Bharathidasan University

Tiruchirappalli – 620 023, Tamil Nadu

6 Yr. Int. M.Tech. Geological Technology and Geoinformatics

Course : MTIGT0501

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Unit-1 : Basics of GIS

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Professor, Department of Remote Sensing

Course Objectives:

- To learn the basics and concepts of GIS
- To know the components and importance of GIS
- To study the capabilities of GIS in input, verification, analysis, modelling and outputgeneration
- To understand the importance of manipulation and their applications
- To learn the methods of spatial data analyses, simulation and modelling aspects.

MTIGT0501: GEOGRAPHIC INFORMATION SYSTEMS **--- 3 credits**

1. **Basics of GIS:** Definition - Usefulness of GIS - Components of GIS - Computer Hardware, Software Modules and Organizational Context of GIS. **6 Hrs.**

2. **Data Structure:** Data Structure in GIS - Types of Data (Points, Lines and Polygons)- Data Base Structures (Raster Data Structures and Vector data Structures) - Data Conversion, (Vector to Raster and Raster to Vector). **6 Hrs.**

3. **Data Input, Verification, Storage and Output:** Spatial Data Input Processes and Devices (Sources of data, - Different Types of Data Entry methods, viz., Manual input, Run length code, Digitization, Automated Scanning, etc. – Vector to Raster conversion – Raster to Vector conversion - Input devices) - Entry of non-spatial data – Linking of Spatial & Non-spatial data – Data Verification (Errors of different types) – Correction (Rubber Sheet Transformation, Bilinear interpolation, Cubic Convolution, etc.) – GIS capabilities for Data correction – Data output (Types of Output, GIS Capabilities for output, Output devices). **12 Hrs.**

4. **Methods of Spatial Interpolation and Digital Elevation Model:** Spatial Interpolation: Basic Principles of Interpolation – Methods of Interpolation (Interpolation by Joining Boundaries, viz., Simple vector maps, Theisson polygons) – Global Methods of Interpolation, Local Interpolation (Trend Surface Analysis) – Local Interpolation (Splines) - Optimal Interpolation (Kriging).

   Digital Elevation Modeling: Need for Three Dimensional Models - Methods of DEM - Products of DTM (Contour Maps, Shaded Relief Map, Maps Related To Slopes, Line of Sight Maps, Drainage Analysis, Volume Estimation, etc.) - Usefulness of DEM/DTM. **12 Hrs.**

5. **Data Analysis and Spatial Modeling:** Simple data retrieval – Data retrieval through Boolean Logic – Map Overlaying and Cartographic Modeling (Two layers, Multiple layers, Binary, Index, Regression, and Process Models) – Overlay analysis, Capabilities (Point Operations, Regional Operations, Neighbourhood Operations) – Buffering – Cartographic Modeling using Natural Language Commands – Advantages and disadvantages of Carto modeling – Net work analysis. **12 Hrs.**

6. **Current Contours: (Not for Final Exam, only for Discussion):** Recent advancements in GIS; Application of GIS in automation, decision making and query building processes in Geological Technology; Modules and capabilities of QUGIS, GRAM++, IDRISI GIS software.

1. Burrough, P.A 1986: Principles of Geographical information Systems for Land Resources Assessment, Clarandone Press, Oxford.
2. Kang - Tsung Chang, Introduction to Geographic Information System, MC Graw Hill, Boston. 2002.
3. Avery, T.V, Interpretation of Aerial Photography Burgass, Publishing Company.
4. Gautham, N.C 1970: Urban Landuse Study Through Aerial Photo interpretations Techniques, Pink Publishing House, Mathura.
5. American Society of Photogrammetry, 1983: Manual of Remote Sensing (2nd Edition), ASP Falls Church, Virginia.
6. Campbell, J 1984: introductory Cartography, Printers Hall Englewood Cliffs, N.J
7. Dent B.D 1985: Principles of Thematic Map Design, Addition - Wesley, Reading, Mass.
8. Freeman, H and GG.Pieroni 1980: Map Data Processing, Academic Press, New York.
9. Monmonier, M.A 1982: Computer Assisted Cartography - Principles and Prospects, Prentice Hall, Englewood Cliffs, NJ
10. Tomlinson, R.F Calkins, H.S and D.F.Marble 1976: Computer Handling of Geographic Data, UNESCO, Geneva.
11. Grame F. & Bonham – Carter; Geographic information Systems for Geoscientists; Modelling with GIS, Pergamon.

Course outcomes:

After the successful completion of this course, the students are able to:

1. Understand the basic concepts and virtues of this important tool providing various platforms to handle Geospatial data
2. Gain basic ideas to generate, group, store Geospatial data in effective data structures
3. Develop skills on manipulation, 3D visualization, Spatial Analysis and Spatial Modeling.
4. Handle Geologic problems Geospatially in GIS platform independently.

Why do we need GIS?

It is necessary to have a customized and automated digital spatial platform wherein,

- **Routing to a new area / Vehicle Tracking**
- **Mapping of surface / subsurface properties in 2D / 3D**
- **Understanding of actual Earth System Processes that are responsible for ongoing activities strategically and preparing pragmatic action plans immediately through**
  - **Database generation, storage and manipulation digitally**
  - **Visualizing, analyzing, comparing, modelling, predicting, forecasting, representing and sharing of data and information by all**
- **Calibrating the model developed and Validating the results &**
- **Implementing the results pragmatically & monitoring impacts.**

1.1 GIS: Defined simply

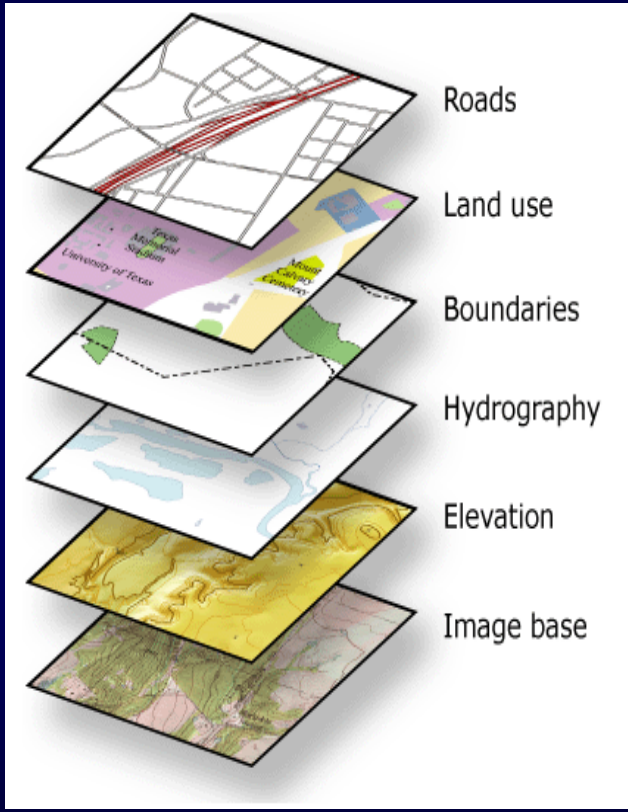
- **A computerised spatial information system on resources and hazards**

GIS can also be defined based on it's Capabilities or Virtues or Usefulnesses or Credibilities

Virtues of GIS

1. GIS Can hold large amount of geospatial data / maps and non-spatial / aspatial data

Geospatial data / maps



Non spatial / Attribute / Aspatial data

	BLOCK_NAME	BK_AREA	SALI_AREA	PERCENTAGE	SALINITY_TYPE
2	AGASTISWARAM	97755036.16	47651257.35	48.75	COASTAL SALINE SOIL
3	ALWARTHIRUNAGARI	314587683.28	13483201.16	4.29	COASTAL SALINE SOIL
4	ARANTANGI	546979186.79	19699964.93	3.60	COASTAL SALINE SOIL
5	ARIMALAM	382442584.63	38056.28	0.01	COASTAL SALINE SOIL
6	AVUDAIYARKOIL	317311598.56	124505284.05	39.24	COASTAL SALINE SOIL
7	BHUVANAGIRI	198728518.35	26522056.91	13.35	COASTAL SALINE SOIL
8	CHENNAI	173276620.57	116210285.58	67.07	COASTAL SALINE SOIL
9	CHITHAMUR	266707327.11	82036026.70	30.76	COASTAL SALINE SOIL
10	CUDDALORE	301090086.77	234349321.02	77.83	COASTAL SALINE SOIL
11	GUMMDIPOONDI	418232625.80	198485820.68	47.46	COASTAL SALINE SOIL
12	KADALADI	801377568.81	518714059.26	64.73	COASTAL SALINE SOIL
13	KANDAMANGALAM	233537210.04	3561928.61	1.53	COASTAL SALINE SOIL
14	KEELAIYUR	173072850.20	9083648.32	5.25	COASTAL SALINE SOIL
15	KEERAPALAYAM	123066985.35	50184462.65	40.78	COASTAL SALINE SOIL
16	KILLIYOOR	27797205.53	975230.88	3.51	COASTAL SALINE SOIL
17	KOLLIDAM	272680537.73	465285.90	0.17	COASTAL SALINE SOIL
18	KOTTUR	321190878.64	437653.63	0.14	COASTAL SALINE SOIL
19	KURINJIPADI	403874698.25	102104013.42	25.28	COASTAL SALINE SOIL
20	KURUNTHENCODE	150643684.38	76575441.17	50.83	COASTAL SALINE SOIL
21	LATHUR	378322678.78	227214144.85	60.06	COASTAL SALINE SOIL
22	MANAMELKUDI	187969286.34	90731336.29	48.27	COASTAL SALINE SOIL
23	MANDAPAM	221958482.90	221958448.74	100.00	COASTAL SALINE SOIL
24	MARAKKANAM	423770925.99	169722836.98	40.05	COASTAL SALINE SOIL
25	MINJUR	459683083.78	452608481.54	98.46	COASTAL SALINE SOIL
26	MUNCHIRAI	187408797.71	123207679.80	65.74	COASTAL SALINE SOIL
27	MUTHUPETTAI	372762749.08	275672726.32	73.95	COASTAL SALINE SOIL
28	NAINARKOIL	265298425.88	5869174.18	2.21	COASTAL SALINE SOIL
29	OTTAPIDARAM	789985062.30	58580178.42	7.42	COASTAL SALINE SOIL
30	PARANGIPETTAI	232530511.68	202813776.86	87.22	COASTAL SALINE SOIL
31	PATTUKKOTTAI	414210092.49	142415280.27	34.38	COASTAL SALINE SOIL
32	PONDI	304809120.44	168067150.78	55.14	COASTAL SALINE SOIL
33	PUZHAL	134550930.49	77517267.23	57.61	COASTAL SALINE SOIL
34	RADHAPURAM	309678174.59	151774863.02	49.01	COASTAL SALINE SOIL
35	RAJAKKAMANGALAM	147554170.04	86895022.01	58.89	COASTAL SALINE SOIL

