Basics of GIS

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INTRODUCTION

GIS is a computer based technology for handling geographical data in digital form. It is designed to capture, store, manipulate and perform analyses of spatially distributed data. It contains both geometry data (coordinates and topographical information) and attribute data (i.e., information describing the properties of geometrical objects). In GIS we can make the presentation of results in both graphic and report form, with a particular emphasis upon preserving and utilizing inherent characteristics of spatial data.

MAIN FUNCTIONS OF GIS

- All GIS operations can, in principle, be done manually, but many tasks are so time consuming that they can be manually performed only for very small research areas. By using computers and their graphics facilities and a GIS software, the laborious tasks can be performed with ease. The early concepts of map handling by a computer had a serious drawback in that they could not handle the tabular or attribute data in conjunction with spatial features. This led to the development of additional methods and techniques where the spatial and attribute data both could be handled and integrated so that the outputs are more meaningful for planners and decision-makers. The upcoming of this technology has enhanced our capability not only of map handling but also of map manipulation and analysis. Therefore, using a GIS:
- Users can interrogate geographical features displayed on a computer map and retrieve associated attribute information for display or further analysis.
- Maps can be constructed by querying or analyzing attribute data.
- New sets of information can be generated by performing spatial operations (such as polygon overlay) on the integrated database.
- Different items of attribute data can be associated with one another through a shared location code. Before any spatial analysis or modeling operations can be carried out in a GIS, it is necessary to input the requisite data. Data input is the procedure of encoding data into computer-readable form and writing the data to the GIS database. The data to be entered in a GIS are of two types - spatial data and associated non-spatial attribute data. The spatial data represent the geographic location of features. Points, lines and areas are used to represent geographic features like a street, a lake or a forest land. These data will normally be obtained from one or more of the following sources:
  - Existing maps
  - Aerial photographs
  - Satellite imageries
  - Existing digital data
  - Other GIS data bases

Remote sensing is an important source of data for GIS analysis and conversely, GIS data can serve as an important aid in image analysis. The need of integration of GIS and remote sensing is thus inevitable, and is rapidly emerging because of the complementry role played by these technologies.

BASIC TYPES OF SPATIAL DATA

There are four elementary types of geometric entities designed to encode spatial data: Points, lines, polygons and continuous surface (area).

Point Data: Points are the simplest type of spatial data. Points can be of two kinds: observations relating to discretely distributed phenomena such as oil and water wells and observations relating to continuous distributions such as weather station reporting precipitation measurements of soil temperature.

Line data: Line entities are linear features made of many points or straight line segments made defined of two or more pairs of coordinates. The line entities can be static (structural type) or dynamic (flow). An arc, chain, or a string is a set of x-y coordinate pairs describing a continuous complex line.

Polygon or area data: Polygons constitute the most common data type used in GIS. They are bounded regions determined by a closed continuous sequence of many segments. The boundaries may be defined by natural phenomena such a land forms or by man made features such as forest stand or land use units.

Continuous surface: Examples of continuous surfaces are elevation (as part of topographic data), rainfall, temperature, etc. Most of the GIS systems handle these, essentially three dimensional data as topographic data, usually as Digital Elevation Model (DEM).

SPATIAL DATA STRUCTURE

Traditionally spatial data has been stored and presented in the form of a map. Two basic types of spatial data models have evolved for storing geographic data digitally. These are referred to as:

- Vector
- Raster

Vector Data Formats

All spatial data models are approaches for storing the spatial location of geographic features in a database. Vector storage implies the use of vectors (directional lines) to represent a geographic feature. Vector data is characterized by the use of sequential points or vertices to define a linear segment. Each vertex consists of an X coordinate and a Ycoordinate. Vector lines are often referred to as arcs and consist of a string of vertices terminated by a node. A node is defined as a vertex that starts or ends an arc segment. Point features are defined by one coordinate pair, a vertex. Polygonal features are defined by a set of closed coordinate pairs. In vector representation, the storage of the vertices for each feature is important, as well as the connectivity between features, e.g. the sharing of common vertices where features connect. The most popular method of retaining spatial relationships among features is to explicitly record adjacency information in what is known as the topologic data model. Topology is a mathematical concept that has its basis in the principles of feature adjacency and connectivity.

Advantages: Much greater precision in the definition of objects is possible by defining the geometric extent of the regions in which they occur. This means that one can draw far better maps with vector data than with raster data. Much less space is required to store all the information, since empty space on the map can be ignored.

