CE432A

Geographical Information System

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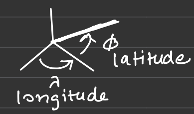
Aman

Introduction to GIS (Lecture 1)

- Plan Drawing → Coordinates can assume origin
- Grid Reference :- 6 figure grid references.
- 2D ⇒ small area
- But for globe ⇒ latitude, longitude
- North Pole, South Pole
- Equator
- Line that passes thro' N-S pole — Meridian / longitude lines
- Line parallel to equator — latitude line.
- Longitude – meridian ; Parallel — latitude
- Meridian that passes through Greenwich
- Curvilinear Coordinates — Degree, Minutes, seconds



ELEMENTS OF A MAP AND MAP SCALE

MAP SCALE :- A scale is the ratio of the distance between any two pts. on a map to the actual distance between the corresponding pts. on the ground.

1: 1000 ⇒ larger scale

1: 25000 ⇒ smaller scale ⇒ features will be smaller.

Map scale can be expressed in any of the three ways:-

- By a statement — 1cm is 4 km
- By a Numerical Fraction — 1: 250,000
- By graphical section or linear scale

Approximate Measurements on the Earth.

- 1 Degree of arc = 110 km
- 1 Minute of arc = 1 mile or 1.6 km
- 1 second of arc = 30 metres

Classification of Maps

on basis of scale

- large scale : > 1:25K
- medium scale : 1:25K, 1:50K, 1:250K
- small scale : < 1:250K
- very small scale : < 1:1M

on basis of contents and purpose

- Physical Maps
- Cultural Maps

Plottable Error

- It is considered to be a pencil dot on the map which is ≅ 0.25 mm in measurement
- It is smallest dimension of a feature that can be represented on a map.
- Plottable Error determines the scale of the map.
- Eg:- 1: 10,000 scale 1 mm = 10,000 mm

  Plottable error 0.25 mm = 0.25 × 10,000 = 2500 mm or 2.5 m

  ⇒ Topographic features smaller than 2.5m in dimension cannot be shown on this scale of map.
- Eg:- 1: 250000

  Plottable error 0.25 mm = 0.25 × 250000 = 62500 mm or 62.5 m

Lecture 4 GIS

- GEOID — Geopotential Surface — Potential is constant
  — Gravity is perpendicular at every point.

- REFERENCE ELLIPSOID — Just a mathematical function.

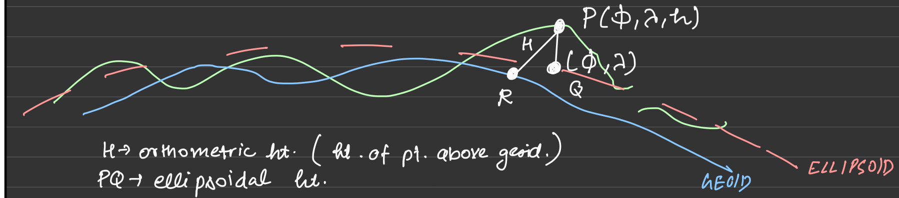
Representation of a Point

- Height — water flows from one point to another.
  — got to do with gravity.

← Refering a pt. is difficult here.

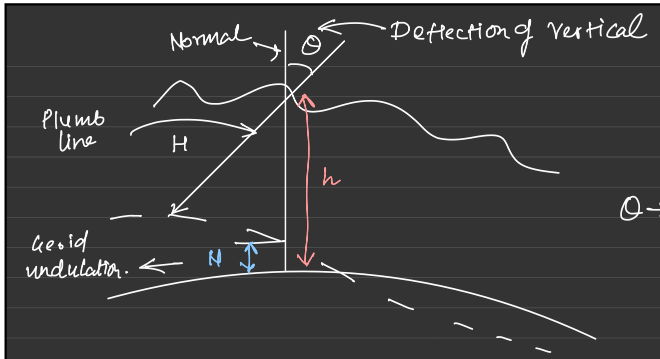
- Ellipsoid — Used to represent a horizontal coordinate
- Geoid — used for referring height

Ocean Surface — Geoid is referred w.r.t. it.
BUT ocean circulates . . . . .
Ocean moves because of tides → Main cause of circulation.



H → orthometric ht. (ht. of pt. above geoid.)
PQ → ellipsoidal ht.

- H = Height of point above 'P' measured along the plumbline.
- h = Ellipsoidal ht = above reference ellipsoid and measured along the ellipsoidal normal.



H
h

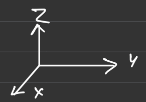
θ → hardly 2" or
θ → negligible.

* Levelling → H → orthometric ht
* GPS → h →
* $\boxed{h = H + N}$

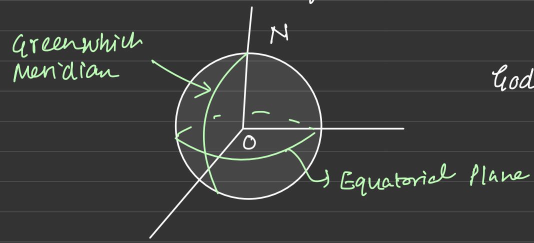
COORDINATE SYSTEM

Requirements to define Coordinate System

- Location of the origin
  GEOCENTRIC → center of earth's surface
  HELIO CENTRIC → center of the sun
  TOPO CENTRIC → center of topocentric origin (specific location)
- Orientation of the Axis.

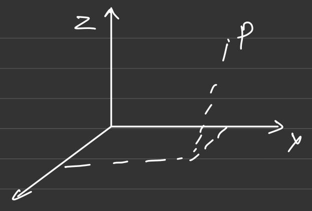


- Parameters which define the C.S.

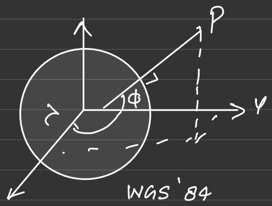


God → N, O

RIGHT HANDED SYSTEM — Geodetic
LEFT HANDED SYSTEM — Astronomical, etc.

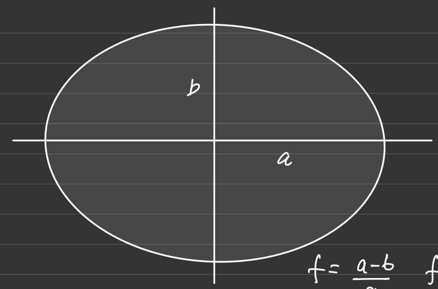


Cartesian Coordinate
↳ called Geocentric → (Its center is geocenter
(center of earth's surface)



WGS '84
(WORLD GEODETIC SYSTEM), 1984 → Reference Map on which GPS gives the coordinates.
→ Globally accepted reference ellipsoid.
→ Geocentric in nature

ECEF ($\underbrace{\text{Earth Centered}}_{\text{Geocentric}}$ $\underbrace{\text{Earth Fixed}}_{\text{X-axis fixed on surface of earth}}$)



$f = \frac{a-b}{a}$ flattening

$e^2 = \frac{a^2-b^2}{a^2}$

RADIUS OF CURVATURE
IN MERIDIANAL DIRECTION

$$M = \frac{a(1-e^2)}{(1-e^2\sin^2\phi)^{3/2}} = f(\phi)$$

ϕ → latitude

RADIUS OF CURVATURE
IN PRIME VERTICAL SECTION

$$N = \frac{a}{(1-e^2\sin^2\phi)^{1/2}}$$

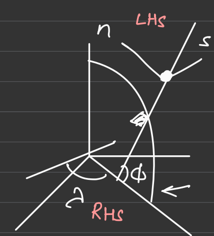
$$\boxed{\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} (N+h)\cos\phi\cos\lambda \\ (N+h)\cos\phi\sin\lambda \\ (N(1-e^2)+h)\sin\phi \end{bmatrix}}$$

Relationship b/w Ellipsoidal and Cartesian Coordinate system

↳ It is not a empirical formula, it is a derived formula.