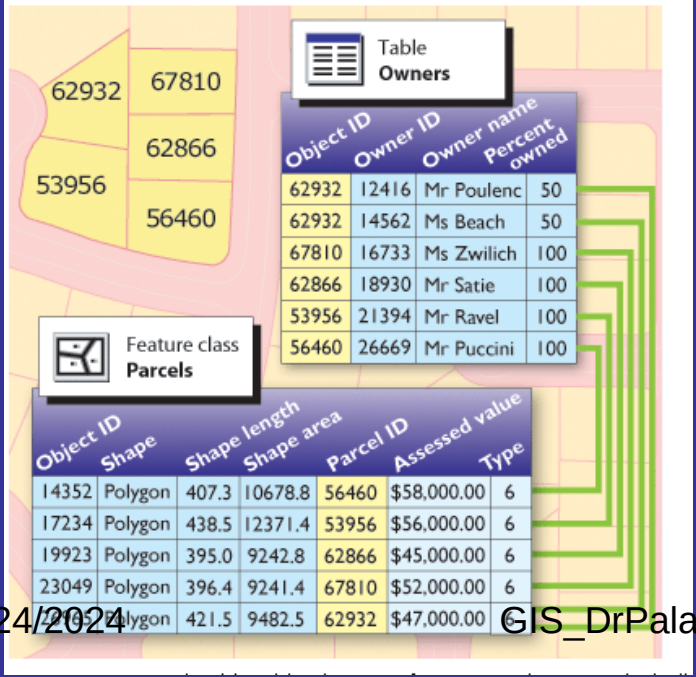
Data Base Storage Unit

2. GIS can Store, Edit, Manage, Manipulate and Retrieve data / maps

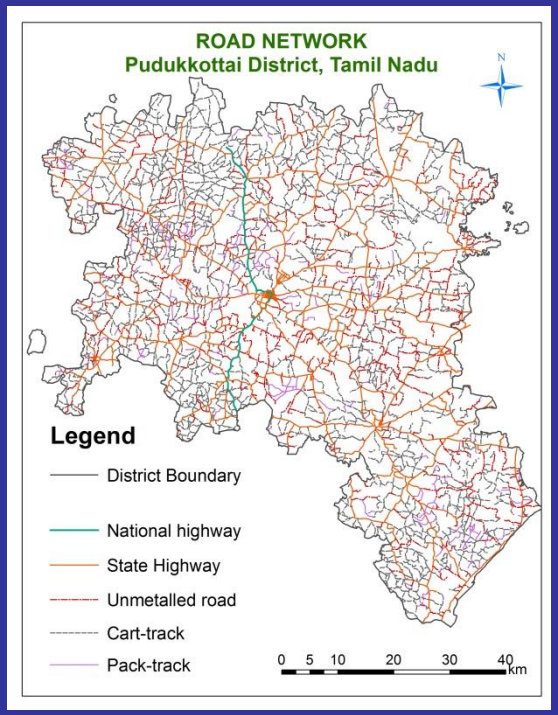
Data Base Management

Spatial Data | **Non Spatial Data**

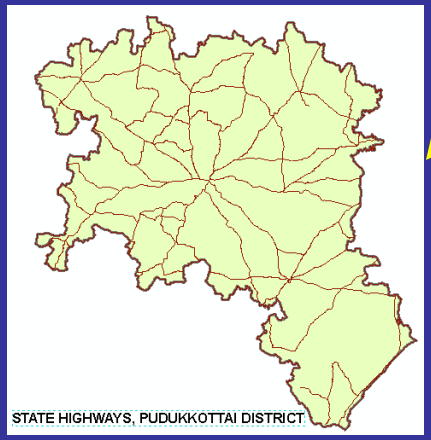
Provide Link using Join & Relate methods



Preferential display of map



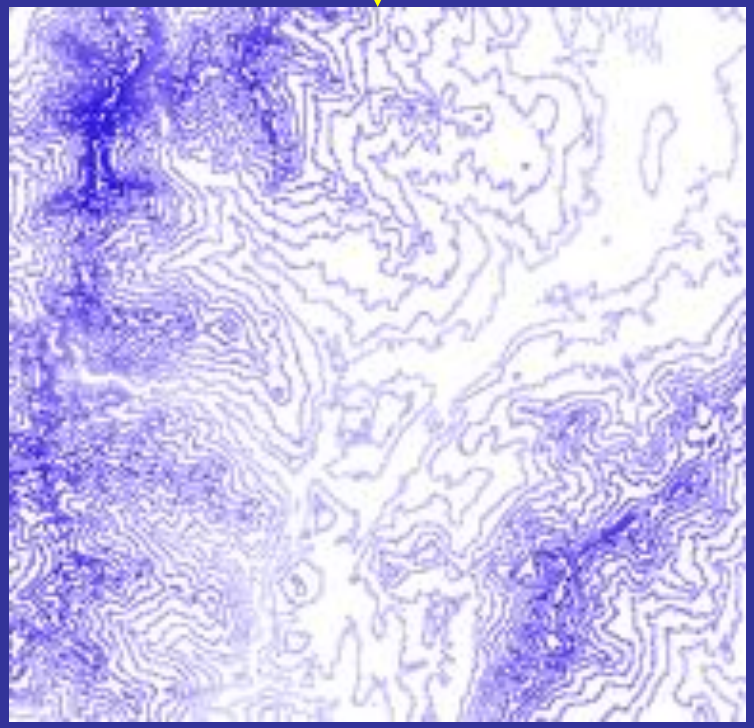
National Highway
State Highway
District Road
Panchayat Road
Unmetalled Road
Cart Track
Pack Track
Foot Path
Concrete pavement
Village Road - Metal



State Highway alone

3. DATA MANIPULATION

Contouring



Filling of Data Gaps
Providing continuity
Viewing 3 Dimensionally

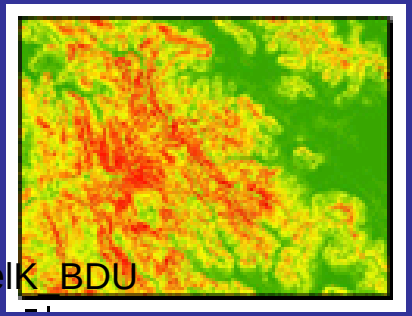
4. DATA SORTING and PERFORMING STATISTICAL OPERATIONS

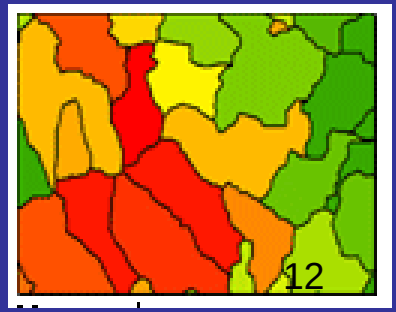
Data Sorting → Classification of Data

Mean, Mode, Average, Regression → Bring out relationship amongst Data

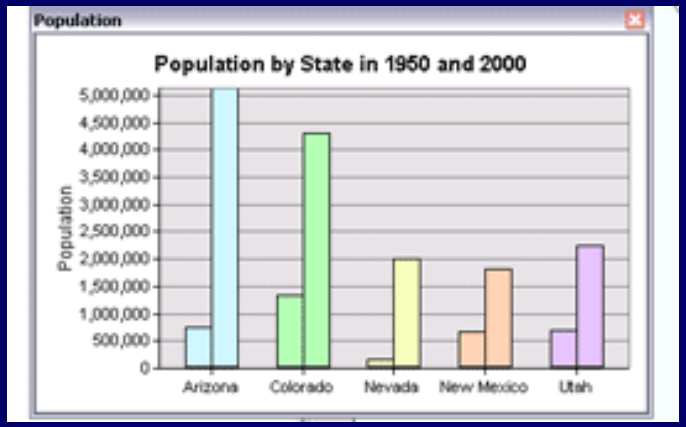
5. DATA CONVERSION

Raster ⇄ **Vector**

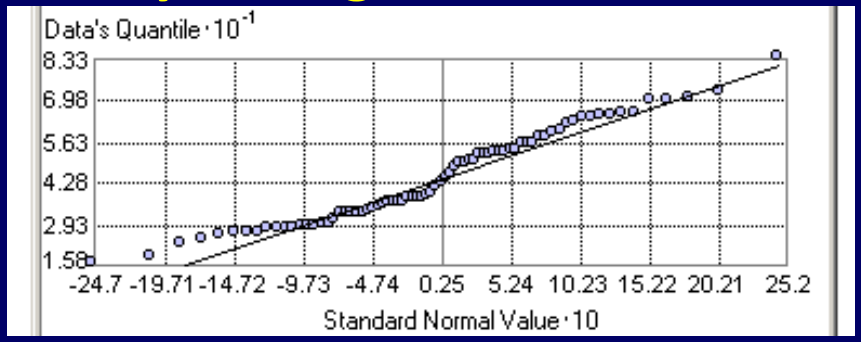




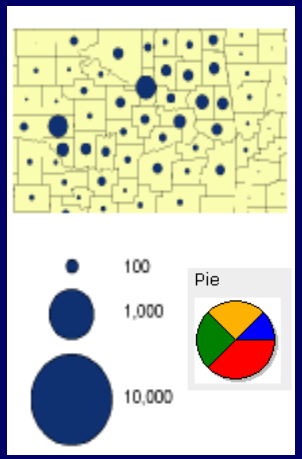
6. GIS can Display data (Output) in multiple forms - Maps, Charts, Histograms, 3D visualized outputs, DEM, Fly through models, etc,.

