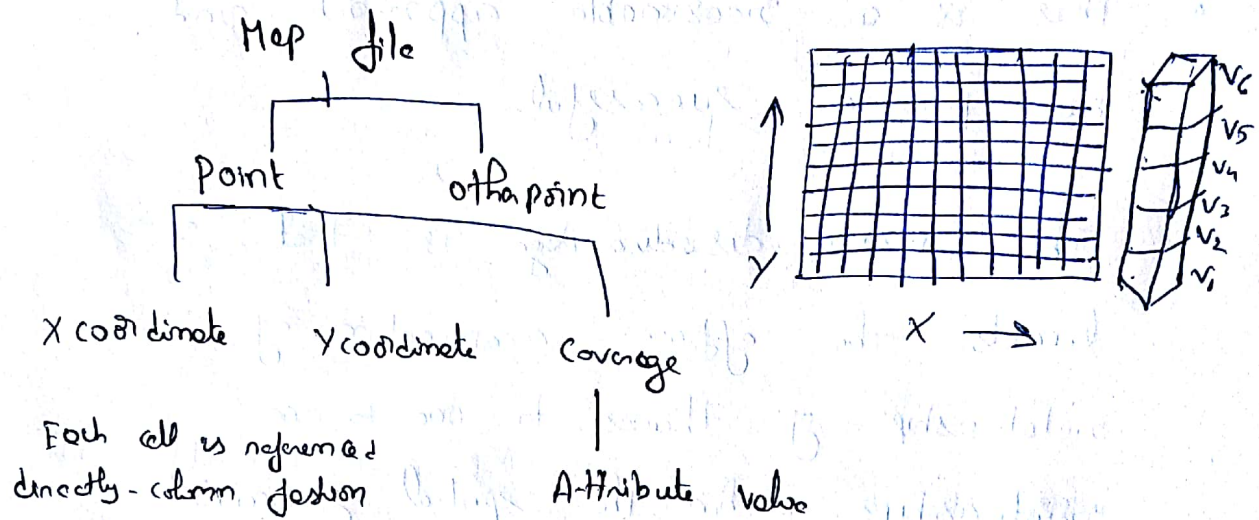
- This is a reasonable approach, and has proven successful.

- The main disadvantage is that it limits the efficient examination of relationships of themes to one-to-one relationships within the spatial framework.

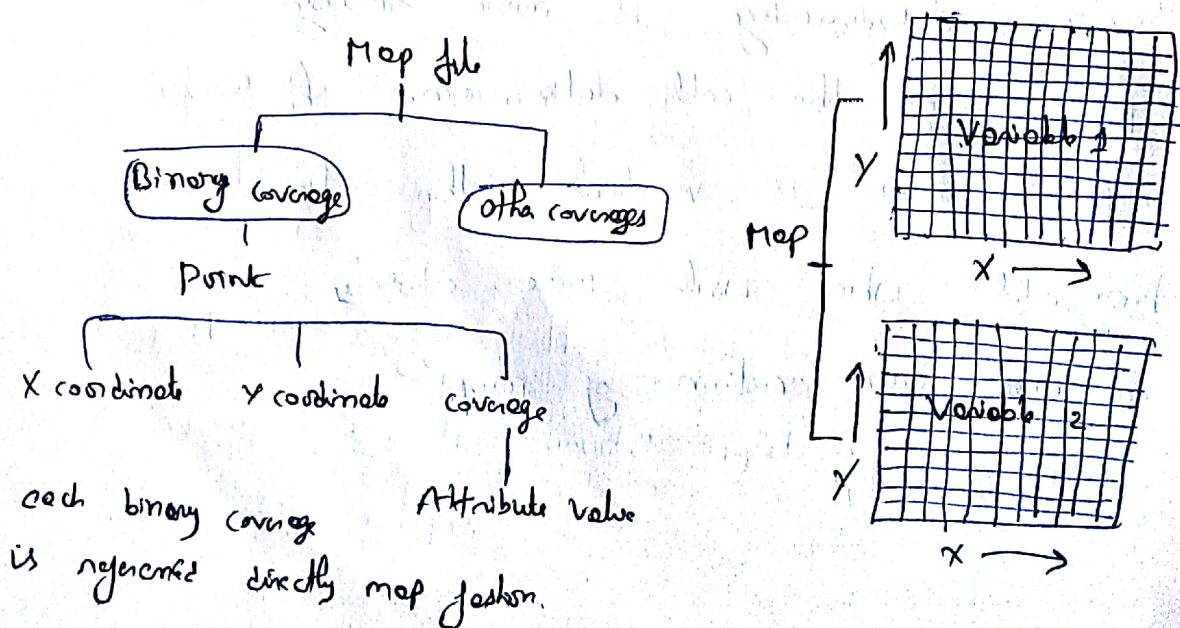
- Second disadvantage is more storage space for the cell data and the representation is vertical rather than horizontal, which would more closely resemble our notion of maps.