TOPOCENTRIC COORDINATE SYSTEM

Origin: From where you're carrying survey (location).
X → towards North Pole
Y → perp. according to LHS → towards South Pole
Z → Ellipsoidal Normal
$(X, Y, Z) \equiv$ (Easting, Northing, Ellipsoidal Normal)



$r = 90 - \phi$
$s = 180 - \lambda$

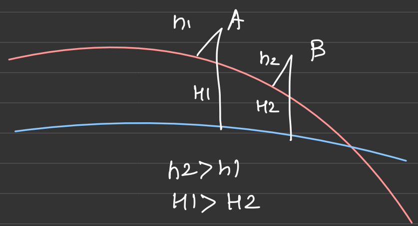
$$\begin{bmatrix} e \\ n \\ u \end{bmatrix} = P_2 R_2(-(90-\phi_A)) \cdot R_3(-(180-\lambda_A)) \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

e → easting
n → northing
u → upright

$$P_2 \to R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \text{Rotation} + \text{It is flipped}$$

VERTICAL DATUM

- GEOID → Reference Surface
- Mean sea Level is approximated as geoid. (It's not geoid)
- But there is variation b/w Mean sea Level and Geoid.
- Tides caused by pull of earth and sun
- It is called Sea surface Topography (SST)
  - ↳ Difference b/w MSL and Geoid.
- MSL ≅ Geoid



$h2 > h1$
$H1 > H2$

GPS → h
Levelling → H

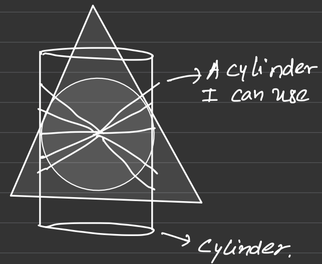
RELIEF REPRESENTATION

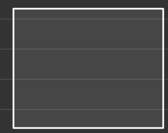
- Contouring
- Flow Lining

- $X, Y, Z \rightarrow \phi, \lambda, h$
  H

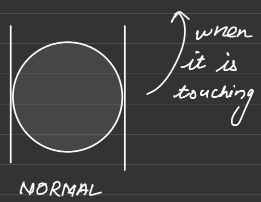
6 or 8 Qs

- $h = H + N$
- Contours → Imaginary lines of same elevation.
- Map Projection:
  Transformation of 3D space to 2D map.
- No projection is without distortion.



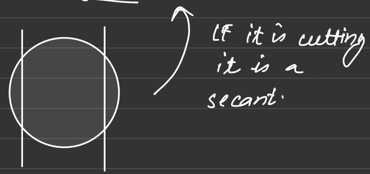


Normal Projection

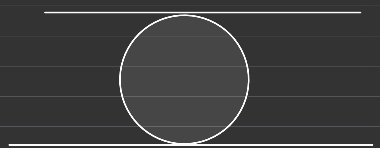


NORMAL

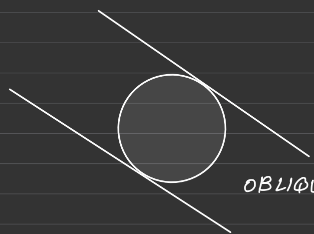
Secant Projection



SECANT



TRANSVERSE



OBLIQUE

CARTOGRAPHIC PROPERTY

- CONFORMAL → Maintain the shape on 3D same as in 2D.
- EQUAL AREA PROJECTION → Maintain equal area.
- EQUIDISTANT PROJECTION → Maintain the same length

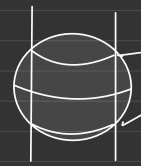
→ These 3 properties are mutually exclusive properties. If I want to maintain area, I lose the others. Similarly for others.

SCALE 1:25000 1cm on map = 25000 cm on ground

SCALE FACTOR $SF = \frac{\text{Map Distance}}{\text{Ground Distance}}$

1
$K > 1$ EXAGGERATED
$K < 1$ DIMINISHED

- As you move away from meridian, it get more and more exaggerated.



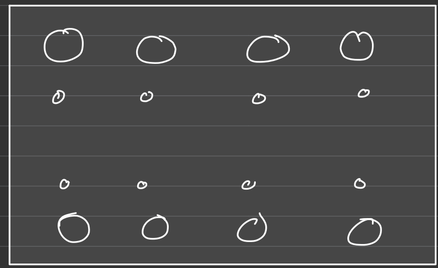
Standard Parallel
↓
Here SF = 1 [Scale Factor]

secant

- Mercator Projection: → conformal (shape is maintained)
- Google Map have used Modified Mercator
- Transverse Mercator
- Cassini - Soldner Projection → equi-distant (for land records)

RHUMB LINE: Line having same bearing (Azimuth is maintained) wherever you want to go, you put its bearing.

GREAT CIRCLE: – The shortest distance that you drave.



TISSOT INDICATRIX → The Distortions in the map.
As you go away from equator, SF ↑es.

Modified Mercator → Modified in y-axis.
↓
Many call Chess Board Projection.

Advantages.
Somehow shape is maintained.

- It not only maintain shape but also maintain the area.

$K_m + K_p = 1$ → indicates equal area projection.

UTM – Universal Transverse Mercator.
→ secant case
→ Cylinder is kept at a particular dir^n.
→ It has 60 zones it is divided into.

→ From Longitude → I can tell the zone in which I am lying.
Le Learn it from the slide UTZ zones. (Slide Lec 5).

Why rhumb line is not the shortest dist. and great circle is?
why don't they use equidistant map. → Google maps?

error gets decreased.

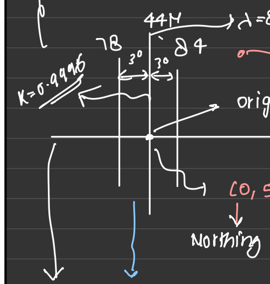
44N – Northern Hemisphere
44S – Southern "

44N → λ = 81°E

78, 84, 3°, 3°

K = 0.9996

add this one from



origin for this UTM zone → Coordinates are given to its reference.

Easting

(0, 500000)
↓ Northing ↓ Easting

– We give false easting and false northing.

For Northern I keep on adding.

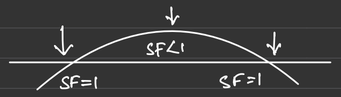
Equator
Lattitude = 0

(10,000,000, 500,000) → For Southern

I keep on subtracting.

→ subtract this one.

- Between one UTM and other, there is a 40 km overlap area.
-



- Distortion, you are bifurcating
- Balancing the errors.
- Scale distortion is lesser
- for larger area, we use the secant case.

- UNIVERSAL POLAR STEREO GRAPHIC PROJECTION → It is also a conformal projection.

- UTM is also a conformal projection.
- Both can be merged.

- Cassini - Soldener Projection → used for cadastral surveying.
  All state govt. records are in this projection.

Azimuthal Projection

Three prespective projections → Gnomonic Projection.
↓
Keep at the centred earth

→ Stereographic → At the other side of earth.

→ Orthographic Projection
↳ comes from infinity the rays.
Lunar. mapping, etc

- Stereographic is very important because it is conformal.
- Gnomonic is a equidistant.

Mercator

Geodesic line
↓
Shortest Distance

Gnomonic

↳ Rhumb Line → Curved

↳ Shortest Distance → Straight line.
↓
Air Force People want them

An enemy plane is coming.
↳ gnomonic projection.

Dist & Bearing is exact

- Aero - Nautical Maps we make use.
- It maintain bearing and equidistant
- It doesn't maintain shape.

How to convert....