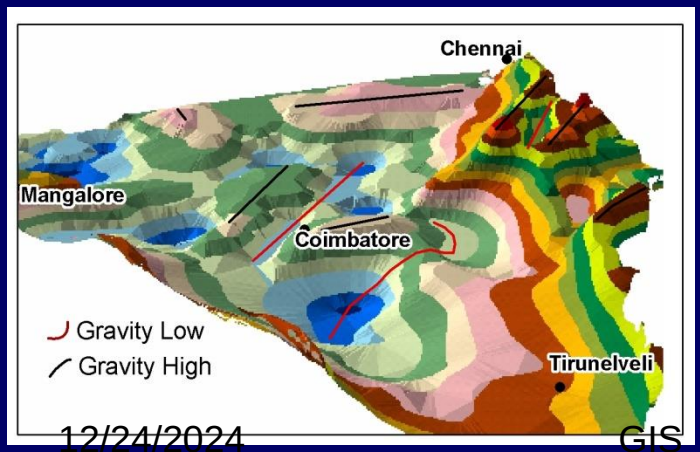


Charts

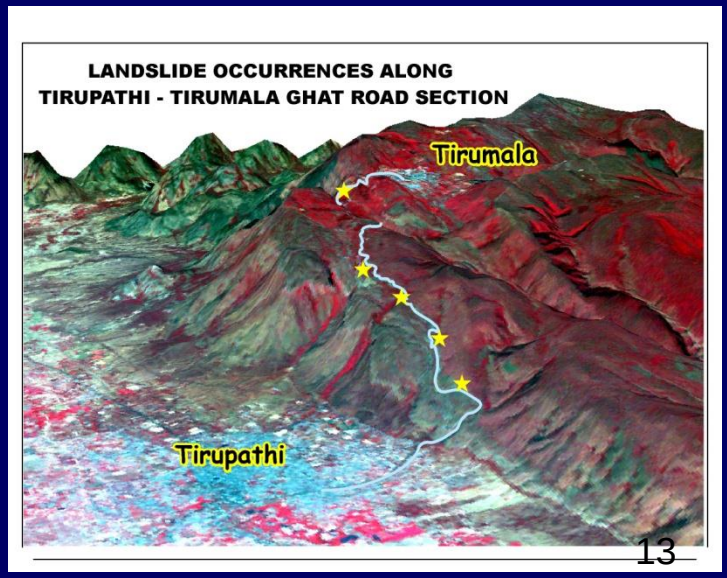


Histograms

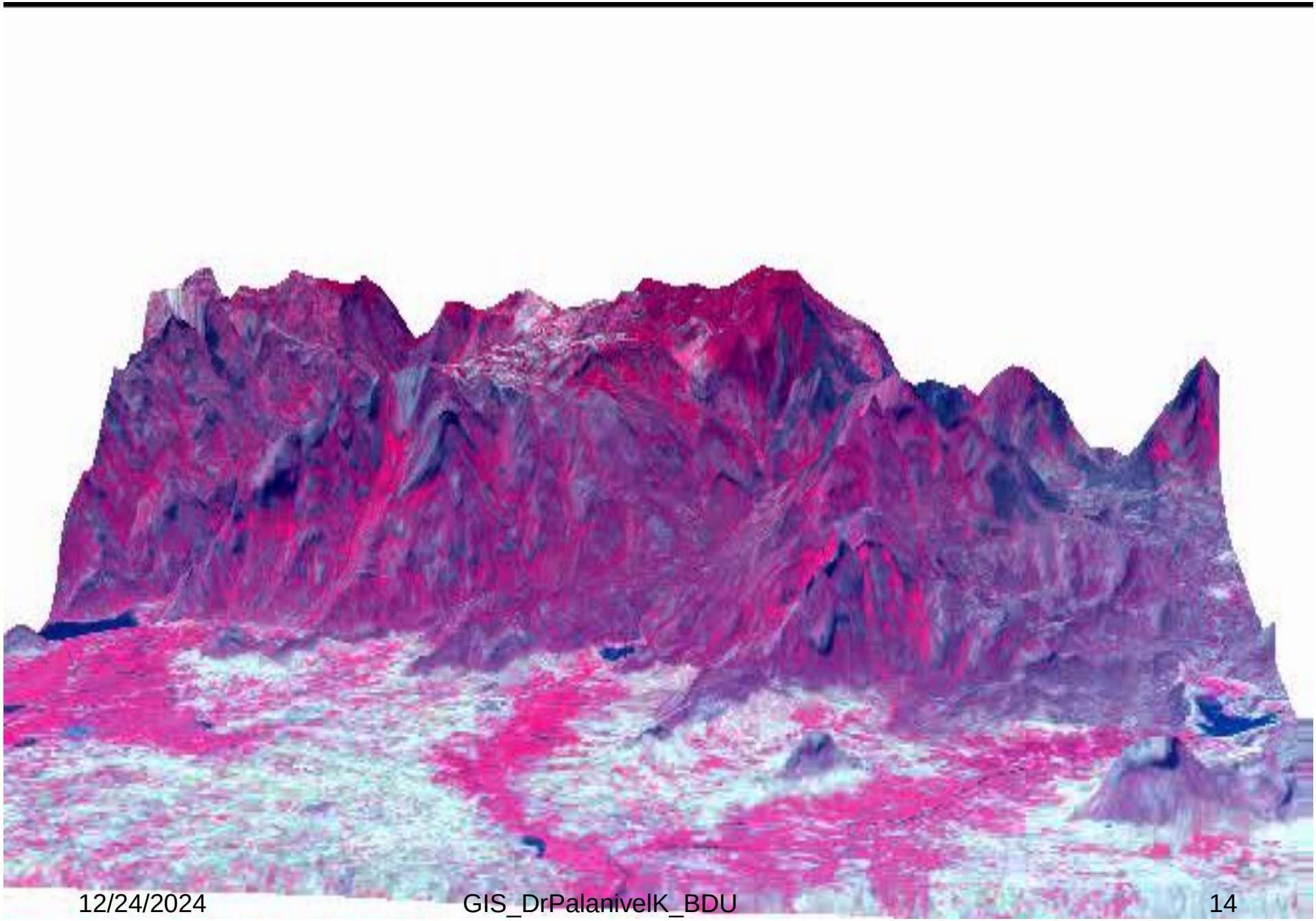




3D - DEM



3D - DTM



BACK

7. GIS Can do many more operations / Analyses like add, subtract, multiply, divide, square, buffer, corridor, integrate multiple layers, etc.

Raster Based Addition

1	1	2	2	2
3	1	3	4	4
3	3	2	4	4
3	2	2	1	4
3	2	2	1	1

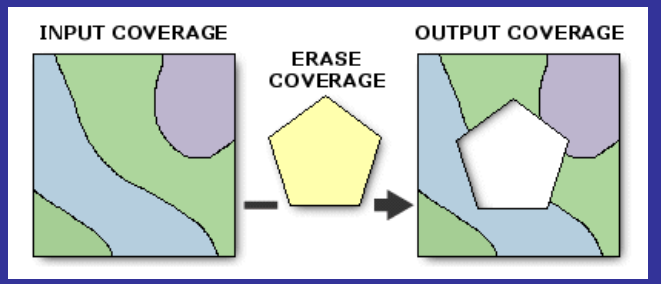
+

3	3	1	2	2
2	3	1	1	1
2	4	3	3	1
2	2	3	4	4
1	2	1	1	4

=

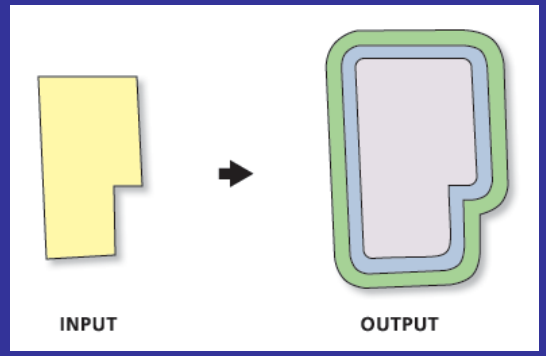
4	4	3	4	4
5	4	4	5	5
5	7	5	7	5
5	4	5	5	8
4	4	3	2	5

