CONCEPT AND BASICS OF AN INFORMATION TECHNOLOGY–THE GEOGRAPHIC INFORMATION SYSTEM

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Abstract *The information technology has developed manifolds, especially in last one decade. The base of any information technology depends largely upon the information inputs in form of a database and its suitable use. Large data sets can be handled on computers under the Data Base Management System using various softwares, however, these softwares can only tackle non-spatial data. To extract selective information relevant to the planning task with reference to the geo-referenced location, analyses of different thematic maps (spatial information) and integration of large amount of attribute data (non-spatial information) is required. This is possible through a comparatively new and sophisticated information technology, known as the Geographic Information System. This paper describes the underlying concepts and basics of Geographic Information System.*

INTRODUCTION

With the advent of computer, the information technology has developed manifolds, especially in last one decade. The base of any information technology depends largely upon the information inputs in form of a database and its use suitably. Large data sets can be handled on computers under the Data Base Management System (DBMS) using various softwares, however, these softwares can only tackle non-spatial data. Whereas, to extract selective information relevant to the planning task with reference to the geo-referenced location, it requires to analyse different thematic maps (spatial information) and integrated large amount of attribute data (non-spatial information). This is possible through a comparatively new and sophisticated information technology, known as the Geographic Information System.

The Geographic Information System (GIS) has evolved from geography and geo-related disciplines. It is essentially an integration of geographic data for resource planning, management and decision-making purposes through well-defined operations. The GIS, though, is primarily based on DBMS functions, it differs from conventional DBMS in the sense that every data set has to be directly or indirectly associated with location on the earth's surface which could be expressed as co-ordinates with respect to the pre-defined co-ordinates system. The GIS technology also resemble closely to Computer Aided Drafting (CAD) system, which is basically used for automation of drafting and designing, however, the GIS manages automation of the drafting and designing with reference to their geographic information. Thus, the term GIS is referred as the computerised information system that handles geographic data used in substantive applications. In other words, the GIS is used to automate, manipulate, analysis and display geographic data in digital form. There are a number of definitions of GIS used by the academicians, vendors and other concerned authorities. The most commonly referred definition is "GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data for the real world for a particular set of purpose".

ELEMENTS OF GIS

The GIS comprises three basic elements: Computer Hardware, Data and GIS Software.

Computer Hardware

The computer hardware element include computer of any type varying from PC to Workstation, however, the one which could process the remote sensing images is preferred. A digitizer or scanner is used as the input device for data collection. The output device is VDU for display and plotter or colour printer for hard copy. A secondary storage device, Disk Drive or Tape Drive, is preferred for use of large volume of data.

Data

The data in the GIS, as stated above, are used with reference to their geographic location, which are either referenced by the global coordinates (latitudes or longitudes). The data, representing any of the earth's features, are described by any of the following spatial entities:

Points These represent a single location, such as well, spring, electric pole, railway station, etc.
Lines These represent point location sharing the same characteristics, such as rivers, roads, pipe lines, telegraph line, etc.
Area It represents a two dimension closed figure that enclose a homogenous mass, such as lake, mountain, country, etc.
Network It is a series of interconnecting lines and points along which there is a flow of information. For example, a network of roads or rivers, showing flow from one direction to another, etc.

The characteristics of the data are described by the associated attributes, which can be numeric as well as textual. Some of the major types of attributes are given in Table 1:

Table 1 Major attributes of data

Entity type	Feature	Unique Identifier	Geometry	Spatial Relationship	Other Properties
Point	Pole	Electric	Height	Location (with reference to a known place)	No. of Electric lines
Line	Road	Name	Length	From a particular place to another	Metalled / Zeepable; no. of intersections
Area	Lake	Name	Circumference	Location (with reference to a known place)	Fresh water (Natural or Man made)
Network	River	Name	Direction of Flow	Draining water into	Pattern, Flow Velocity

The values of an attribute are considered in some scale of measurements. There are four general types of scales used in GIS. These are Ordinal, Interval, Ratio and Nominal.

Ordinal scales These scales are relative, and help in differentiating between entities or locations on the basis of values such as smaller or large, higher or lower, etc., without any numerical values assigned to that difference.
Interval scales These scales provide information about the magnitude of difference between intervals. In this case, attribute values are expressed in terms of some standard unit describing according to difference in interval values. For example – given two temperatures, 5° and 10° C, one can say 10° is warmer than, 5°, but not twice warmer than the later. The interval scales are arbitrary.
Ratio scale This scale is based on absolute origin, which is usually 0. Attributes such as percentage, frequency, physical dimensions and monetary values are frequently measured using a ratio scale.
Nominal scale This scale represents qualities rather than quantities. For example, zip codes and postal codes are nominal values that identify areas.