Lattitude, Longitude → UTM Coord
Lambert C

In grids → we give origin a false easting and a false northing. → to avoid any negative value to any pt.

24 to 30

→ In India we take $\frac{1}{6}$ th. —In China they take $\frac{1}{7}$ th.

- Standard Parallel → Scale Factor = 1
- Limiting Parallel → limit to area that is to be mapped.
- Central Parallel →

  Value of central Parallel is calculated as

$$l = \underline{\log N_1 \cos\phi_1 - \log N_2 \cos\phi}$$

$\left.\begin{matrix} q_1 \\ q_2 \end{matrix}\right\}$ → Isometric latitude

$\frac{(\phi_2 - \phi_1)}{6}$ → Subtract from top / Add to bottom → I get standard parallel.

Basic input

$\left.\begin{matrix} \phi \text{ — Geodetic latitude} \\ \lambda \text{ — Geodetic longitude} \end{matrix}\right\}$

E_0 —

N_0 —

- LCC Projections
  ↓
  To Calculate ?

Conversion to Lambert conformal conic to Geodetic.

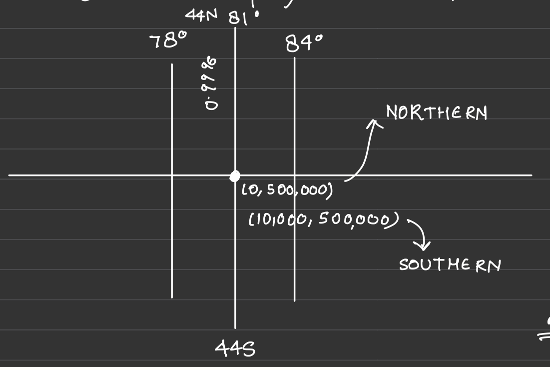
In AGNI → they are using this coordinate system.

3 Things:-

- All state government records are in Cassini.
- Use GPS →

UTM

- Scale Factor → we keep it 0.9996. (not 1)
- Below − 80, we have USM. ----?
- Conformal projection — shape is maintained.



Coordinates of the Origin !!

- For UTM, standard meridian $K_0 = 0.9996$ (Scale factor)

$\left.\begin{matrix} X \\ Y \end{matrix}\right\}$ → UTM Coordinates

$\left.\begin{matrix} \phi \\ \lambda \end{matrix}\right\}$ → Coordinates given here.

- $e^2 = \frac{a^2 - b^2}{a^2}$ → 1st eccentricity ✓
- $e'^2 = \frac{a^2 - b^2}{b^2}$ → 2nd eccentricity ✓
- $f = \frac{a-b}{a}$ ✓

$t = \sin\phi$

$\eta =$

$S_\phi = \int_0^\phi M\,d\phi$

$a(1 - e^2)$

= ---- ----

we just use this.

- A example is given :- In Slides
- For Northing → No false northing added.

John P. Snyder → Map Projections used by US Geological Survey.
↳ He has given all the formulas.

- (x,y) → Polyconic / Everest → Old Maps of Survey of India are in this.
  ↓
  WGS84 / UTM (X,Y) Polyconic → ϕ, λ (Everest)

BURSA – WOLF MODEL

Δs — scale Factor

$$\underbrace{\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}}_{\text{WGS84}} = \underbrace{\begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \end{bmatrix}}_{\substack{\text{Translation} \\ \text{Parameters} \\ (3)}} + \underbrace{\omega_x \, \omega_y \, \omega_z}_{\substack{\text{Rotation} \\ \text{Parameters} \\ (3)}} \; \underbrace{(1+\Delta s)}_{\substack{\text{Scale} \\ \text{Parameter} \\ (1)}} \underbrace{\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}}_{\text{Everest}}$$

7 parameters →

Datum and Projection
↓ If it is different → do datum transformation
↓ If it is different → do projection transformation.

Georeferencing

Geo-referencing: Aligning Raster & Vector Data to the Real World

What is Geo-referencing?
- Geo-referencing refers to process of assigning geographic coordinates to data in order to represent it on a map.
- It is crucial as it allows for the overlay and integration of various kinds of data such as satellite imagery, aerial photography and maps, to create a complete and accurate representation of real world.

Why georefencing is important?
- It provides a crucial link b/w data and the real world.

After talking about importance and significance of geo-referencing.

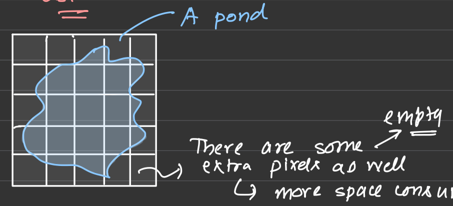
How to geo-reference your data?
GCP (Ground Control Points) / Control Points
or
Other geospatial data having a known coordinate system.

GCPs :- Points that can be accurately identified on dataset (raster data) as well real world coordinates (AOI – Area of Interest).

Points for which → Real world coordinates → accurately known.
Using those we can georeference our whole image.
CPs → Relate raster with real world.

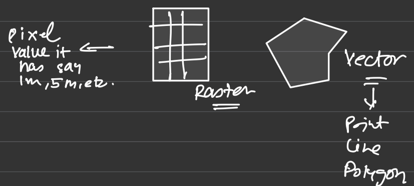
How to choose control points.
- Open to sky → should not be placed near tall building/tree.
- Identifiable in my imagery → should have good contrast to easily identify in image.
- Well distributed in my area of interest.

Raster



- Made up of pixels (grid cells).
- Each pixel has its own value or class.
- Satellite Images — Raster Data

Vector



Transformation Models

$X_{out} = F(x_{in}, y_{in})$
$Y_{out} = G(x_{in}, y_{in})$ } → We are using Mathematical Models

1. Zero order Polygonal

   $X' = X + A$
   $Y' = Y + A$

2. Affine or 1st order Polynomial

   $X_{out} = A x_{in} + B y_{in} + C$
   $Y_{out} = D x_{in} + E y_{in} + F$

   Most Common Choice.

   - Minimum 3 CPs
   - More than 3 should be done — least square adjust and use the best fit.

3. 2nd order — min 6 CPs

4. 3rd order — min 10 CPs

5. Spline Transformation
   - At your CPs there is no distortion.

6. Adjust Transformation.

   TIN — Triangulated Integrated Network.

* Always good idea to take more than minimum and take the best fit.

Goodness Fit of Model — To know how good is georeferencing.

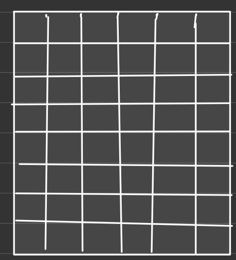
RMSE — Root Mean Square Error is calculated from transformation model.
— It is a parameter used to know how well is your georeferencing.

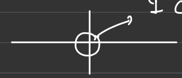
$$RMSE_x = \sqrt{\frac{\Sigma(\cdot X_{predicted} - X_{actual})^2}{n}}$$

$$RMSE_x = \sqrt{\frac{\Sigma(\cdot X_{predicted} - X_{actual})^2}{n}}$$

$$RMSE = \sqrt{RMSE_x^2 + RMSE_y^2}$$

Topo sheet





I can use this point where the latitude and longitude coincide.

Vector

- Model real world objects as liscrete objects.
- Tree – Point
- Road – Polyline
- Pond – Polygon

Raster Data Model

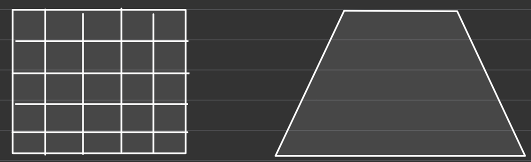
- Model earth as grid of cells (called pixels).
- Store Area is stored in a pixel. (we call it resolution)
- Every cell occupy 1m×1m if Resolution = 1m.