InRaster1 + InRaster2 = OutRaster

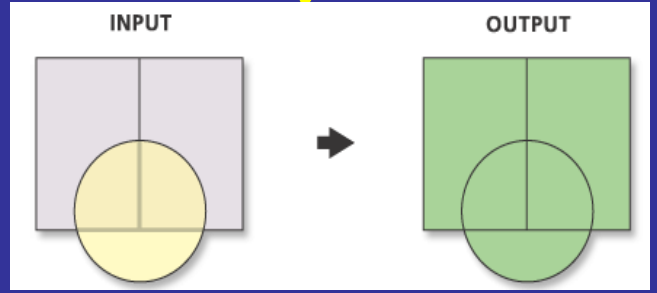


ERASE

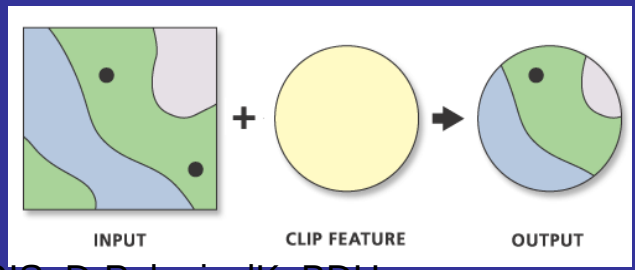
Vector Based Layer Integration



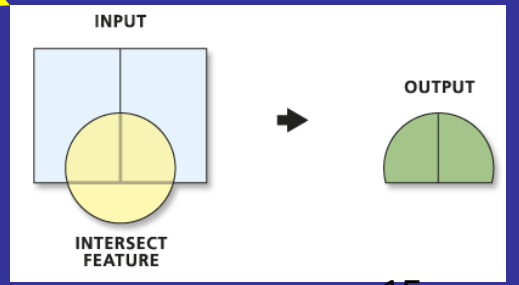
BUFFER



UNION

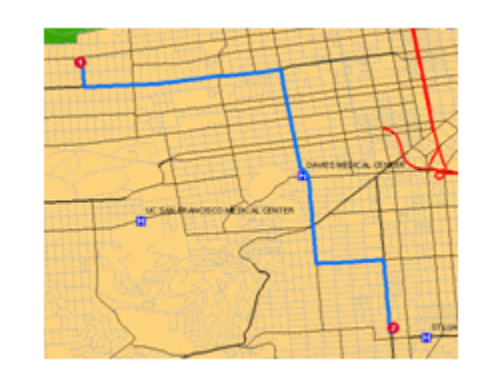


CLIP



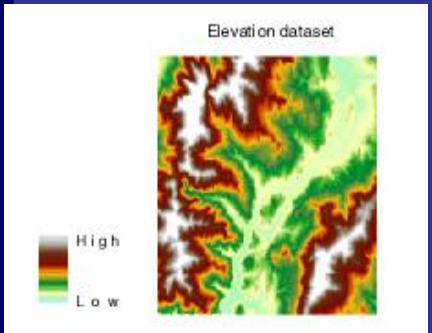
INTERSECT

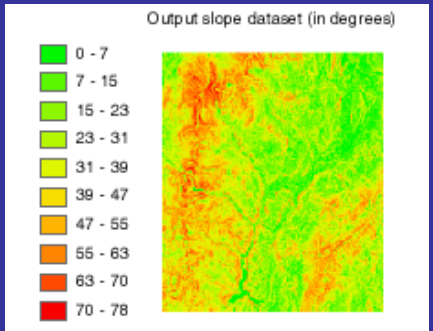
NETWORK ANALYSIS



Route Identification

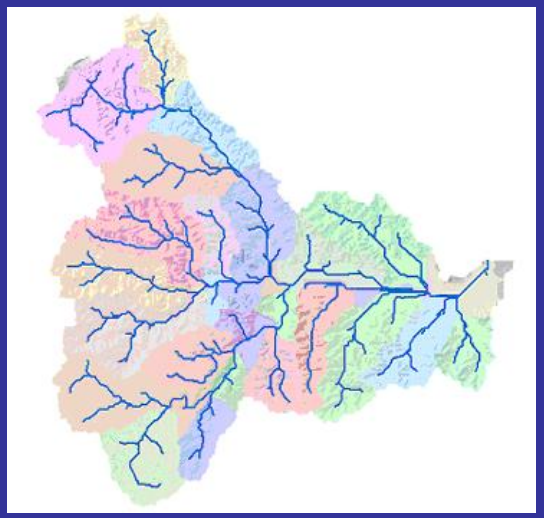
SLOPE ANALYSIS





Slope Categories, Slope Length, 3D Fly-through, Inter-visibility / Line-of-sight Analysis, etc.

DRAINAGE ANALYSIS



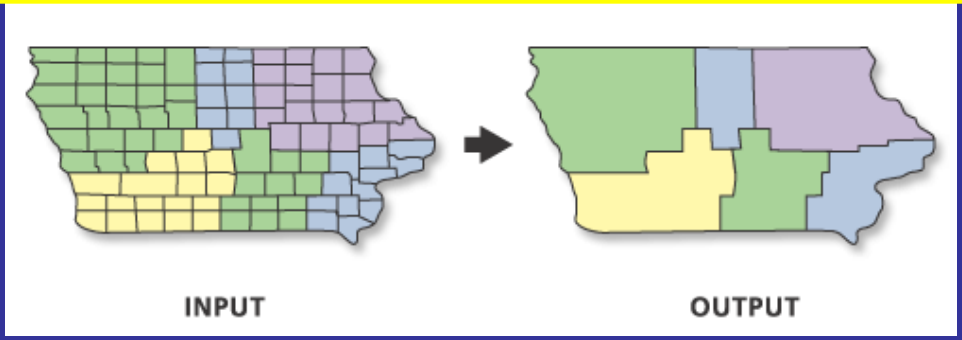
Identification of drainages, Demarcation of drainage basins, Watershed mapping, Runoff estimation, etc.

TIME SERIES ANALYSIS

TREND SURFACE ANALYSIS

Change detection, Pattern of change, Modelling, Simulation...

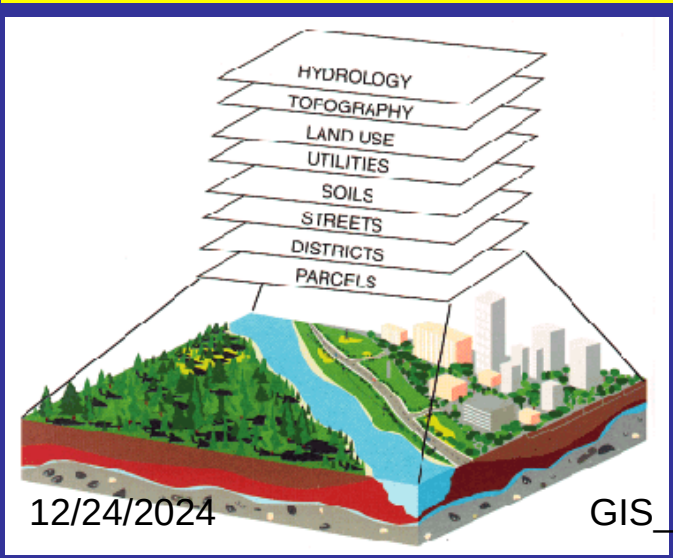
8. Data Pre-processing and Post-processing capabilities Classification/Grouping , Regrouping,/Reclassification



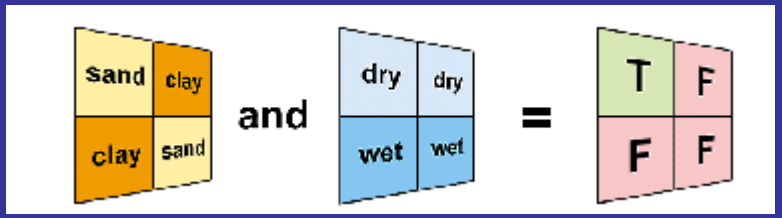
9. MODELLING

For e.g.,

Representation Model



Process Model



Yes / No, True / False, 1 / 0, etc.

10. CUSTOMIZATION

Building up of new working environments through programming in GIS as backend using frontends such as VB, Dartnet, Python, etc.

11. AUTOMATION

GIS Can provide AUTOMATION OF SEVERAL ANALYSIS COMPONENTS FOR VARIOUS NATURAL RESOURCES / DISASTERS MITIGATION

For, example,

AUTOMATED RUNOFF ESTIMATION MODEL can do,

- **Delineation of drainages and watersheds** – from elevation raster data,
- **Generation of Rainfall map** – from rain gauge stations through websites
- **Generation of Hydrological soil group map** – from pre-existing data
- **Generation of Landuse / Land cover map** – from satellite data
- **preparation of watershed wise calculation of all above parameters, and finally Runoff Estimation by applying the values into the formula, automatically.**

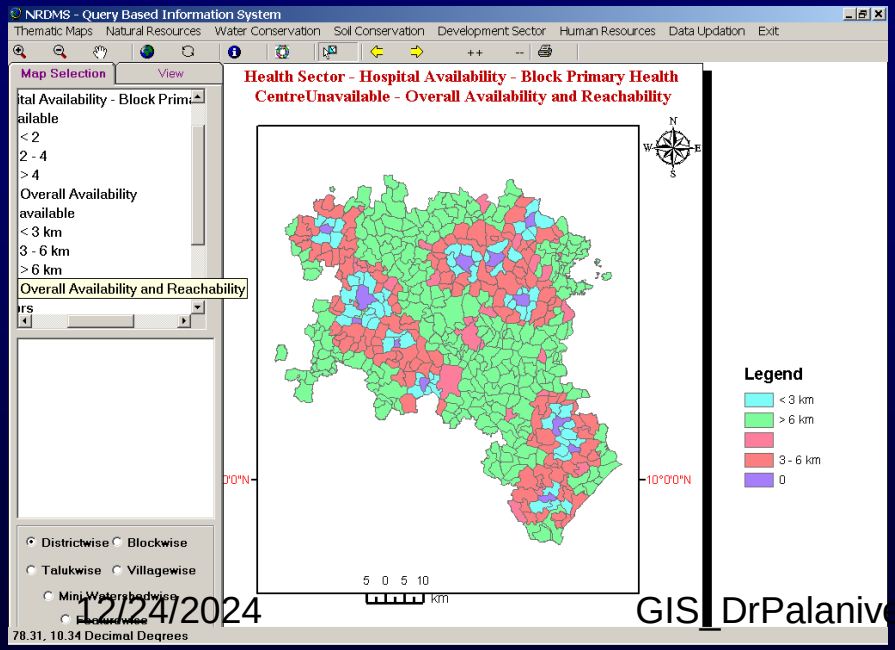
12. Advancements in GIS
a. **Internet / web GIS**