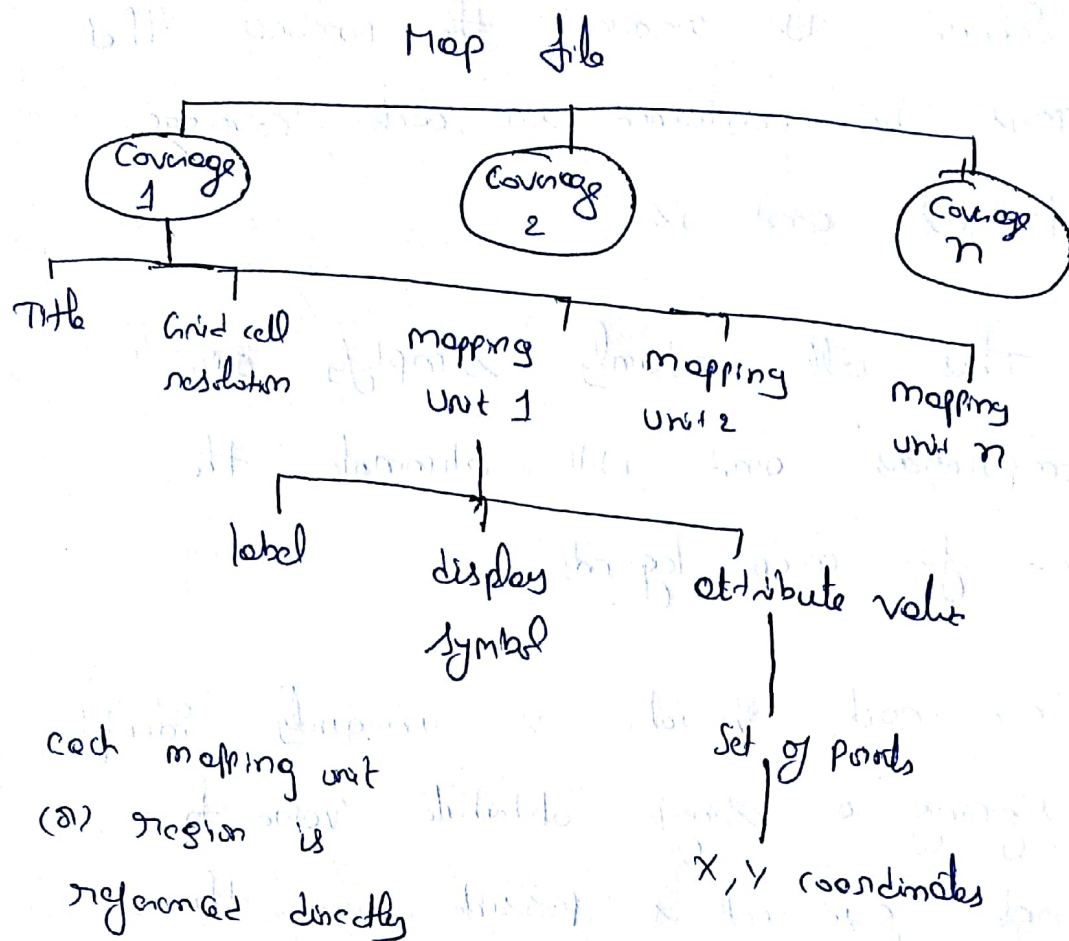
- With a slight modification of the checkboard analog, the second basic raster data model, that is the IMGRID data model.

- This model is also called used in the early GIS system.



(a)





(c)

- IMGRID system has two major advantages
- First, we have a contiguous object that more closely resembles how we think about a map.
- That is our primary storage object is two dimensional array of numbers, rather than a column of numbers for different themes

- Second We reduce the numbers that must be contained in each coverage to 0's and 1's

- This will certainly simplify our computations and will eliminate the need for map legends

- Since each variable is uniquely identified, assigning a single attribute value to a single grid cell is possible and this is a third advantage.