Both the models we need to model our real world data. ↓

- It just have 1 value at its pixel.

- We can put aside some CPs to serve as check points.
- Then we can find the RMS Error at those check points.
- Read RMS Error carefully.

In Transformation, shape of image changes. → We need to make those pixels square

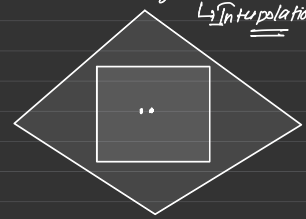


$$\text{Columns} = \frac{(X_{max} - X_{min})}{\text{cell size}}$$

$$\text{Rows} = \frac{(Y_{max} - Y_{min})}{\text{cell size}}$$

Resampling:

① Nearest Neighbour : Default method of resampling → Most comm
↳ Interpolation



- Each cell gets value as the closest neighbour.
- Quick
- Default in most softwares.
- Sometimes blocky appearance bcoz many cell get same value.
- Good for continuous data.

② Bilinear

- Do weighted mean (based on distance) of the 4 nearest neighbour
- Very suitable for continuous data such as Temperature
- We also remove certain high frequency data but good for continuously varying data.
- Blurriness present.

③ Bicubic

- Generate surface from 16 nearest points.
- Time-taking because it has to take 16 points.

No. of CPs for polynomial transform, $n = \frac{(p+1)(p+2)}{2}$

Lab:-

① Select WGS 84 (It is known coordinate system of CPs)
② Georeference →
- For most of topo sheets → make CP the intersection pt. of gratitude lines.
- Add CPs.
- Auto-apply → can on/off based on convenient.

* "L" → To on/off raster layer

Data

- Images — Sat. / Aerial / Drone
- Maps / SoI
- Charts
- Census survey, etc.

How to input these data in a GIS?
Need for Data Models.

Metadata

- Data about data or information about data.

Header
Data

- .GIF
- .jpg
- .png
- .tif

When you take a photo from mobile
It stores 3 images → in the form of raster.

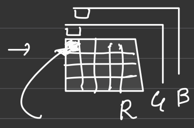
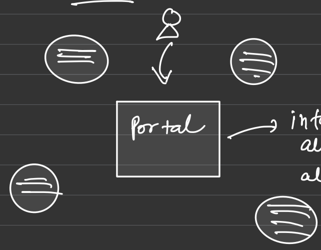


Image Data

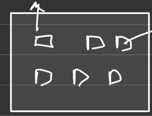
- Database
- Dissemination
- Data portals



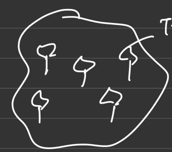
→ information about all the metadata of all images.

Geo-Data (Geospatial Data)

- Spatial Data → depend upon location
- Non-spatial Data (Attribute Data) → does not depend upon location



→ Name of person sitting here
↳ attribute



Trees
H
DBH
canopy.

New Geospatial Data Policy — 15 Feb 2021

- Indian entity can capture any data, disseminate the data, process the data, etc. all can be done.
- Restrictions for foreign countries.

$$RMSE = \sqrt{\frac{\Sigma(z_i - z_r)^2}{N}}$$

z_i → measured, z_r → reference

15th Feb 2021
↳ Guidelines

25th Dec 2022
↳ Policy.

Negative Attribute

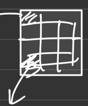
lots of free data

- * BHUVAN
  ↳ ISRO site
  something like Google Earth
- * USGS
- * Sentinel

Data is stored in two types:—

Raster — Vector

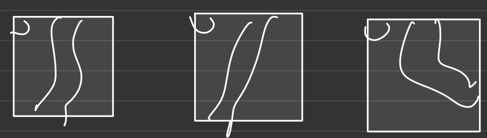
For image — pixel
In GIS — grid.



DN → (Image)
Cell Value (GIS)

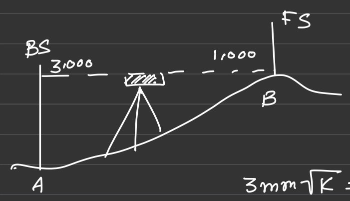
Raster — Georefenced.

Location specific manipulation of attribute data is easy.
↓
Bcoz of



Height

Levelling



SoI

$3mm\sqrt{K} =$ 3cm

$\rightarrow$

A 100km B

$\boxed{N+H=h}$

Earth Gravity Model (EGM) 08

EGM 20

Geoid Models are there.

Contour Accuracy = $\frac{1}{5}^{th}$ x (Contour Interval)

DEM $\longleftrightarrow$ Analog Map

Index Contour - Thick Contour

5000 $\rightarrow$ That's how you draw contour.

Form Lining

* For a map, contour interval is constant.

DTM (x, y, z) $\rightarrow$ can be gravity, etc.

DEM — (x, y, h)

DSM – Digital Surface Model.

SRTM

Aster DEM $\rightarrow$ Satellite and Photogrammetry. } 10-15m accurate

Carto DEM $\rightarrow$ ISRO

Regional Geoid Model.

Midsem

Part A $\rightarrow$ UTM small x 25

Part B $\rightarrow$ x 50 — 10M

3

2

Half peach !

Short Ques.

Feature class

— Pond

— Road

Topology — defines Relationship.

↳ based on geometry.

Any edit you do in one dataset — bcoz of topology, it reflects to other datasets.

Topology in ArcGIS Pro?

Shapefile $\longrightarrow$ Non topological data structure.

Khasra map

Hardcopy

↓

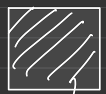
GIS

Crop insurance

Soil Type map.
Channel Network map.

Startups → transverse Ashwini, & .. etc.

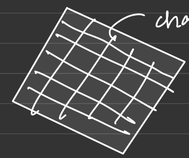
Source of Data :- Freely Available data
- Google map
- OSM
- Bing map
- Bhuvan — ISRO site
- USGS
- Sentinel (satellite data)

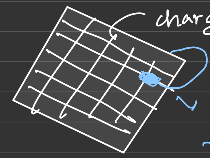
OSM — 
- Download data
- different layers
- non-spatial data (ATM data)

Query.

DPI :- 300 Finer
(Dots per inch) 600 Coarser

Heads down method

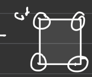
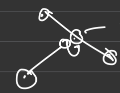

charged wires


charged wires

puck
↓
record coordinates of pt. you're picking up.

Heads up method

scan — store as jpg file
mouse pointer → puck here. — can click with pointer of mouse.

- snapping to point / line —   snd.

Automatic approach

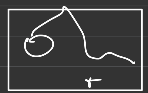
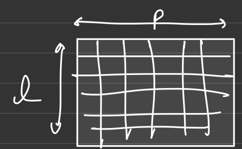
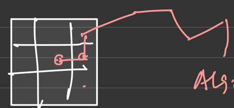


Image Processing



A(i, j)

A(0, 0) = 1 →
= 0 →

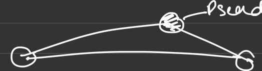


Algorithm

662 — Errors as well

Semi-Automatic

Q Advantage of semi-automatic?

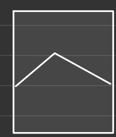
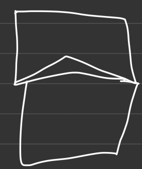


Pseudo node.

Snapping helps in this case.

? → Network Analysis → I will not be able to analyse correctly.

Sliver Polygons created

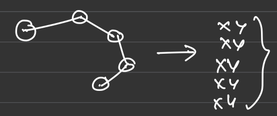
~ way of checking should be there.

Link based topology model.