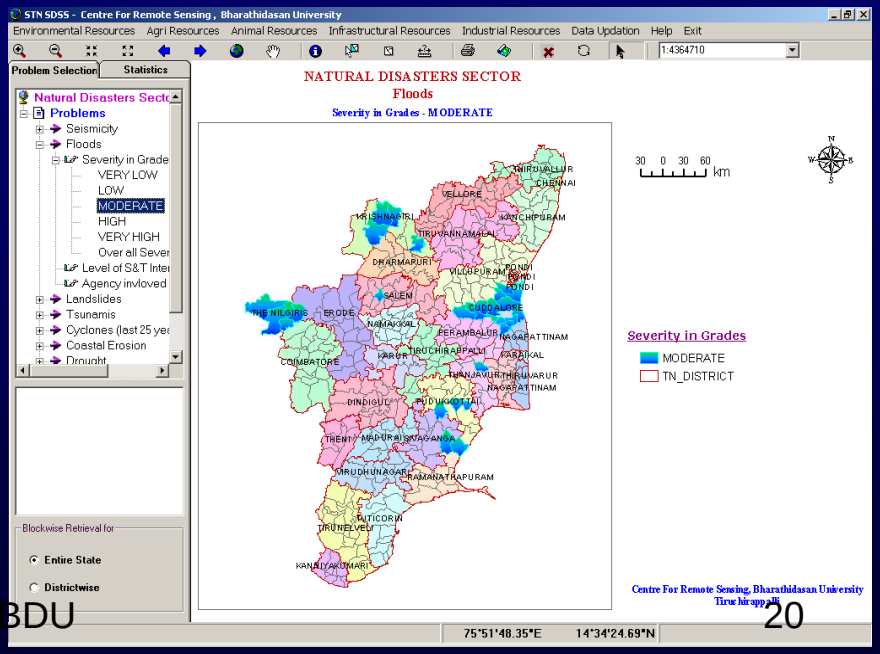
- - Open source GIS
- Non-Commercialisation
- Increase data usability
- Decrease work duplication
- Easy access by GIS community
- Quick and easy planning during crisis

12.b GIS can provide Spatial Decision Support System (SDSS) for various developmental planning

- ➔ User defined, query based, spatial data retrieval / map display
- ➔ Display of non spatial data by linking spatial data
- ➔ Data listing, map wrapping
- ➔ Programming for automated mapping, spatial database generation, spatial / tabular analysis, spatial modeling and suggestion of remedial measures / providing action plan map, etc.

NRDMS SDSS

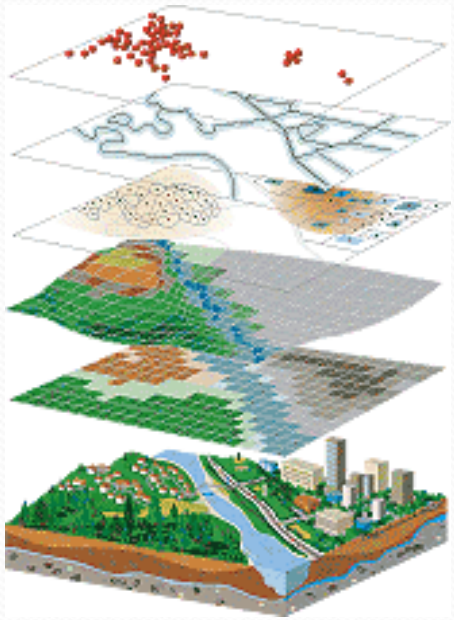




Capability based definition of GIS

GIS is a computerized / digital system for

- **Capturing / generating,**
- **editing,**
- **manipulating,**
- **systematically storing,**
- **analyzing,**
- **integrating,**
- **modeling,**
- **visualizing,**
- **sharing,**
- **retrieving, and**
- **representing / displaying**



huge quantity of both *spatial* and associated *attribute data* with customization and automation capabilities.

1.2 ADVANTAGES OF GIS over Manual Cartography

1. All data can be stored in digital formats in computer
2. It occupies less space in contrast to very larger maps and data sheets
3. Data / maps doesn't shrink or damage
4. Does not require large storage cabins
5. Data searching and retrieval is easy

6. Preferential filtering of selective data

➔ From the set of various road type digitised with labels separately as:

* National Highways
* State Highways
* District roads alone
* Village roads – metalled
* Village roads - unmetalled, etc.,

- the planner required roads for further developmental activity can alone (for e.g., **VILLAGE ROADS - Unmetalled alone**) be retrieved / shown as preferential layer.

How GIS differs from other related Systems?

- **DBMS—**typical data base contains implicit but not explicit locational information
  - city, county, zip code, etc. but no geographical coordinates
  - is 100 N. High around the corner or across town from 200 E Main?
- **Automated Mapping (AM)** --primarily two-dimensional display devices
  - thematic mapping (choropleth, etc., such as SAS/GRAPH, DIDS, business mapping software) unable to relate different geographical layers (e.g. Aadhaar & Location)
  - automated cartography--graphical design oriented; limited database ability
- **Facility Management (FM) systems**--
  - lack spatial analysis tools
- **CAD/CAM** (computer aided design/drafting)--primarily 3-D graphic creation (engineering design) & display systems
  - don't reference via geographic location
    - CAD sees the world as a 3-D cube, GIS as a 3-D sphere
  - limited (if any) database ability (especially for non-spatial data)
- **Scientific Visualization Systems**--sophisticated multi-dimensional graphics, but:
  - lack database support
  - lack two-dimensional spatial analysis tools.

But **GIS** offers a holistic platform possessing all possibilities from DBMS, Map, 3D visualization, Spatial Analyses combined with Statistical Models, Networking, WebGIS, to QUBIS & SDSS, and its advancements.

IMAGINE THE FOLLOWING SITUATIONS:

- My village has got very good fertile soil, man power, facilities, etc.,
  - ***but, there is less rain.***

- Undulating hilly terrain covered with dense vegetation looks like a green carpet–a scenic beauty - is my area,
  - ***now-a-days affected frequently by forest fire, soil erosion, landslides and flash floods.***

- In my very calm and wealthy village,
  - ***due to continuous burglary / robbery problem in many nights of a month and also during day time recently, most people are decided to shift their families.***

Some… more …requirements.

- A Highway Patrol officer likes to know ***a feasible route to take the ambulance to the nearest hospital having a particular Life-saving-treatment Facility***.
- A Forest Officer immediately wants to ***preserve the forest from a fast spreading tree disease.***
- A Fireman has to ***reach the target within short time and to know about the water/other relevant facility therein nearby.***
- A district level Planner (the Collector), plans to ***utilize the fund for development on priority basis.***
- Election Commissioner, wants to ***identify/install possible booths based on the population, reacheability, etc.***

Can GIS help in dealing the above important tasks?

- Resource Management
- Resource Conservation
- Resource Exploitation
- Resource Planning – Integrated and Sustainable manner
- Resource Estimation
- Resource Prospecting / Exploration

- Disaster Management
- Disaster Mitigation
- Disaster Prevention
- Disaster Inducing Parameter (s) Identification
- Disaster Vulnerability Assessment
- Disaster Relief fund distribution / Rehabilitation
- Disaster Damage Assessment

All the tasks can be dealt together?

If yes, How? Using GIS – by exploring its capabilities.

FUNDAMENTALS OF GIS

- GIS works on the basis of both location data as well as attribute data
- Spatial data have been generated on par with world real coordinates and defined with specific projection to maintain accuracy in all measurements
- Attribute data have been linked with location data and spatial layers can be created on the attribute data and
- Analysis can be done with both by spatial integration techniques
- 2D / 3D visualization can be done based on interpolation techniques.