- The INGRID model is seen to be more intuitive from a map abstraction viewpoint and requires us to be very specific about the attributes to be contained in each coverage.

- But it offers the advantage of using the coverage as the direct object of reference for the computer.

Map Model:

- The third raster GIS model Map Analysis Package (MAP) model developed by C. Dana Tomlin formally integrates the advantages of the above two raster data structure methods.
- This is accomplished by recording each variable, or mapping unit, of the coverages theme as a separate number code or label, which can be accessed individually when the coverage is retrieved.
- It is easy to perform operation on individual grid cells or groups of similar grid cells, and the resolution changes in value require rewriting only a single number per mapping unit, thus simplifying the computations.
- Map data model can be used as teaching

- Many software systems already have both sets of capabilities, and still are more likely in future.

Metadata:

- Metadata is a summary document providing content, quality, type, creation and spatial information about data set.
- It can be stored in any format such as text files, Extensible Markup language (XML), or database record.
- Because of its small size compared to the data, it describes, metadata is more easily shareable.
- Metadata makes data discovery easier and reduces data duplication.

- GIS metadata has a spatial component such as the extent of earth's surface the data covers.
- Metadata can describe GIS data, a GIS Web service, or an online metadata catalog.
- Metadata can also describe non-electronic data such as paper maps or offline electronic data such as data stored on CD or tape media.
- Open ^{standards} ~~(source)~~ for metadata enable the data clearinghouse concept, also known as catalog service.
- Two well known GIS Metadata catalog services are the geography network and the NSDI Clearinghouse.

Remote Sensing data

- In many applications, a visual interpretation of remotely sensed data may be adequate.
- Resulting maps (or) similar products can be used as a stand alone product and as input for further analysis in a GIS or a hydrological model.
- For digitally processing remotely sensed data recorded in the optical range of electromagnetic spectrum.
- For processing and analysing remotely sensed data in hydrological applications, several concepts can be distinguished, namely multispectral, multitemporal and near real time concepts.
- All remotely sensed data have to undergo certain degree of pre-processing i.e. data must be calibrated, normalized, atmospherically

Basic concept of Remote Sensing:-

- Remote Sensing is the science and art of obtaining information about an object, area (or) phenomenon through an analysis of data acquired by a device which is not in contact with the object, area (or) phenomenon under investigation.
- The definition of remote sensing is restricted to mean the process of acquiring information about any object without physically contacting it in anyway regardless of whether the observer is immediately adjacent to the object (or) millions of miles away.
- It is further required that such sensing may be achieved in the absence of any matter in the intervening space between

the object and observer

- Consequently the information about the object, area (or) any phenomenon must be available in a form that can be impressed on a common vacuum.

- The information carrier, or communication link, is electromagnetic energy

- Remote sensing data basically consists of Wavelength intensity information acquired by collecting the electromagnetic radiation leaving the object at specific wavelength and measuring its intensity.

- Remote sensing of earth's environment comprises measuring and recording of electromagnetic energy reflected from (or) emitted by planets surface and atmosphere.

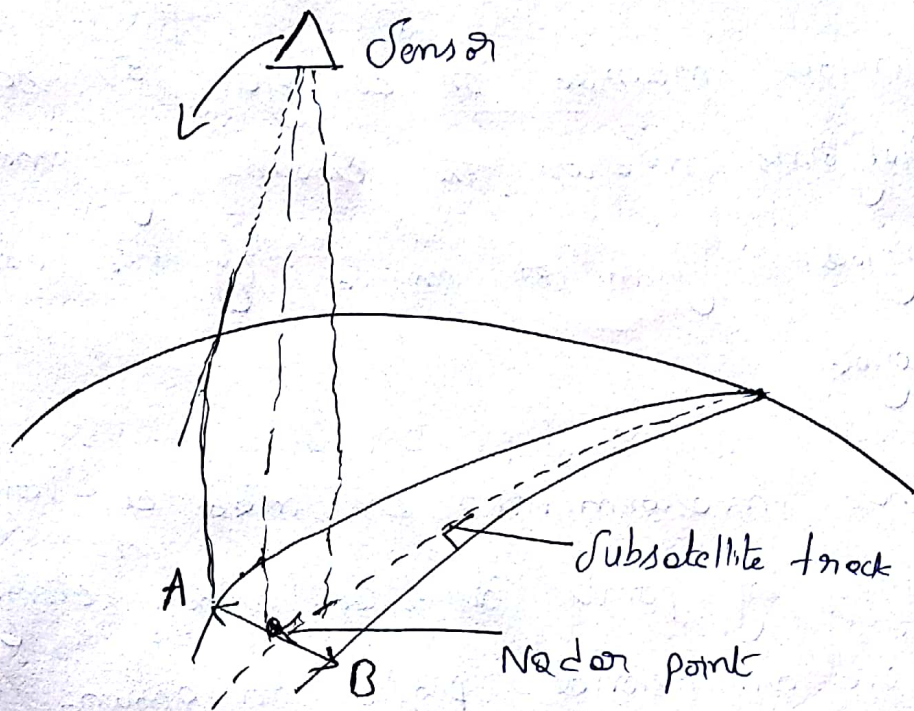
- Sensors mounted on aircraft (or) satellite platforms measure the amounts of energy reflected from (or) emitted by the earth's surface.