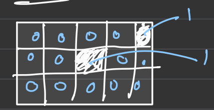
Topology

(X,Y   Attribute information.

we need to quantify and store the relationship in the



Raster — Array — some elements are 1
some elements are 0

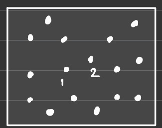


Link-based Topology :- LINK COORDINATES — Based on this we create other files.

NODE
POLYGON
LINK

TIN (Triangulated Irregular Network)

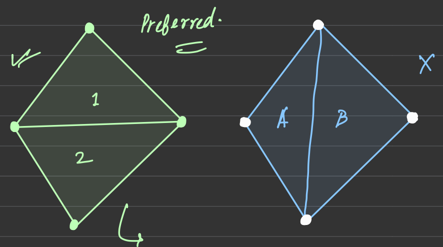
• Wherever you have to draw a surface → use TIN



$Z_2 > Z_1 \nRightarrow$ water will flow from 2 to 1.

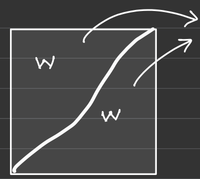
→ We need to know surface (terrain) as well.

TIN → used in computer graphics → Very. imp.



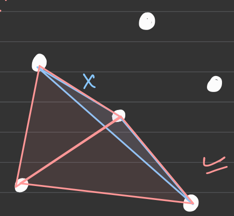
well conditioned △

More accurate representation of the terrain.
Because the area is well distributed and more close to an equilateral triangle.



spatial merge

TIN:



Delaunay Triangulation

• more accurate representation.

★ SIMPLICES (△s in 2D shape) or Tesselation

★ VORONOI TESSELATION
(Thiessen or Dirichlet tesselation)

• Thiessen Polygon or Voronoi Tile → same name.
Delaunay Triangulation.

Theisen Polygon or Voronoi tile — same name

Delaunay triangulation

V.Imp. pt. ☆ circumcircle of each Δ is so formed that it does not contain any other data point.

A — more undulating

B

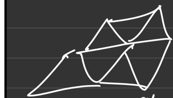
TIN - Mesh
→ .obj file
↓
V.Imp in
Computer graphics

Δ size is changing as per information in that area.

TIN - any surface property

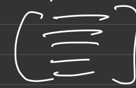
- elevation,
- temperature
- Optimal in the sense that it adjust as per the surface.

MATLAB, softwares, etc.
↳ You give points — you'll get the TIN as well as the topology.



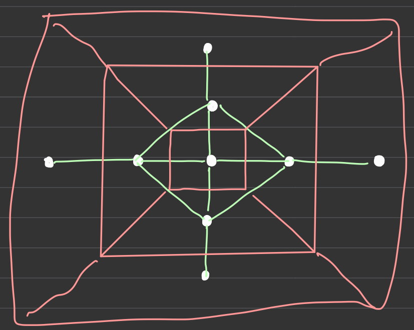
Delaunay triangulation → Graphically → Difficult

Want to do it with a Algorithm
↓
working on



× 4 pts.

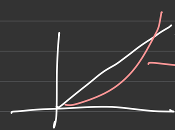
Diagonal swapping algorithm



Theissen Polygon

Watson

n



→ Average is 6

→ $6 \times n$

→ $n \times n$

n^2

Attribute information input

To location → add some information → attribute

Q Is there any relⁿ b/w degradation and engineer?

Q Is there any relⁿ b/w degradation and soil type?

crux - along with geometric information (raster) — has a list of attributes is also there

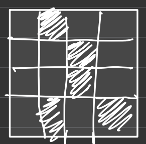
Information button
↓
show attributes when you click on pts.

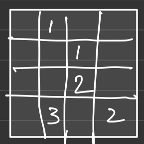
soil type

· GIS — combining spatial + non spatial information.

· Attributes are non-spatial.

· We need to connect these attributes to individual geometry.





1 — Engineer Roy
2 — Engineer Jaiswal
3 — Engineer Gupta.

· Types of attributes — Er
— Material
— Date
⋮

Ranking!!

skid resistance of road

Ranking → Rank data based on skid resistance

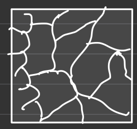
How information is stored in computer?

GIS — handle vector and raster layer together.

Raster   Vector   Hybrid

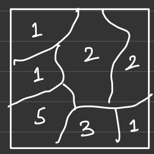
· Sometimes some data are good to be stored as raster, whereas in other as vector.

Land use



· ArcGIS — most commonly used commercial
· QGIS — " " " open-source.

ESRI georelational database

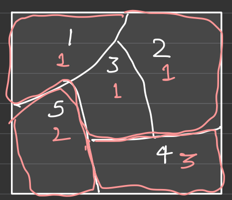


Spatial Data

Soil ID	
1	
1	
3	
2	

Non-spatial Data

Soil ID	Suit	Soilc
1		
2		
3		



What is important?
① Geometry

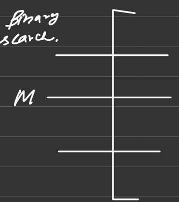
ESRI geodatabase — object based — Just one table.

Storage of Information

* Ordered Sequential files. — Now it is arranged alphabetically

steps are — binary search — $\log_2 (n+1)$

Binary search.

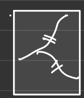


* Indexed files — Index also has a problem.
* DBMS.

Project :-
· Vinoba Bhavay

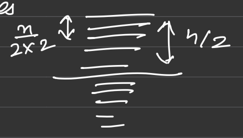
Now ML also

AHP — Decision Rule
↓
A kind of technique.



Reference Data

- Non-spatial data – stored in foreign key.
- Simple list
- Ordered Sequential files



$\frac{n}{2^k} = 1 \Rightarrow n = 2^k$

$\log_2 n = \log_2 2^k$

$k = \log_2 n$

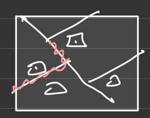
- Not good because always have to search in order.

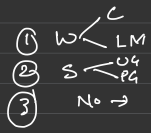
Indexed Files

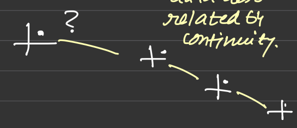
- Soil Profile defined on some attributes. Reverse the table
  - ↳ Index file of unique attributes
  - ↳ helps in making search fast.
    - ↳ Problems → Anything changes, have to change index files.

DBMS

- GIS < Spatial, Attribute
- Imp. All these data are inter-related.

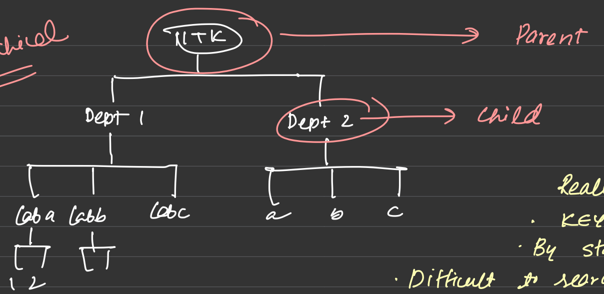






spatial data also related by continuity.

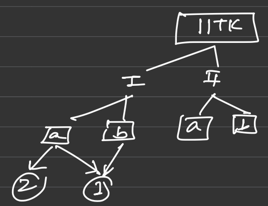
Hierarchical



Realized?
- Keys
- By storing all the paths
- Difficult to search other the key attr.
- If data becomes large it is not efficient
- Not used in GIS
- Folder access.

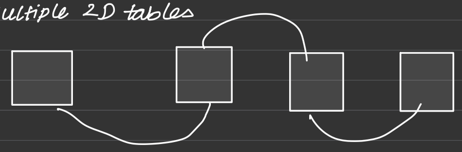
Network database

- Pointers



★ Rel. DBMS → 95% used for GIS

- Multiple 2D tables



- Stores no pointers / hierarchy.