Database Organisation

The Data in GIS is organised in forms of different thematic layers, such as roads, rivers, locations, etc. Features are in form of points, lines or polygons. Thematic description, such as name, symbol, classification or other information of the features is stored in attribute tables. Thus, a thematic layer contains both locational data (that defines points, lines and polygons; for example, Fig. 1 illustrates feature classes in a soil layer) and attribute data (which describes the points, lines and polygons), where each feature has one corresponding set of attributes stored as a single record in the feature attribute table (refer Table 1 which gives feature attributes for the soil layer shown in Fig. 1, as an example). The attribute records are related to the features by the User-ID, which link coordinate features to their attributes.

There are four types of primary features that are used to represent points, lines and areas on maps. These are Arcs, Nodes, Label Points and Polygons. Beside these, there are secondary features that are used for registration of the layer, defining the map extent & primary features and annotating maps. These are Tics, Coverage Extent and Annotation.

- Arcs represent line features, the borders of polygons, or both. One line feature may be made up of many arcs. Arcs can be topologically linked to their endpoints (nodes) and to the areas (polygons) on each side of them. Descriptive data about arcs are stored in an Arc Attribute Table (AAT).
- Nodes represent arc endpoints and intersection of line features. A node may be topologically linked to the set of arcs, which connect to each other at the node.
- Label Points are used for three different purpose – to represent point feature; to assign User-IDs to polygons; or to place label text within a polygon. Any single label point cannot be used for all three purposes.
- Label Points are used to represent point features, which are locations defined by single coordinate pair (x,y), such as mountain peak, well site, town location, etc. Each point

feature is represented by a label point. Descriptive data about these points are stored in a Points Attribute Table (PAT). Label points are also used to assign User-IDs to polygons or to position text within polygon. One label point is placed within each polygon. When polygon topology is created, the label point's User-ID becomes the polygon's User-ID. If a polygon does not contain a label point, its User-ID will be 0.

Polygons represent area feature. A polygon is defined topologically by a series of arcs, which compose its border and by a label point positioned inside its border.

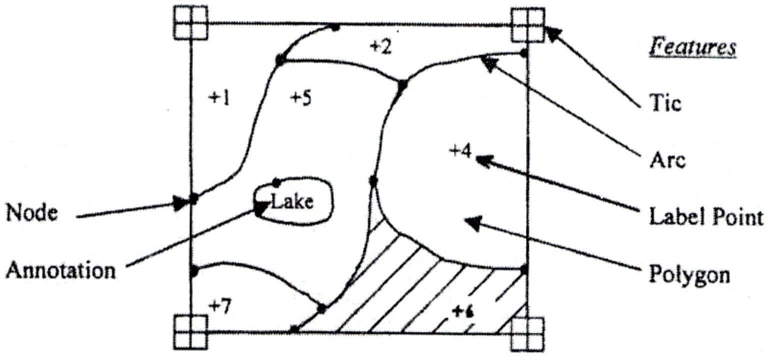

Fig. 1 Feature classes in a soil layer

Table 1 Feature attribute table for the soil layer shown in Fig. 1

Rec.No.	Area	Perimeter	Soils	Soils ID	Soil	Class	Suitability
1	36.0	24.0	1	0	-	-	-
2	3.0	9.0	2	1	A3	113	High
3	2.5	8.5	3	2	C6	95	Low
4	15.0	15.0	4	3	B7	212	Moderate
5	4.0	8.5	5	4	B13	201	Moderate
6	2.0	4.5	6	5	Z22	86	Low
7	5.5	12.0	7	6	A6	77	High
8	4.0	7.0	8	7	A1	117	Low

- Tics are registration or geographic control points for a layer. Tics are usually calculated form known reference points found on a base map. For example, known latitude-longitude values may be recorded for a series of points on the map. Tics are used to orient the layer during digitization, map merging, overlay and plotting. At least four Tics must be created for each layer, though more tics increase the accuracy of map registration.
- Coverage Extent represents the map extent. It is a rectangle that defines the coordinate limits of layer arcs and label points.
- Annotation is text used to label coverage features. Annotation is not topologically linked with any other features. Annotation is used only for display purposes and is never used in analytical processes.