TEN Important challenges in solving issues

In every case, we need to

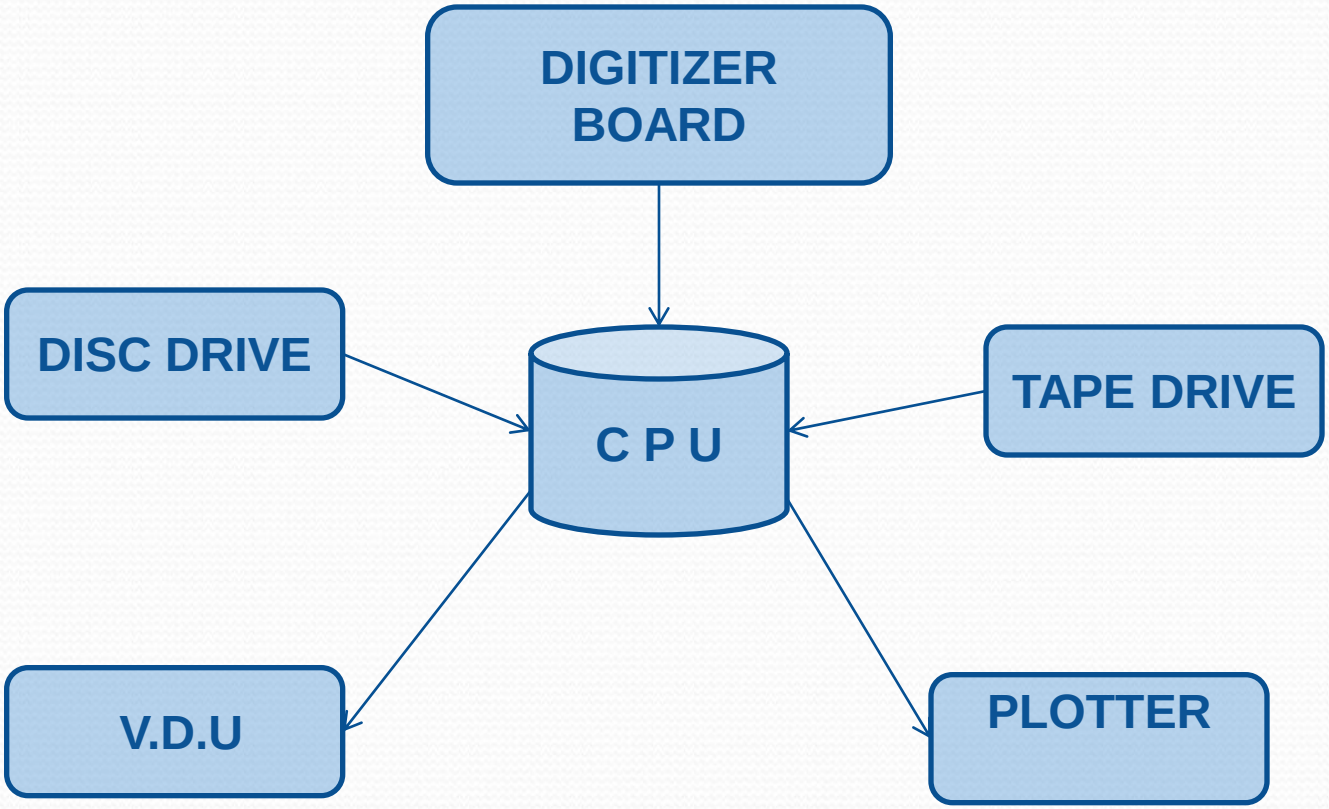
1. Collect, store & Preprocess the relevant data
2. Prepare a genuine database
3. Regroup / Reclassify the data
4. Analyze through comparison, integration, classification, prioritization, buffering, etc.
5. Derive the fact / information by post-processing techniques
6. Identify / understand the reasons – qualitative / quantitative – to develop model
7. Prepare pragmatic plans, ways & means for precise, efficient & economic for implementation,
8. Implement properly in correct location
9. Follow-up / monitor its functionality
10. Update / Manage the mechanism to work properly.

All the above tasks can be easily done in GIS environment…

1.2 COMPONENTS OF GIS

- **1.2.1 COMPUTER HARDWARE**
- **1.2.2 APPLICATION SOFTWARE**
- **1.2.3 PROPER ORGANIZATIONAL CONTEXT**

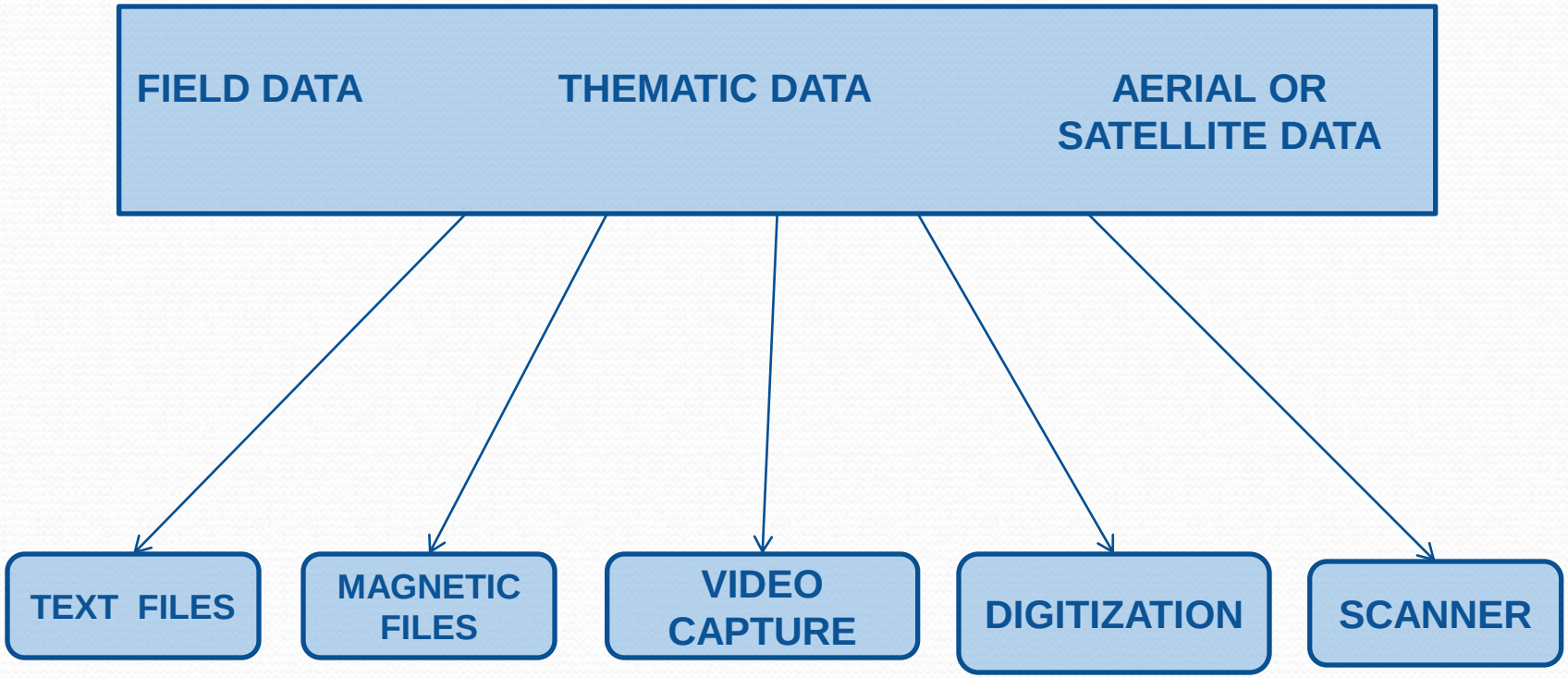
1.2.1 COMPUTER HARDWARE



1.2.2 APPLICATION SOFTWARE

- 1. Data input and verification
- 2. Data transformation
- 3. Data analysis and modelling
- 4. Data output and presentation
- 5. Data storage and database management &
- 6. Interaction with user.

1.2.2.1(a) DATA INPUT



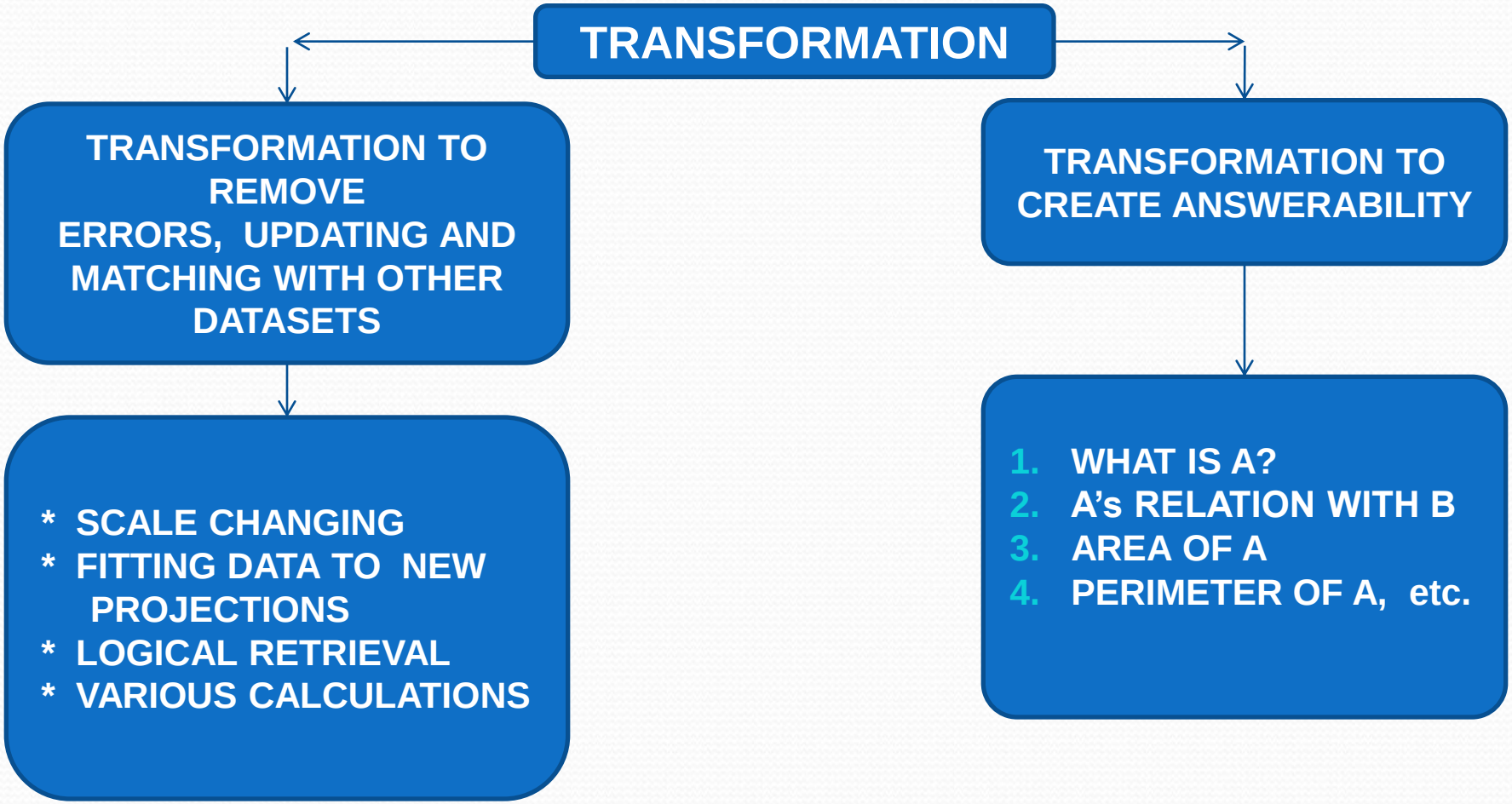
1.2.2.1(b) DATA VERIFICATION

- **Topology** – Generating details as separate files containing **geometric properties** of spatial data such as,
  - Containment
  - Connectivity / Continuity / Contiguity
  - Adjacency …. etc.