- These measurements are made at large number of points distributed either along a one-dimensional profile on ground below the platform (or)

- Over a two-dimensional area on the either side of the ground track of the platform

- The sensors scan the ground below the satellite (or) aircraft platform and as the platform moves forward an image of the earth's surface is built up

- The following figure shows how a sensor on board satellite scans along line AB.



- Each scan line of remotely sensed image is digital (or) numerical record of radiance measurements made at regular intervals along the line.
- A set of consecutive scan lines forms an image.
- Two dimensional image data can be collected by means of two types of imaging sensors namely, nadir looking (or) side looking sensor.

- In the case of nadir looking, the ground once to either side of the satellite or aircraft platform is imaged by means of side looking sensor.

Remote Sensing data collection process:-

- Broadly there are two types of sensing systems to record the information about any target.
- They are Active sensing system and passive sensing system.
- An active sensing system generates and uses its own energy to illuminate the target and records the reflected energy which carries the information content (or) entropy.
- Synthetic aperture radar (SAR) is one of the best examples of active sensing systems.

- These sensing systems operate in the microwave region of electromagnetic spectrum and include radiation with wavelengths longer than 1mm.
- These systems do not rely on the detection of solar (or) terrestrial emissions as the solar irradiance in microwave region is negligible.
- The active remote sensing operation principles and the general details of latest imaging radar systems are described.
- The second type of remote sensing systems are passive systems mainly depending on the solar radiation operates in visible and infrared region of electromagnetic spectrum.
- The nature and the target properties

- The remote sensing system that uses electromagnetic energy that can be termed as electromagnetic remote sensing.

Wavelengths (m)