Topology All map features are represented by a set of lines (arcs) and label points having relationships between connected lines and points. This relationship, which is used to represent the connectivity or contiguity of these features, is referred to as Topology. It is the highest level of generalisation at which geographic features can be stored that provides the basis for various geographic analysis without having to access the absolute locations held in the coordinate files. In other words, connectivity, route finding and contiguity are derived through topology, which is separate for both Polygon and Arc-Node. Thus, topology gives the number of the arcs/polygons in sequential order and their direction (from one node to end node). It also stores their Internal-ID, both for arc and polygon separately.

Computer Software

The software forms the most crucial part of the system. There are various standard softwares available in the market having their own proprietary data structure. Some of the well known GIS softwares are: ARC/INFO, Intergraph, Map Info, SPANS, IDRISI, etc. The softwares generally have five basic technical modules:

- Data Input
- Data Storage and Database Management
- Data Processing
- Data Output and Presentation
- User Interface

Data Input Data is entered into the database of the GIS through digitizer, scanners or image processing system, or conversion from other existing digital files. The data is stored in a computer compatible digital form either in vector or raster format.

Data Storage and Database Management The collection of data is usually referred to as the database, and the way in which the position, linkage and attributes of the geographical data are structured to handle is referred to as Database Management. A Database Management System (DBMS) consists of a collection of interrelated data and a set of programs to access that data. The prime aim of a DBMS is to provide an environment that is both efficient and convenient to store and retrieve the information. Upholding the security against unauthorized use or access to the data and integrity to protect data from accidentally loss or from contamination by extraneous data are some of the other major tasks of a DBMS.

Data Processing It includes two operations – Transformation and Analysis. Data Transformation comprises removing the error or any incompatibility amongst the datasets, which may arise because of data coming from different sources and in different formats. It also includes converting the data from one type to another, such as point data to line or area. Analysis of the data forms the core and uniqueness of the GIS. Large arrays of operations are carried out to answer the questions. Some of the general questions are:

- Where is object 'A'? or Where is 'A' in relation to 'B'?
- How large is 'B' (area, perimeter, volume)?
- What is the result of intersecting various kind of spatial data?
- Reclassify object having certain combination of attributes.
- Stimulate the effect of process 'P' over time 'T' for a given scenario 'S'.

The common analysis function found in the softwares include – classification (grouping), address matching, calculation of area/perimeter/volume, overlay, network, etc. Beside these, there are some advanced modules, such as Digital Terrain Modeling, Simulation, Optimisation, Impact Assessment, etc. Apart from these, some specific applications analysis are also possible.

Data Output and Presentation One of the most exciting aspects of the GIS technology is to obtain variety of information in different ways. Maps and three-dimensional images supplement traditional tabulating and graphic data. Most of the softwares have provision to save the maps in form of slides and also facilitate their presentation as slide shows for quicker display. High-resolution printers and plotters are also supported for hardcopy presentation.

User Interface This concern with which the User interacts with the software. There has been considerable improvement in the User Interface with the availability of windows environment on various platforms. The old command line interface has taken the new look of user friendly Graphical User Interface (GUI). The availability of hypertext on-line help facilitates guide the User to run the programs successfully.

GIS DATA TYPES AND STRUCTURE

As mentioned earlier, the GIS handles a large volume of data and process it in a variety of data types as per need. A GIS database is, thus, a computerised extension of a map representing a geographical model of reality. There are two distinct data requirements for any GIS project, viz. Spatial and Non-spatial. Spatial Data include the type of geographical entities, their location and geometric or topographical relationships with each other. Non-spatial Data is the attribute information associated with spatial entities. Modelling through spatial data alone would not be enough for analysis purpose, unless it is supported by quantitative / qualitative non-spatial data.

The spatial entities are viewed in two different ways. The first has evolved from cartography and represents mosaic of interconnecting lines and points, which indicate location and/or boundaries of the entities. The second emerged with computer technology and is based on grid structure of variable dimensions, representing an entity by its presence or absence within a specific grid cell. These two approaches as referred as the Vector and Raster Data Models, respectively.