	T	MC	—	—
ST_1	1	1	1	
ST_2	2	2	1	
ST_3	2	1	2	
ST_3	1	2	2	

→ unique soil type
→
→ " " "
→ " " '

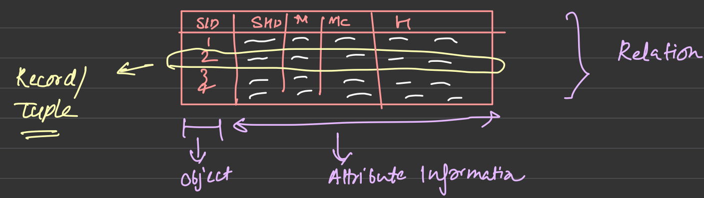
	S	Size	—	—
T_1	m	S		
T_2	M	L		
T_3	U	S		
T_4	U	L		

} All of them are unique

· Object (Properties)

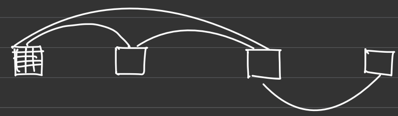
TERMINOLOGY

· Made of large no. of relⁿ linked / connected to each other thro' keys.

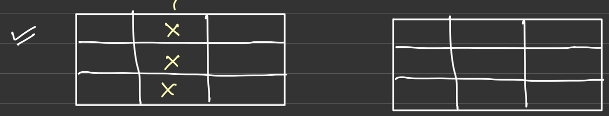


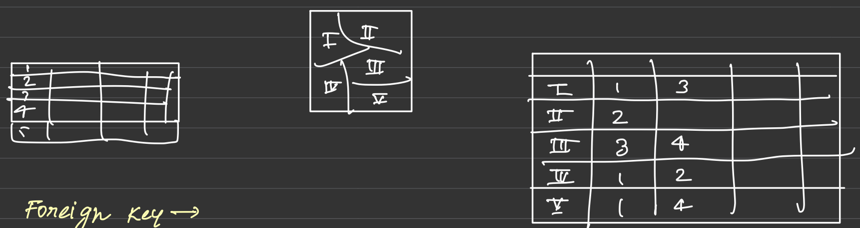
Unary —
Binary —

Keys → helps to connect multiple tables.



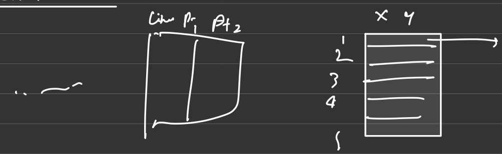
Primary Keys → one attribute that is considered primary key.
• unique • value of key is unique for each tuple.





Foreign Key →

RDBMS structure



NORMALIZATION

	height
1	0-3
2	3-6
3	6-9
4	9 & above

→

1	0-3
2	3-6
3	6 & above

change get reflected everywhere.

1. HA-2
2. Project → Be consistent

What we know now? — GIS
— What queries it answer
— Data Model < V, R } Topology

Attribute
(R)DBMS

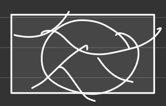
All information is stored by means of some relations

SQL Queries

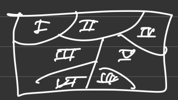
Spatial Analysis → 80% of our day to day activities are spatial (related to space)

Types of Queries

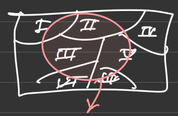
II Retrieval



Re-classification



Overlay Operations

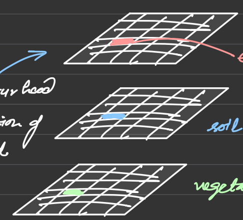


overlay.

Neighbourhood queries
· corresp. to soil I what are neighbouring soil type.

Operation / Analysis / Query

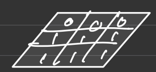
① Local → No contribution from neighbourhood
② In a Neighbourhood → Contribution of neighbourhood



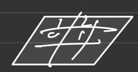
Retrieval → Retrieve some information

— Arithmetic Operation
— Relational Operation

EQ
GT
LT
GE
LE
NE
} → 0, 1 output (True / False)



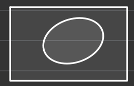
LC
S=0
W=1



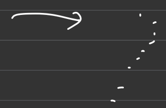
LU
C=0
NC=1

— logical operations

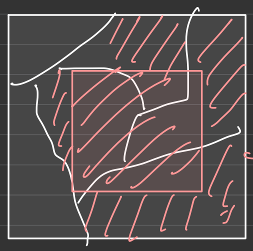
Selection → Given a data, trying to select some data.

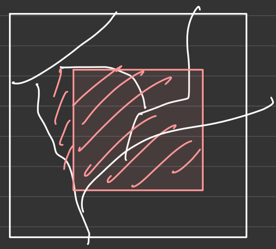


— Topological Rel^{ns} — features inside a selected object.



→ All the connected parcels are taken

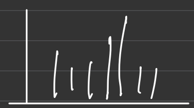




· Dissolve → Aggregate → Multiple parcels having same attribute value — dissolved in one parcel.

· Re-classifying → Two ways

- User controlled
- Automatic — It is also user controlled but computer decides class breakpoints.
  - ↳ Table generated based on some model.
  - · Equal freq. classes.



Histogram

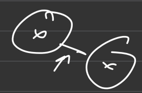
5 classes → 25 items

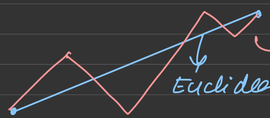
$\frac{25}{5} = 5$

1^{st} 5 → 1^{st} class
2^{nd} '' → 2^{nd} ''
3^{rd} '' → 3^{rd} ''
} and so on . . .

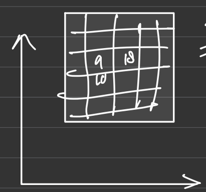
Measurement operations

{Minimum Euclidean}





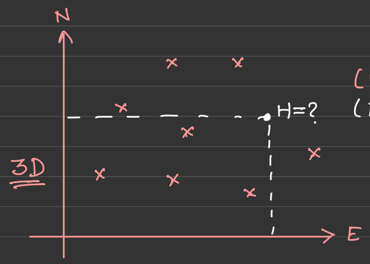
↳ Taxi Distance / Manhattan Distance

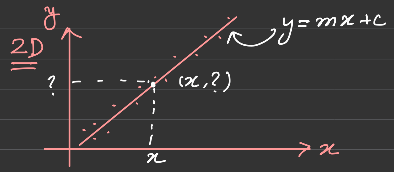


ht.

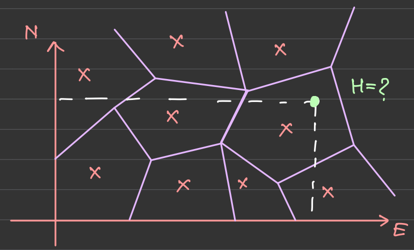
3D

INTERPOLATION ⟶ To find the value of unknown values with the help of known values.