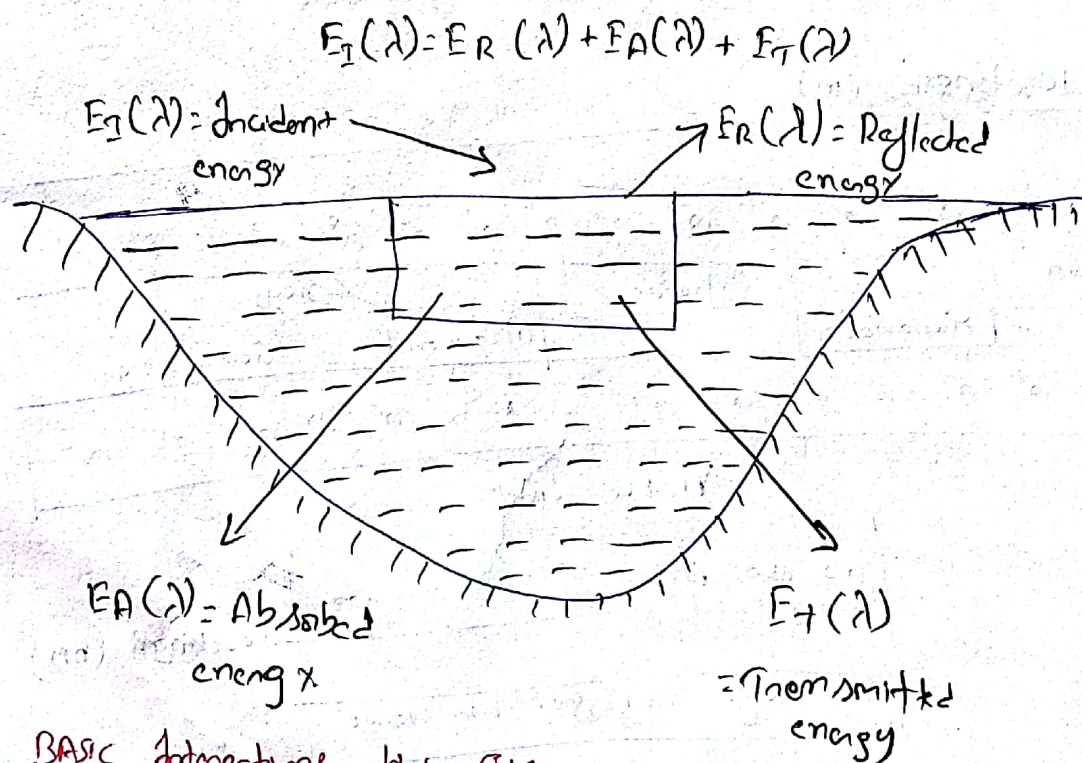


$\mu m = \text{micrometer} = 10^{-6} \text{ meters}$

The micrometer is the most common unit used to quantify the wavelength of EM energy.

Energy interaction with Earth surface materials

- When electromagnetic energy is incident on any feature of the earth's surface such as a water body, various fractions of energy get reflected, absorbed, and transmitted.



BASIC Interactions b/w EM energy and water body

$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda) \quad \text{--- (1)}$$

Where E_I = Incident energy

E_R = Reflected energy

E_A = Absorbed energy

E_T = Transmitted energy

- All the energy components are functions of wavelength, (λ)
- In remote sensing, the amount of reflected energy (λ) E_R is the more important than the absorbed and transmitted energies.

- Therefore it is more convenient to rearrange these terms like

$$E_R(\lambda) = E_I(\lambda) - [E_A(\lambda) + E_T(\lambda)] \quad \text{--- (2)}$$

- The (2) equation is called balance equation
- From this mathematic equation, two important points can be drawn, Firstly

$$\frac{E_R(\lambda)}{E_I(\lambda)} = \frac{E_I(\lambda)}{E_I(\lambda)} - \left[\frac{E_A(\lambda)}{E_I(\lambda)} + \frac{E_T(\lambda)}{E_I(\lambda)} \right] \quad - (3)$$

- According to principles of physics, it is known that

$$\frac{E_R(\lambda)}{E_I(\lambda)}, \frac{E_A(\lambda)}{E_I(\lambda)} \text{ and } \frac{E_T(\lambda)}{E_I(\lambda)} \text{ are called}$$

reflectance, absorbance and transmittance
can be denoted as $\rho(\lambda)$, $\alpha(\lambda)$
and $\gamma(\lambda)$.

- Simply, it can be understood that, the measure of how much electromagnetic radiation is reflected off a surface is called its reflectance.
- The reflectance range lies between 0 and 1.

- The reflective characteristics are quantified by spectral reflectance, $P(\lambda)$ which is expressed as the following ratio

$$P(\lambda) = \frac{E_R(\lambda)}{E_I(\lambda)}$$

= energy of wavelength (λ) reflected from the object

energy of wavelength (λ) incident upon the object

Interaction of EM radiation with Atmospheric constituents :

- EM radiation from the sun interacts with atmosphere constituents and gets absorbed
(or) scattered.

- Essentially, two types of scattering takes place,

- Elastic scattering - In which the energy of radiation (ν or λ) is not changed due to scattering.
- Inelastic scattering - In which the energy of the scattered radiation (ν or λ) is changed.
- Inelastic scattering takes place when high energy photons are scattered by free electrons in the ionosphere (a) or by the loosely bound electrons of atoms and molecules in the atmosphere.
- As regards the elastic scattering, we recognize three types of such scattering phenomena in the atmosphere.
- Rayleigh, Mie and non-selective scattering depending on the size of scatterer in relation to the wave length of radiation (λ)

being scattered.

- The atmosphere scattering process are.

Scattering process	Wavelength dependence	Particle size (nm) Approx.	Kind of Particles
Rayleigh	λ^{-4}	< 0.1	Air molecules
Mie	λ^0 to λ^4	0.1 to 10	Smoke, Jumes, haze
Non-selective	λ^0	10	Dust, fog, cloud.

Table: Atmospheric Scattering Process

- The Rayleigh scattering is the most important type of scattering; it causes a distortion of spectral characteristics of the reflected light when compared to the measurements taken on the ground.
- Whereas the Mie scattering influences the

entire spectral region from ultraviolet to near infrared regions.