Data Structure

Within each data model there are many methods of structuring data for efficient and effective manipulation. These methods are referred to as Data Structure. The Data Structure of the two models, Vectors Data Model and Raster Data Model are explained below:

Vector Data Model

It is the most common method for representing spatial data and is based on cartography. The lines or vectors are used to represent entities such as roads and streams and to define edges between different spatial entities such as land and water. The Vector Data Model is best suitable for representing points, lines and areas. There are four main types of different Data Structure within this model, viz., Spaghetti, Topological, Hierarchical and Triangulated Irregular Network.

Spaghetti Data Structure In this type of structure, points are represented as pair of spatial coordinates, lines as strings of coordinate pairs and area as line that forms closed loops or polygons. If each point, line and polygon on a geological map is digitised with a line following digitizer, the resulting strings of coordinate pairs can be stored in a relatively unstructured form. If spatial entities are stored with attribute information, usually with spatial and non-spatial data in the same file, points can be plotted with different symbols, lines with different colour & weights, and areas be filled with patterns and colours, depending on the value of the associated attributes. The two main disadvantages of Spaghetti Structure are:

(i) Data redundancy, and
(ii) Computational expenses due to the absence of topological attributes.

Topological Structure In this type of structure, points are either isolated or linked to form lines, in which case these are vertices. A line is a sequence of ordered vertices, where beginning of the line is a start node and end of the vertex is called end node. A chain is a line that forms a part of one or more polygons. It can have (left, right) polygon identifiers as well as (start, end) nodes. Chains are also called arc or edges. Node is a point where line or chains meet or terminate. Polygon consists of one outer ring and zero or more inner rings. A ring consists of one or more chains. A simple area polygon has no inner ring, whereas a complex polygon has one or more inner rings and is said to have 'holes' or 'islands'. In the Topological Structure, boundaries of the polygon are broken down into series of arcs and nodes and the spatial relationship between arcs, nodes and polygons are explicitly defined in attribute table. The disadvantages of the Topological Structure are:

(i) Topological tables must be generated in the first instance, which is computationally expensive and requires more storage space.
(ii) Some simple operations like graphic display are slow and cumbersome.

Difference between Spaghetti and Topological Structures i) In the Spaghetti Structure, boundary between two adjacent polygons is stored twice, once for each polygon. This leads to wasteful storage and double boundaries that do not match exactly. In the Topological Structure, polygon to the left and right of each arc is explicitly defined, so polygon boundaries are never repeated. ii) In the Spaghetti Structure, polygons need not form an interlocking mosaic that is exhaustive. It leads to creation of artificial gaps and overlaps between adjacent polygons. This problem is tackled in the Topological Structure by planner enforcement, which results in creation of a set of polygon objects that completely fill the plane of the map. iii) Information in the Topological Structure is explicitly stored and is separated from spatial coordinates, facilitating search that requires adjacency, containment and connectivity information.

Hierarchical Structure In this type of data structure, points, lines and polygons are stored separately in a logically hierarchical fashion, which includes explicit links between the features. Here, the link is made by identification of nodes defining a line to the line record and identification of lines defining the polygon boundary to the polygon record. It also includes topological information.

Raster Data Model

It is well suited for representing area and surface entities.

Grid Structure It represents a two-dimensional space as an array of square or rectangular cells, called pixels. In a Grid Data Structure, points are represented as individual cells (pixels), while lines and areas are represented as clusters of adjacent pixels. Each pixel is assumed to have only one value for any given attribute. A cell attribute value may represent a point measurement (elevation, etc.) or an integrated areal measurement (reflection, land use, etc.). Attributes for multiple geographical entities may be conceptualised as multiple layers. Processing Raster Data using Grid Data Structure is efficient for some tasks, such as neighborhood query, operations such as spatial filtering that carry out calculations on a square window of adjacent pixels, and overlay operations for combining two or more images together. The grid organisation is well suited for modelling spatial continue, particularly where an attribute shows a high degree of spatial variation, such as data on satellite images. The regular spacing of pixels in a lattice is ideal for calculating and representing spatial gradients.

Region Quadtree It is a Hierarchical Data Structure and is based on successive partitioning of map layer into four quadrants until each quadrant reflects only one cover type. As soon as the map becomes complex, more layers to the hierarchy are introduced. The basic advantage of using Quadtree is to reduce the space requirement for raster data. The disadvantage of the Quadtree Structure are: i) Display of Quadtree Data is comparatively slower; ii) Quadtree are not simple to translate, rotate or scale operation that require creation of a totally new tree; iii) Quadtree from one universe can not be used directly with Quadtree from another universe. Quadtree are, therefore, better suited for project related rather than the custodial GIS.