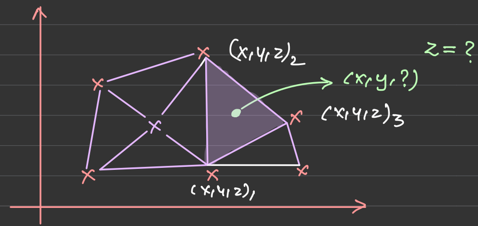
① Nearest Neighbour Method
↳ Voronoi Polygon



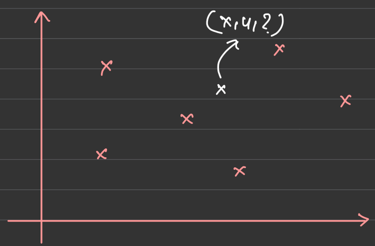
② TIN based Interpolation

(x,y,z)
↓
'z' can be anything

$$z' = \frac{(D - Ax' - By')}{c}$$



③ IDW (Inverse Distance Weighted)



over a neighbourhood (N)

$$\boxed{z_{(x,y)} = \frac{\Sigma w_i z_i}{\Sigma w_i}}$$

$w_i \equiv$ weight

N — nearest 'n' no. of points
OR
all points within a radius

$w = 1/r$
$= 1/r^2$

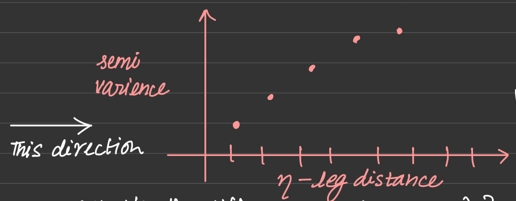
- Why $\propto 1/r$ → As distance ↑ weight ↓
- When to use $\frac{1}{r}$ or $\frac{1}{r^2}$ ⟶ based on property of 'z' attribute

④ Kriging Interpolation

- "Asymmetric Case" — Magnetic Field
  — Factory near water body — contamination

Not distributed in a symmetric or uniform manner

- Same as IDW but weights are generated by the behaviour of 'z' attribute.
- Establish how property is varying in different directions.
- Nearer the points ⟶ diff. in z value = low
  Farther the points ⟶ diff. in z value = high



'n' ⟶ $\frac{(\Delta I)^2}{n}$ ↳ semi-varience
Diff. in z-value

↳ similarly we can do the same for all other directions.
↳ curve can be like anything

What's the difference (semi-varience) ?

Overlay operations

complex

Back to class . . .

Lookup Table

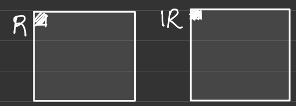
What's the use ?
To minimize the computations.

· All the intersecting polygons.
(intersections)

	1	2	3 . . . .
a	1a	2a	3a
b	1b	2b	3b
c	1c	2c	3c

- Do you think there'll definitely be a polygon having attribute '2a' in the output ? No, not necessary
- Do you think there'll be definitely a property 2 in the input? Yes! It has to bcoz there is a class.

NDVI (Normalized Difference Vegetation Index)



$$NDVI = \left(\frac{N_{IR} - N_R}{N_{IR} + N_R} \right)$$

- From Satellite Data → R and IR image
- Indication of the health of the vegetation
- More NDVI ⇒ healthy vegetation

Lithology — How rocks are distributed ?
— Rock types

Taluka — block or administrative division

Revised Universal Soil Loss Equation — Model

The average annual rainfall depends on (A) = R K L S P
A = Average Soil Loss

Rainfall ← R; K → Soil Erodibility Factor; L → Slope length factor; S → Stiffness Factor; P → Crop Management factor

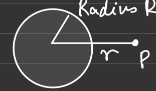
R K L S P . . ⇝ Maps (overlay operation)

· Multiply the values of pixels' digital no. → Giving a new map.

i.e. the map of av. soil loss.

A point is outside or inside a polygon → How to know ?

For circle



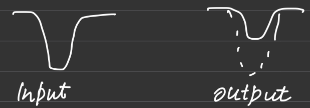
If r > Radius of circle ⇒ outside

In general, how ?

★ If the line from point intersect the polygon
- even no. of times ⇒ outside
- odd no. of times ⇒ inside

common problem!
– pole lying inside house

Low pass filter — those areas which are having low frequency will not get effected much and high freq' will get subdued.



Grayscale image — 8bit (2^8-1) — (0-255)

white – 255
Black – 0

low pass example.

Kernel sum = 0, then divide by 1.

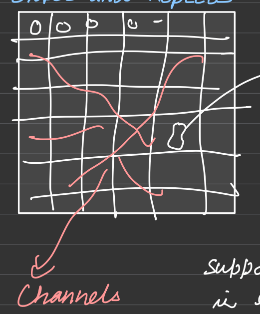
DEM — No building, trees, etc — only ground
DSM — All " " " + ground.

High Pass Example :

low pass example.
high freq. area — highlighted

Edges →

Slopes and Aspects



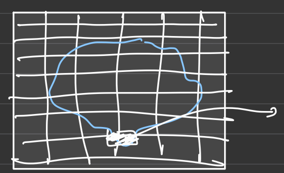
drop of water
(zero percolation area)

Q1 where will this drop go?

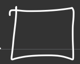
can trace the path of drop in that area.

Suppose rainfall happens and one drop falls in every pixel. where will water go.

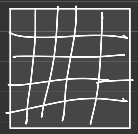
Q2



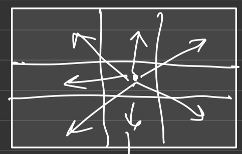
how much area contributing water to this pixel?
Catchment.

Ex:- Derivation of hydrological parameters. DEM 
8 Neighbourhood

Convolution Filter

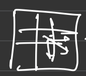


Aspect
↓
Direction of the slope



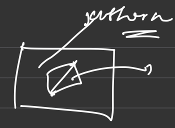
8 Aspects.

How to handle edges of data



→ take three or don't calculate. →

Aspect :- Direction



Southern
Northern

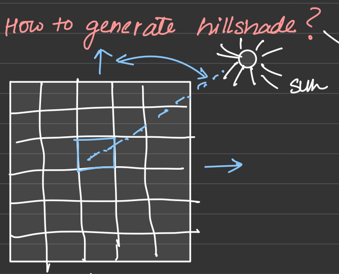
Q Why and where channels will form ??

DEM – Hillshade View

→ 2.5D (B/w 2D and 3D)

DEM → Hillshade.
↳ not only for elevation data
↳ it can be for any other data, → temperature, economy, etc.

Q How to generate hillshade? → Good for visualisation.

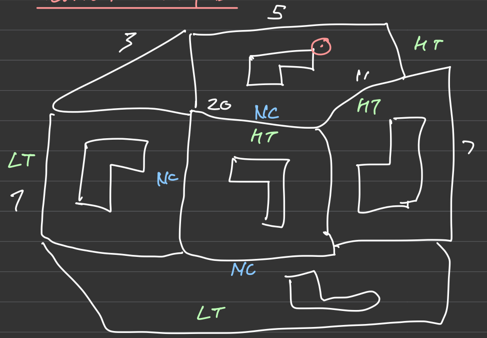


0	–90
255	–0

→ Giving pixels like this!!

When incidence angle is small?
→ Well lit
As it gets inc from 0° to 90°?
→ Poorly lit