- Occurrence of non-selective scattering mechanism gives a clue to the existence of large particulate matter in the atmosphere above the scene of interest.

Advantages of remote sensing

- Large area coverage: Remote sensing allows coverage of very large areas which enables regional surveys on a variety of themes and identification of extremely large features.
- It allows repetitive coverage which comes in handy when collecting data on dynamic themes such as water, agricultural fields and so on.
- It allows for easy collection of data

- over a variety of scales and resolutions.
- It can easily be processed and analyzed just using a computer and the data utilized for the various purposes.
 - It is unobstructive especially if the sensor is passively recording the electromagnetic energy reflected from (or) emitted by the phenomena of interest.
 - Data collected through remote sensing is analysed at the laboratory which minimizes the work that needs to be done on the field.
 - It allows for map revision at a small to medium scale which makes it a bit cheaper and faster.
 - It is easier to locate floods (or) forest fire that has spread over a large region.

which makes it easier to plan a rescue mission easily and fast.

- It is relatively cheap and constructive method reconstructing a base map in the absence of detailed land survey methods.

Disadvantages of remote sensing:-

- It is fairly expensive method of analysis especially when measuring (a) analysing smaller areas
- It requires a special kind of training to analyze the images.
- It is expensive to analyze repetitive photographs. If there is need to analyze different aspects of the photography features
- Powerful active remote sensing systems such as radars that emit their own

EM radiation can be intrusive and affect the phenomenon being investigated.

- The instruments used in remote sensing may sometimes be un-calibrated which may lead to uncalibrated remote sensing data.
- Sometimes different phenomena being analyzed may look the same during measurement which may lead to classification error.
- The image being analyzed may sometimes be interfered by other phenomena that are not being measured and this also should be accounted for during analysis.
- Sometimes large scale engineering maps cannot be prepared from satellite data which makes remote sensing data collection incomplete.

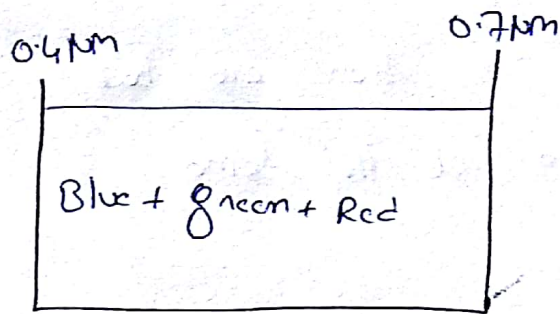
Resolution:

Four types of resolution.

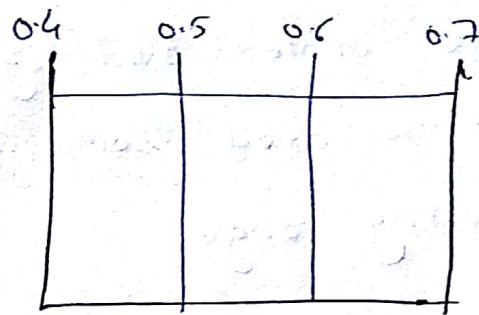
- 1) Spatial resolution: Instantaneous field of view (IFOV)
 - Pixel: smallest unit of an image
 - Pixel size
 - Spatial coverage: field of view (FOV) or
 - Area of coverage such as MODIS: 2300 km²
(or) global coverage, weather radar
(NEXRAD): a circle with 230 km as radius.

2) Spectral resolution

- It describes the ability of a sensor to define fine wavelength intervals.
- The finer the spectral resolution, the narrower the wavelength range for a particular channel (or) band.



Black & White
film



Colour
film

3) Radiometric resolution

- Sensor's sensitivity to the magnitude of the EM energy
- Sensor's ability to discriminate very slight differences in energy.
- The finer, the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in energy

4) Temporal Resolution

- It is the revisit period, and is the length of the time for satellite to complete one

one entire orbit cycle, i.e. start and back to the exact same once at the same viewing angle.

- For example, Landsat needs 16 days, MODIS needs one day, NEXRAD needs 6 minutes for rain mode and 10 minutes for clear sky mode.
- Temporal coverage is the time period of sensor from starting to ending.
- False color: It refers to a group of color rendering methods used to display images in color which were recorded in the visible (or) non-visible parts of the electromagnetic spectrum.
- A false color image is an image that depicts an object in colors that differ from those a photograph would show.