Building of Topology details to any spatial data can **identify, locate** and then **remove** all the geometrical errors such as **open polygons**, **sliver polygons, multiply digitized features**, **undershoots, overshoots, unlabeled features, multi-labeled features**, etc., quickly.

GIS has options for Editing / Updating of spatial data sets and making them accurate and error free.

1.2.2.2 DATA TRANSFORMATION



1.2.2.2 DATA TRANSFORMATION … CONTD…

1. **Updation of ground control points**

   - **Raw digital data are either in digitizer board unit or display screen unit**
   - **Update their coordinate values with decimal degrees**
     - **DD = (degree + (minute / 60) + (seconds / 3600))**

2. **Project them to the required projection system**

   Details required:

   Input data details

   - Projection type – geographic
   - Units – DD

   Output data details required (after projection)

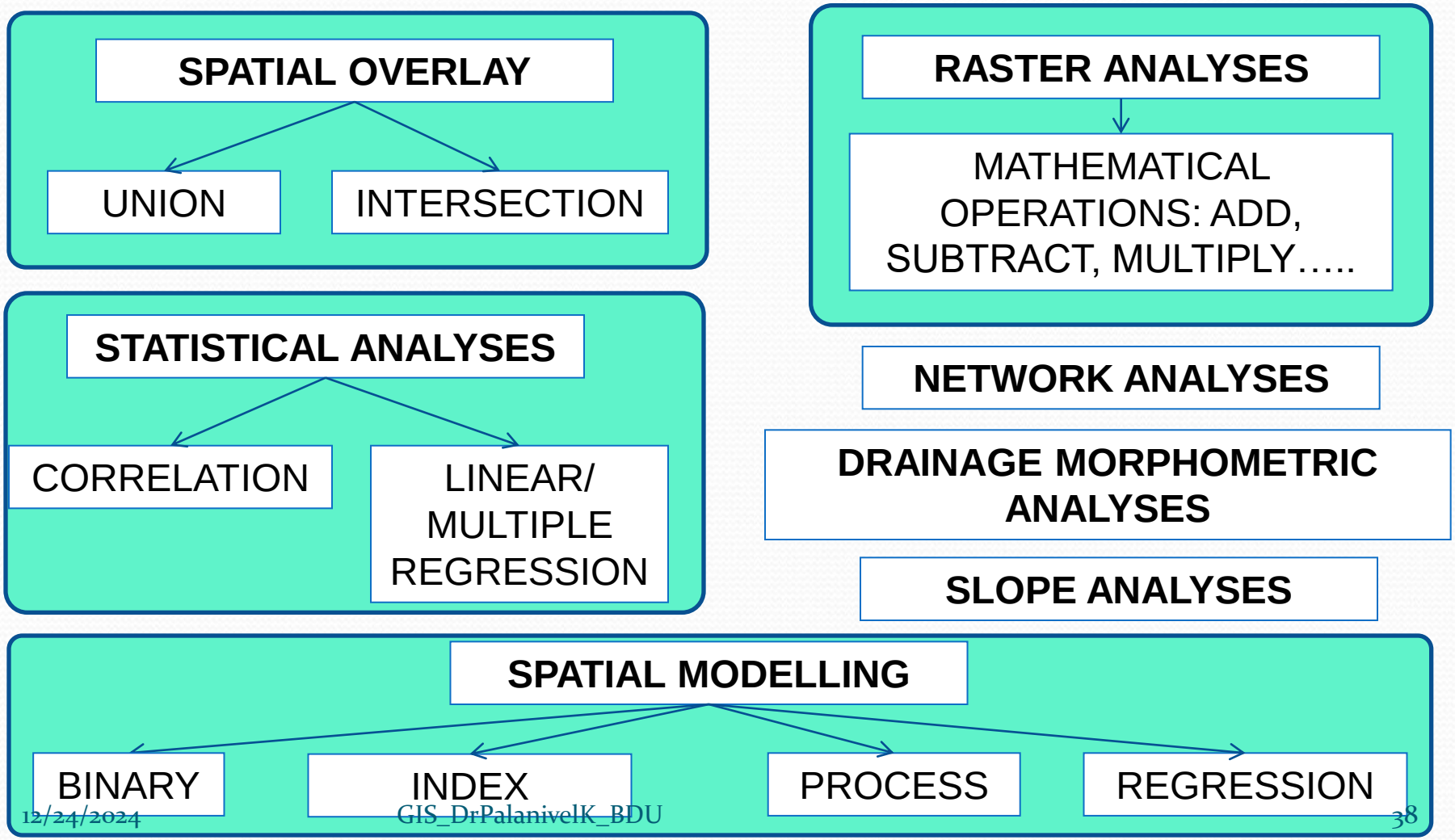
   - Projection type (expected) – polyconic …
   - Units – meters
   - Central meridian in dms (max – min longitude/2)
   - Lattitude of projections origin in dms

1.2.2.2 DATA TRANSFORMATION … CONTD…

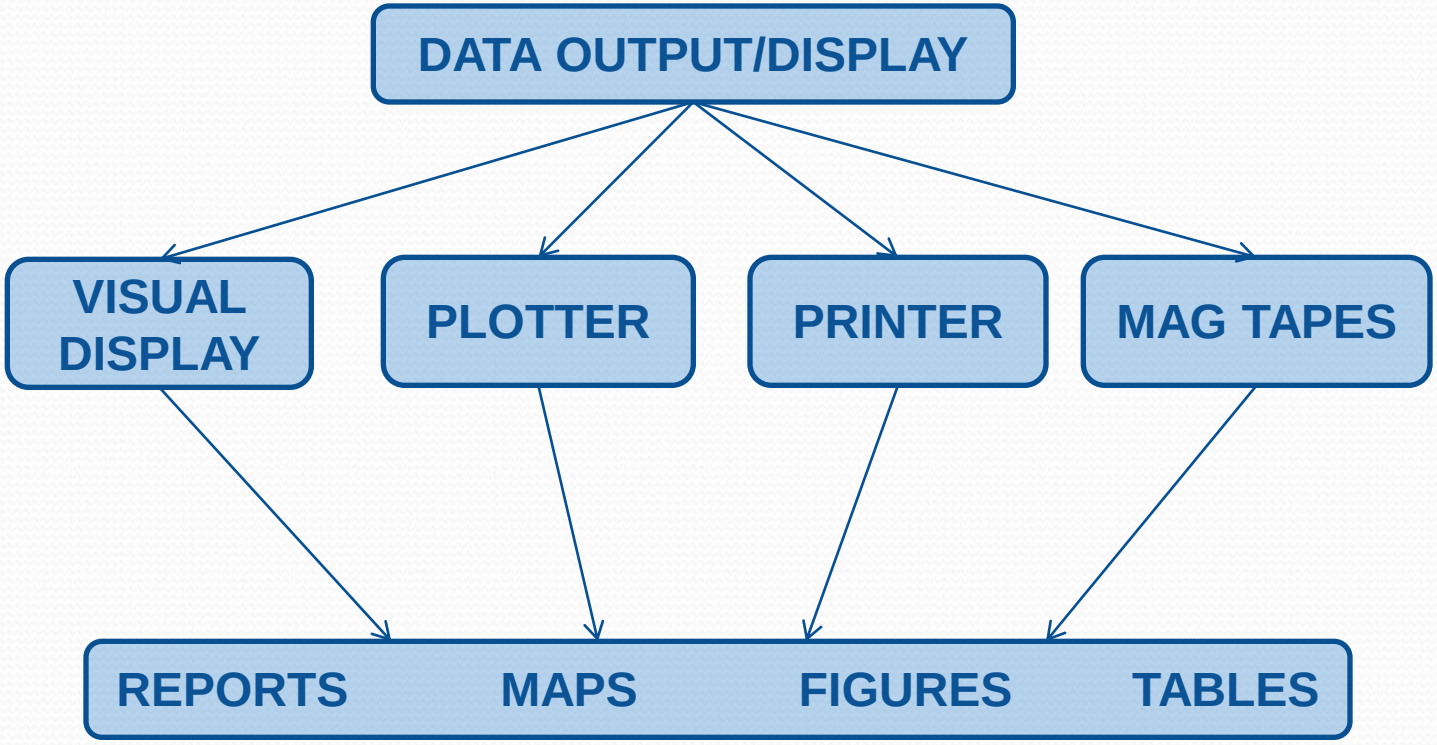
3. TRANSFORMATION OF ALL DIGITAL SPATIAL DATA (using Import Spatial References option)

- Making a copy of projected coordinates pertaining to the same study area
- Transformation of all themes to the projected real world coordinates using “transform” option
- In addition, the spatial data can be transformed or converted to any type from Vector to Raster (rasterisation) or vice-versa .
- Similarly, from one format to other format transformation (export and import of data) is also possible. For e.g., Shape file to layer file or coverage file, compressed formats, etc., So as to use them in any GIS s/w.