Data Structure of Available GIS Softwares

As mentioned above, the Vector Data Model is best suitable for representing points, lines, areas and network, while Raster Model is well suited for representing area and surface entities. Some of available FIS softwares in the market are:

ARC/INFO is a vector based GIS package, which consists of spatial database build around RDBMS. It organises the data using topological structure.

PAMAP adopts an integrated raster as well as vector representation for the spatial entities, it uses vectors to create line entities and then these are converted to raster images for analysis purposes.

SPANS is a hybrid raster-vector based GIS package with Quadtree data structure.

QUERY IN GIS

The fundamental purpose of any Information System is to allow retrieval of desired information. This retrieval in GIS is achieved through 'Query' function. The various types of queries are:

Spatial Query Here queries are made on the spatial properties of the geographic objects.

Query a Location Location is represented by point, which is zero-dimensional spatial entity having specific geo-reference, hence the point entities are retrieved base on query by specific location. Usually, a locational query can return any combination of the following information:

- The record number, or point-ID number
- Coordinates specific to spatial data model
- Latitude-longitude of the point
- The projection coordinates

Query Distance While performing distance queries, both the current and cumulative distances are computed. To make a query, the interactive cursor is moved to the start of the route that is measured and a 'rubber band' line is adjusted till the end location is reached. There are several ways to return the distance information, viz.

- the longitude and latitude of the interactive cursor location
- projection coordinates of the cursor location
- the pixel resolution of the current window
- the great circle distance between two points
- the cumulative great circle distance along the route
- the cumulative distance along the route in the projection plane

Circular / Rectangular / Polygon Area Search Useful for querying a data layer and select only those entities that fall within a user specific radius / rectangular / polygon area.

Non-Spatial (Attribute) Query

Attribute refers to the characteristics of any feature or phenomenon, which are stored in form of a table in a database with a unique identifier key. This 'attribute' table can be queried to locate row or column that satisfies the search conditions.

The data linkage is established between the spatial elements and their corresponding attribute tables through the common feature identifier key. Exact Matching is most often employed. Here the attribute table has a corresponding record entered for each of the spatial elements. In some cases, some attribute information is collected in more detail than the other attributes. In such cases, Non-exact Matching is carried out. Non-exact Matching is of two types: (1) Hierarchical Matching, e.g., finance and unemployment data covering large area are collected more frequently, where as the population data are collected for small area at a less time interval. In this case matching is done through hierarchical method; and (2) Fuzzy Matching, e.g., crop boundaries usually define the field edges that rarely match the boundary between the soil types. In such case Fuzzy Match allows for acceptable deviations in the value.

Topological Query

Topology defines as the inter-relationship amongst he features that are dependent of distance or direction. The key topological relationships are connectivity, adjacency and containment. For example, Connectivity – shows all the homes sold last month which are within ten km driving distance from the airport; Adjacency – shows all the homes sold last month which lie next to banks of a certain river; Containment – shows all the homes sold last month which lie completely within the Protected Greenery portion of the metropolitan area.

Spatio-Temporal Query

This query provides ready answers to simple questions of feature, areal histories and attributes for the past moments in time.

SQL Based Query Formulation

A Structured Query Language (SQL) is a tool to extract data from a database and present results in a useful manner. SQL is used extensively in many database applications and has become a standard for relational DBMS.

OVERLAY

The major advantage of a GIS is that it allows to identify spatial relationships between map features and to create new relationships by integration of map layers on various themes. It is performed under the Map Overlay, which is a spatial analysis involving two or more maps. Each map can be thought of as a layer containing information on a particular theme. These maps can be integrated to produce an output map on the basis of some logical and / or arithmetic operation.

Logical Overlay

Logical Overlay is a method of creating new map layers by classifying the intersection of two map layers. There are different kinds of Logical Overlay:

Impose Overlay One of the most common two maps overlay requirement is to be able to cut away portions of map based information which lie outside the study area. Some of the example applications include: i) Establishing the area covered by different crop types within a region; ii) Determining the location and species of tree burned in forest fire in a region; iii) Showing unemployment rates for only urban areas within a district; and so on.

Stamp Overlay There is often a need to construct a complex map form other simpler maps. For example, i) Creating a complex landuse map form maps showing rural, urban, commercial and urban residential landuse; ii) Recording historical developments, such as expansion of a municipality; iii) Creating a map of forest fire history for a region from maps showing forest fires for three different study periods.