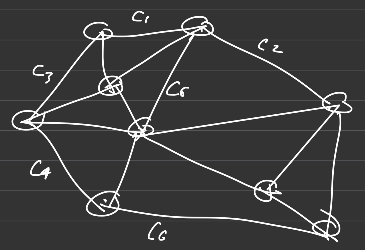
Network Analysis



$T = f(\text{length}, VT, TD)$

$\text{cost} = f'(-,-,-)$

Simplifying same network

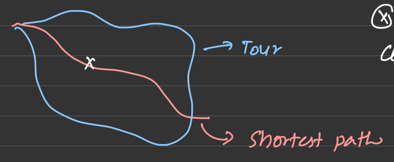


Nodes – junction points → lines or arcs or points

undirected graph

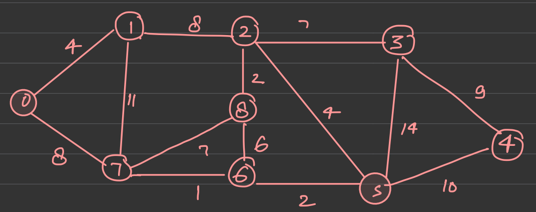
directed graph

+ve or −ve arc
↓ coming towards ↓ going away

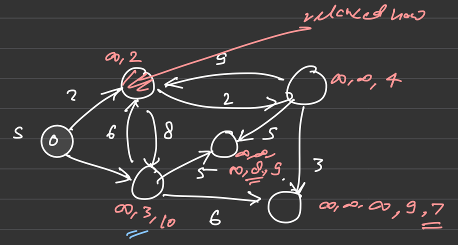


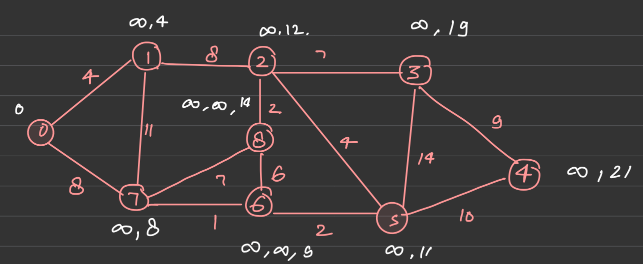
⊗ stop – where path must reach
center – location where resources are supplied.
Turn

Dijkstra's Method



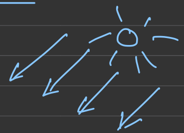
If cost < prev cost computed
↓
then new value
or
If cost > prev cost computed
↓
then retain the old value.



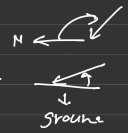


0	0	1	2	3
1	4	4	4	4
7	8	8	8	8
2	∞	12	12	12
8	∞	15	15	14
6	∞	9	9	9
3	∞	∞	∞	19
5	∞	∞	11	11
4	∞	∞	∞	21

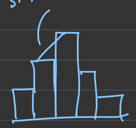
BACK TO HILLSHADE



- Azimuth Angle N
- Elevation Angle



slope



$(XYZ)_i$

90° —— 0°

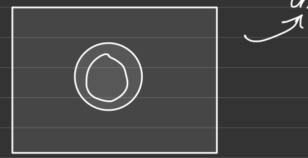
0 —— 255 → Depending on incidence angle

- sunlight – grazing — dark
- sunlight – perp. — light

Neighbourhood operation

Chamfer Transform

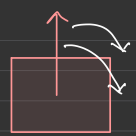
It creates a physical distance map.



chamfer transform of circle
↓
concentric rings

$F_{distance}$.

Viewshed



Start from azimuth angle and ↑sing the angle we see whether that point visible or not.

Extended Neighbourhood operation

Solar potential for rooftop:-

LiDAR → DSM

1st Jan 6AM
6:15AM . . . .
31st Dec 5PM

Models → to determine sun's azimuth

- angle of sun from 'N'.
- angle of sun from vertical.

Calculation of solar radiance as well.
Relate to how much solar energy can be experted.

When we are in Northern hemisphere.
Sun → southern hemisphere.

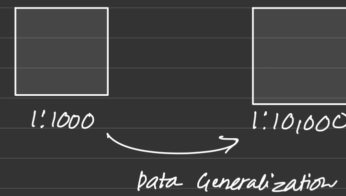
Sky view → If I stand there, you trace all the bounce sun can pass through.

Representation of obstruction in different azimuth.

skyview change over the year? Yes, if a new building come.
It talks about obstructions.

Zonal Operational

Data Generalization

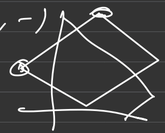


→ can't show same level of details.

Example purchase of mobile

	RAM	HDD	Chipset	Cost	Look
M_1					
M_2					
M_3					
M_4					
M_5					

cost = f(–, –, –)



Scientific

DSS – Decision Support System

- Scientific way to decise something

Imp: •

Better collaboration among decision makers.

- Sensitivity of Decision making — How sensitive is decision with attributes.
  How will it fluctuate

Types of DSS

- Data driven — past year data
- Model driven — mathematical model.
- Knowledge driven — ML / DL / AI — past experience or asking people

MCDM (Multi Criteria Decision Making)

Decision Matrix

If the variables are continuous, → MODM

If the variables are discrete → MADM

We need some method to arrive at weights (ω_i's)

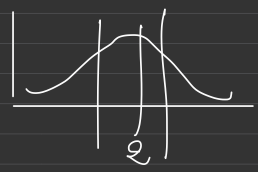
Problem with other -

No units that's why — AHP.

stochastic value

↓

Ex:- life



2 ± 0.1 years.

Need to quantify

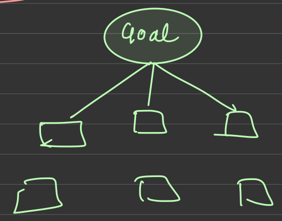
Compare each with each

	m_1	m_2	m_3
m_1	1	9	
m_2	1/9		
m_3			

Judgement Matrix.

Pairwise comparison is being done.

AHP



Criteria

Maximum Eigen Value Process

↓

step 4 and 5.

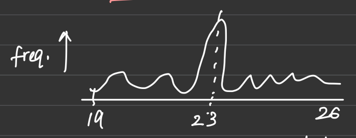
A 2

A 5

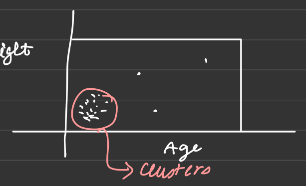
A 4

λ_{max}.

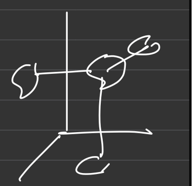
CLUSTER



Age → 1D data

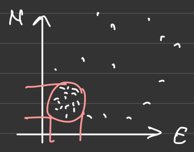


Non-spatial



4D or higher

Cluster Data →



spatial data
(X,Y) axis

Pattern < spatial / non-spatial

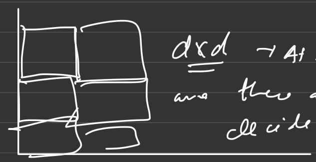
Proximity / Spatial Interpolation Rule

Quadrant Density based analysis :-

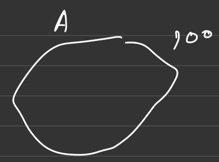
x_i = no. of points inside a quadrant.

Var./Mean Approach — One case where it fail

BoundingBOX



d×d → At least 5 points are there and can decide out it.



A → 100

1 sq → $\frac{100}{A}$

Nearest Neighbour Analysis

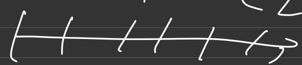
$\bar{d}$

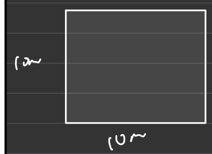
$\bar{d}$ =

$\frac{\bar{d}}{dr}$ ✓

Random Distribution

$\left(\frac{n-1}{2}\right) \to$ Linear





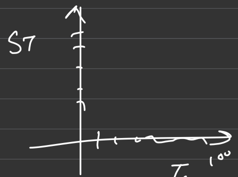
$\boxed{\bar{d} = \frac{\sum d_i}{n}} \to$ For every point.

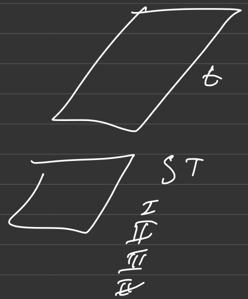
Ripley's function

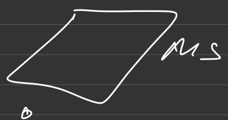
Robust Analysis

---

unsupervised classification

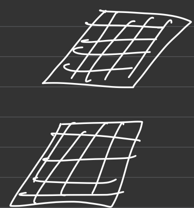






$\left[\frac{T_i}{S_{Ti}}\right]$

K-mean



4 cluster → Expected.