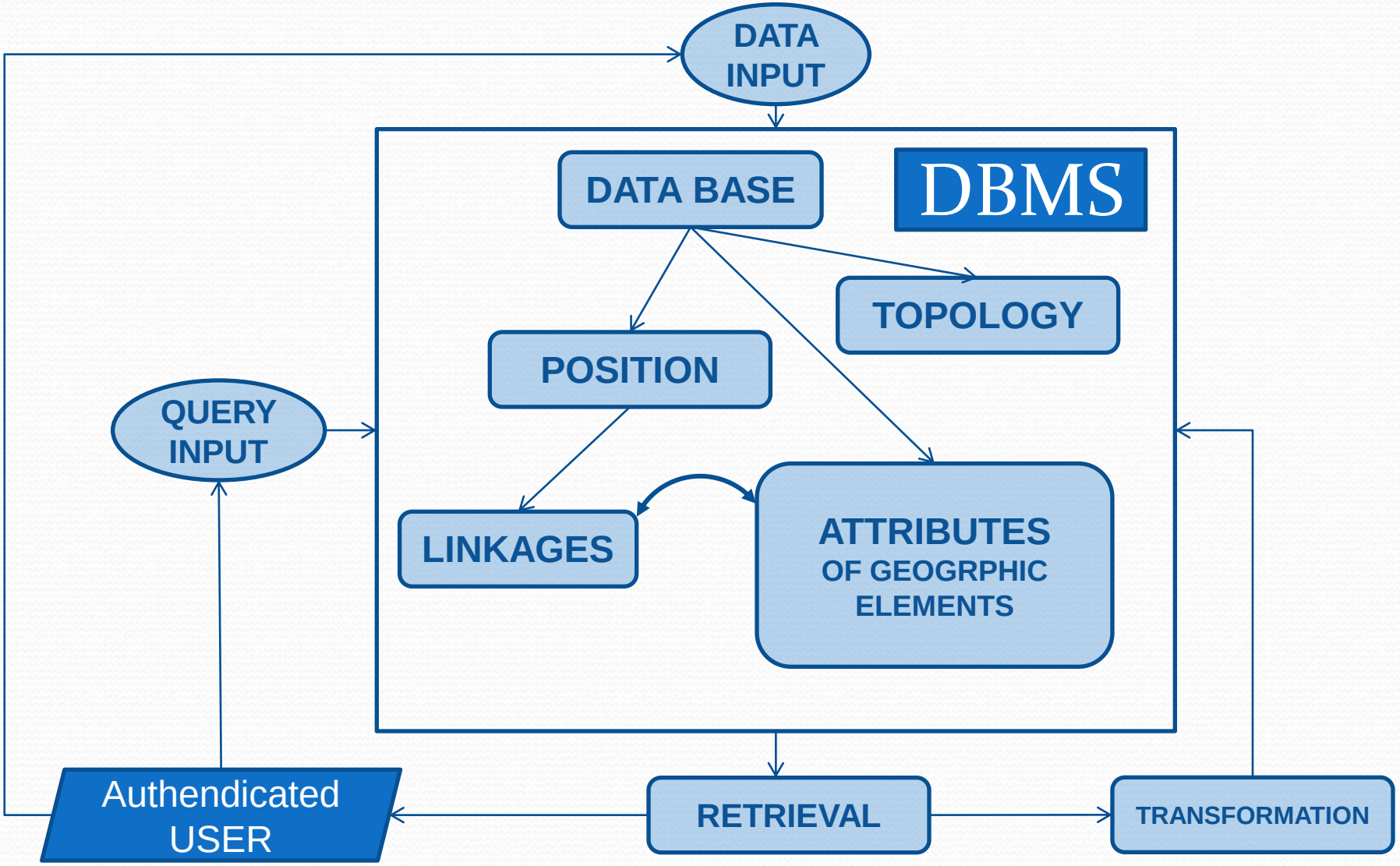
1.2.2.3 DATA ANALYSIS AND MODELLING



1.2.2.4 DATA OUTPUT AND DISPLAY MODULE



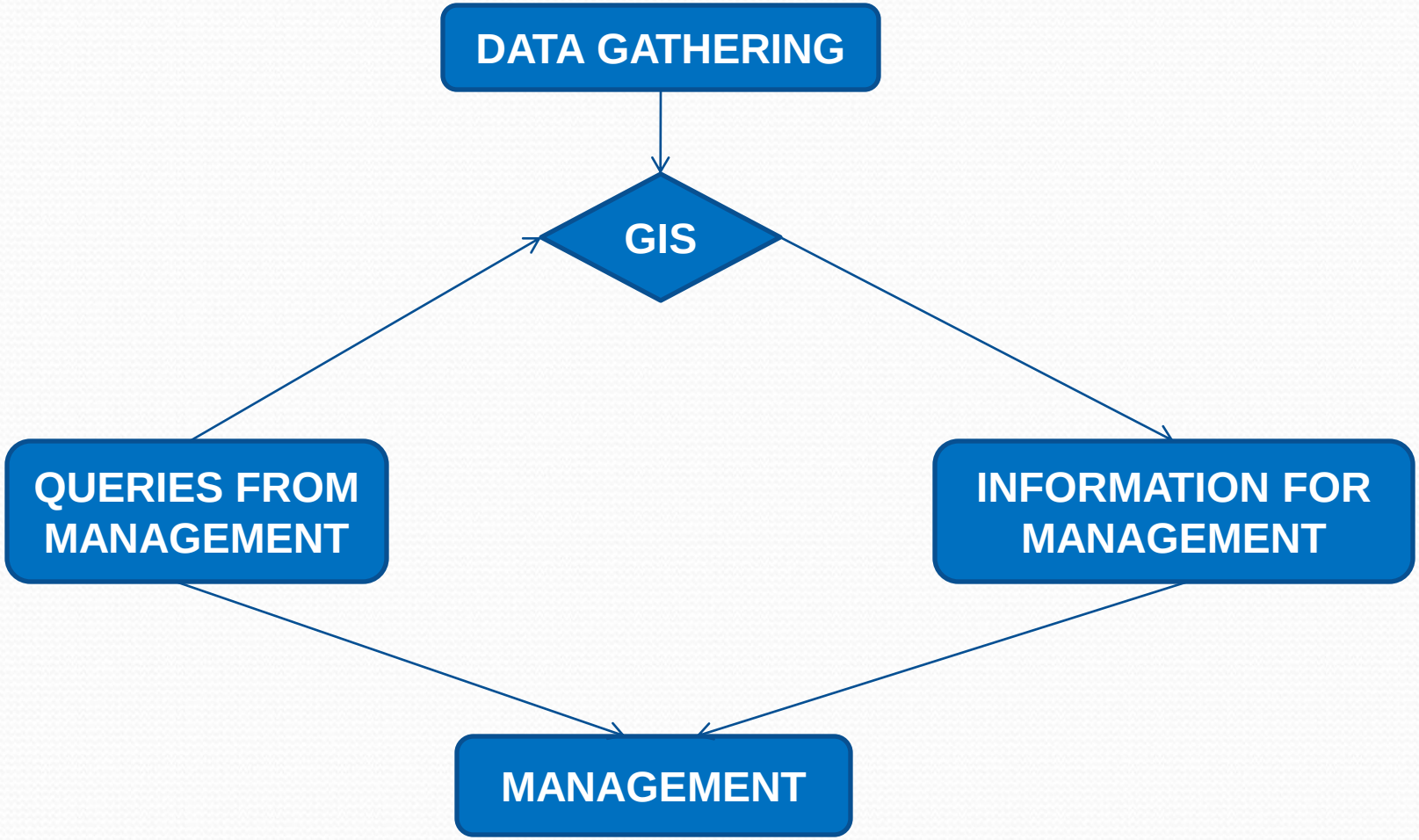
1.2.2.5 DATA STORAGE AND MANAGEMENT



1.2.2.6 INTERACTION WITH USER

- **General interaction**
- **Query input**
- **Commands &**
- **Menu driven systems.**

1.2.3 ORGANIZATIONAL ASPECTS OF GIS



ORGANIZATIONAL ASPECTS OF GIS ...contd...

1. **PROPER INTEGRATION OF DATA WITH GIS INVOLVES, THE PROPER DATA ORGANIZATION,**

For SPATIAL DATA SETS

- **RASTER - CONVERSION POSSIBLE**
- **VECTOR - -DO-**
  - Points
  - Lines
  - Polygons – For e.g. Continuous data - Surface & Subsuface …
    Discontinuous data

ORGANIZATIONAL ASPECTS OF GIS ...contd...

- **CONTINUOUS DATA**
  - Surface
    - **Slope**
      - **Degree / radiance / percent**
      - **Length**
      - **Aspect / direction**
        - **Consequent**
        - **Subsequent**
        - **Obsequent**
      - **Geometry**
        - **Plain**
        - **Convex**
        - **Concave**
      - **Vegetal cover**
        - **Active**
        - **Passive**
  - Subsuface
    - **Ground Water Level**
    - **GW Quality (**40+ Parameters)
    - **Subsurface Lithology**
      - **TTS – Thickness of Top Soil**
      - **TWZ – Thickness of Weathered Zone**
      - **TFZ – Thickness of Weathered Zone**
      - **DBR – Depth to Bed Rock**
    - **Aquifer Characters**
      - **T - Transmissivity**
      - **K - Permeability**
      - **S - Storage Coefficient**
      - **SY - Specific Yield**
    - **Etc…..**

- **Discontinuous / Choropleth data**
  - **Lithology**
    - **Igneous**
    - **Metamorphic**
    - **Sedimentary**
  - **Structure**
  - **Geomorphology**
  - **Landuse / land cover**
  - **Soil types, etc….**

cover parts of surface

For Non-spatial data sets

organise attributes for proper linkage with spatial data

- **For spatial display of non-spatial data**
- **Provide unique identifier**

ORGANIZATIONAL ASPECTS OF GIS ...contd...

2. Data entry – structure type
3. Derivation of information
4. Data retrieval - query building
5. Management – data updation

Thank you

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Let us enjoy using GIS more efficiently & effectively...