Join Overlay It is one of the widely used methods of logical overlay. This is also called as mosaic overlay. There is often a need to join adjacent map sheets to construct a larger study area or a map layer. The application for the Join Overlay may include: i) Creating a landuse map for a metropolitan area by joining landuse maps for the suburbs and municipalities comprising the metropolitan area of a city; ii) Joining four map layers which identify forest fires for different, by adjacent regions to construct one larger map encompassing the four regions.

Matrix Overlay The matrix overlay method is a very general way to create a new layer based on a comparative analysis of two layers. The method is based on a matrix in which the classes of Map layer 1 represent the rows and classes of Map layer 2 represent columns, and the cells represent classification assigned to intersection of the two map layers. The classification scheme defines the classes in the output layer.

Arithmetic Overlay

Arithmetic Map Overlays is widely used for integration of map layers to generate suitable or potential map. In this method, each layer is assigned a weight depending on its role in the analysis. Then the maps are combined and the output map is classified to contain final meaningful classes only. One of the common Arithmetic Overlays is the Index Overlay Analysis, which are used for both Binary Maps and Multiclass Maps.

Index Overlay Analysis with Binary Maps Binary Maps contain only two classes – 0 (to indicate absence of the feature) and 1 (for presence of feature), These maps are simply multiplied by their respective weight factor and then summed over all the maps being combined and normalised by the sum of the weight. The result is a value ranging between 0 to 1, which is further classified by the analysis into required number of intervals. At any location the output score 'S' is defined as:

$$S = \frac{\sum i^n W_i class(Map_i)}{\sum i^n W_i}$$

where W_i is weight of i^{th} map; and class (Map_i) is either 1 for presence or 0 for absence of a class in binary condition.

The output score is either 1 for highly unfavourable and 0 for highly favourable.

Index Overlay Analysis with Multiclass Maps In this case, the map class occurring on each input map are assigned different scores, as well as the maps themselves are given different weights as in the case of binary maps. It is convenient to define the scores and weights in an attribute table for each input map. The average score is then given by:

$$S = \frac{\sum i^n W_i S_{ij}}{\sum i^n W_i}$$

where S is weighted score for an object (polygon or pixel); W_i is weight of i^{th} map; and S_{ij} is class score for i^{th} map's j^{th} class.

Figure 2 illustrates an example of index overlay with Multiclass Maps.

Thematic Maps	Weights assigned for Land capability	Settlement	Agriculture
Drainage	5	6	8
Slope	3	9	4
Geomorphology	8	7	5
Landuse	5	8	6
Soil	7	3	9

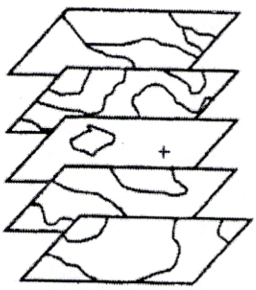

Fig. 2 An illustration of index overlay with Multiclass Maps.

Topological Overlay

As already stated, new map features can be created by overlaying feature from two or more map layers. Features for each layer are intersected to create new output features. Attributes of each input feature are combined from the two layers to describe each new output feature (Fig. 3).

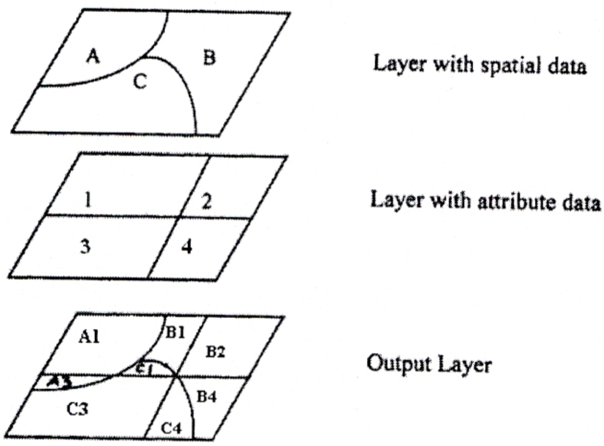

Fig. 3 Conceptual view of Map Overlay.

In topological overlay, polygon features of one layer can be overlaid on polygon, point, or line feature of another layer, and different output features can be obtained depending upon the objective of the overlay.

Polygon Overlay This process merges overlapping polygons from two layers to create new polygons in an output layer. In this case, polygon attributes are also merged. This makes polygon overlay useful for modelling purposes. For example, a polygon overlay of zoning boundaries on soil boundaries might be used to show all areas within a city's commercial zones that have unstable soils.

Point-in-Polygon Point features of one layer can be overlaid on polygon features of another layer to identify the polygons within which each point falls. For example, if well sites are represented as points in a layer, and land holdings are represented as polygons in another layer, a Point-in-Polygon Overlay could be used to determine the well sites contained within each land holding.

Line-in-Polygon Polygon features of one layer can be overlaid on arcs of another layer to identify which polygon, if any, contains each arc or part of arc. Part of arc may also fall directly on a polygon boundary instead of within a polygon. When this occurs, the attributes of one of the polygons are assigned to the arc, which are identified by their topology. For example, roads stored as arcs in one layer can be merged with country polygons from another layer using a Line-in Polygon Overlay. The result can be used to determine the number and type of roads that fall within the Country or State.

Buffer Generation

It is one of the important spatial operations that help in determining the spatial proximity or nearness of various geographic features. For example, a notice to serve to the owners of a locality that falls within a particular distance (say 500 m) along a specific road. In this case, a spatial buffer zone can be created to identify the area and features that fall within the buffer zone. Buffer zones can be generated around any feature – point, line or polygon. Figure 4 shows the buffer zones generated for different types of features.

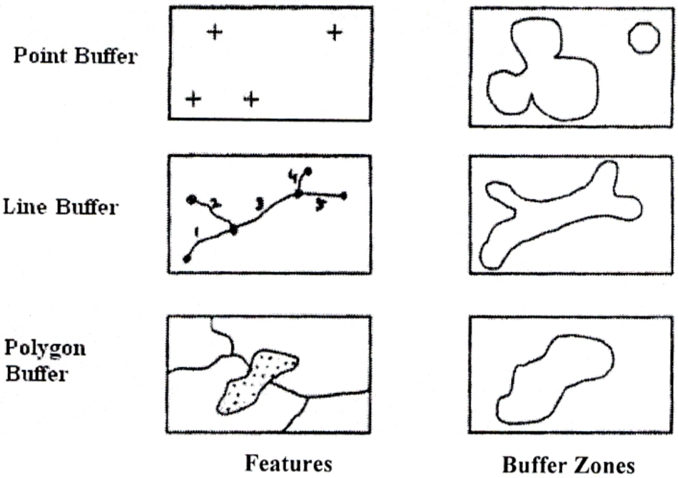

Fig. 4 Illustration of buffer zones generated for different types of features

In addition, Network Analysis may be performed to interpret the collected data and information, and determine the relationship between spatial data and their associated features.

CONCLUSIONS

Geographic Information System is essentially an integration of geographic data for resource planning, management and decision-making purposes through well-defined operations. It is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data for the real world for a particular set of purpose, and has potential for wide application in all disciplines of water resources.

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INDIAN NATIONAL COMMITTEE ON HYDROLOGY (INCOH)

(IHP National Committee of India for UNESCO)

Constituted by the Ministry of Water Resources in 1982

INCOH Publications

Publication of JalVigyan Sameeksha Journal

To disseminate information and promote hydrological research in the country, INCOH brings out the bi-annual Journal '*Jalvigyan Sameeksha*' (Hydrology Review Journal). The papers published in the Journal are by invitation only. The Journal is widely circulated to all organisations and agencies dealing with water sector.

Publication of State of Art Reports

In pursuance of its objectives to prepare and periodically update research trends in different branches of hydrology, state of art reports, authored by experts identified by INCOH from various institutes and organisations in India, are published regularly. These reports are circulated free of cost to state and central government agencies including academic and research organisations.

IHP-VI activities

India is actively participating in the IHP-VI activities and has chalked out a detailed program in accordance with IHP-VI themes towards preparation of reports, taking up research studies, organisation of seminars/symposia at national and regional level, promotion of hydrological education in the country, establishing nodal point for implementation of G-WADI program of IHP, UNESCO, for arid and semi-arid regions of South and Central Asia, and HELP basin program for India. It is envisaged to participate in all the relevant and feasible programs identified under the various focal areas of IHP-VI as given below.

India's participation in IHP-VI programs

Focal Area	Integrated assessment of water resources in the context of global land based activities and climate change
Focal Area	Extreme events in land and water resources
Focal Area	Dry lands
Focal Area	Public awareness raising on water interactions
Focal Area	Continuing education and training for selected target groups

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