Disadvantages: Topology between the geometric objects must be explicitly defined, though it can be done quite efficiently. The file structures required are more complex than the raster data files, and layer overlay operations can be very complex to perform. Spatial variability can be represented, using a *Triangulated Irregular Network*, but it is still not as effective as the use of regularly gridded data, and mathematical operations, such as derivatives, on layers or between two or more layers are all but impossible to perform.

Uses: Very widely used in such fields as computer cartography, analysis of networks, municipal databases that contain descriptions of building footprints, streets, etc. Common GIS packages that are vector-oriented include ARC/INFO and MapInfo.

Raster Data Formats

Raster data models incorporate the use of a grid-cell data structure where the geographic area is divided into cells identified by row and column. This data structure is commonly called raster. While the term raster implies a regularly spaced grid other tessellated data structures do exist in grid based GIS systems. In particular, the quadtree data structure has found some acceptance as an alternative raster data model.The size of cells in a tessellated data structure is selected on the basis of the data accuracy and the resolution needed by the user. There is no explicit coding of geographic coordinates required since that is implicit in the layout of the cells. A raster data structure is in fact a matrix where any coordinate can be quickly calculated if the origin point is known, and the size of the grid cells is known. Since grid-cells can be handled as two-dimensional arrays in computer encoding many analytical operations are easy to program. This makes tessellated data structures a popular choice for many GIS software.

Topology is not a relevant concept with tessellated structures since adjacency and connectivity are implicit in the location of a particular cell in the data matrix. Several tessellated data structures exist, however only two are commonly used in GIS's. The most popular cell structure is the regularly spaced matrix or raster structure. This data structure involves a division of spatial data into regularly spaced cells. Each cell is of the same shape and size. Squares are most commonly utilized. Since regularly spaced shapes rarely distinguish geographic data, cells must be classified as to the most common attribute for the cell. The problem of determining the proper resolution for a particular data layer can be a concern. If one selects too coarse a cell size then data may be overly generalized. If one selects too fine a cell size then too many cells may be created resulting in a large data volumes, slower processing times, and a more cumbersome data set. As well, one can imply an accuracy greater than that of the original data capture process and this may result in some erroneous results during analysis. As well, since most data is captured in a vector format, e.g. digitizing, data must be converted to the raster data structure. This is called vector-raster conversion. The use of raster data structures allows that for sophisticated mathematical modelling processes while vector based systems are often constrained by the capabilities and language of a relational DBMS.

It is also important to understand that the selection of a particular data structure can provide advantages during the analysis stage. For example, the vector data model does not handle continuous data, e.g. elevation, very well while the raster data model is more ideally suited for this type of analysis. Accordingly, the raster structure does not handle linear data analysis, e.g. shortest path, very well while vector systems do. It is important for the user to understand that there are certain advantages and disadvantages to each data model.The selection of a particular data model, vector or raster, is dependent on the source and type of data, as well as the intended use of the data. Certain analytical procedures require raster data while others are better suited to vector data.

Advantages: Layer overlays are really simple, since all layers are defined with the same grid over the region. Topology is implicitly defined, since the location of each cell relative to all the others can be easily found.

Disadvantages: If you want to increase the *resolution* (that is, decrease the cell size) by a factor of two, the data set size will quadruple! In order to reduce this problem, various compression techniques, such as *quadtrees* and *run-length encoding*, are employed. Resolution is also problematic because the discretization process has an effect analogous to rounding of numbers, but in a spatial sense -- that is, what you see in the raster image is usually larger or smaller than the real-world equivalent. Objects smaller than one cell may not appear at all.

Uses: All satellite and aerial photograph data come in raster form. Each pixel represents the amount of light received by the sensor at a particular wavelength at the location. All satellites collect data from more than one wavelength, so a particular satellite pass will create an instant multilayer raster map of an area, as well as business for the magnetic tape industry. Common GIS packages using the raster model are GRASS and IDRISI. Raster data are best used for representing variables that vary continuously in space, such as elevations.

The connection between raster and vector data is critical in hydrology, perhaps more so than in other applications of GIS. Rivers are best represented as lines, and gaging stations and other control points on rivers like water right locations are best represented as points. However, the watershed areas draining to those points are best derived from digital elevation models, which are raster representations of land surface terrain elevation considered as a continuous surface. Moreover, precipitation, evaporation and other climatic variables are defined continuously through space and measured at particular points where there are climate stations. Being able to move back and forth smoothly between raster and vector representations of data is an important feature of spatial hydrology. A well constructed geospatial database for hydrology incorporates both vector and raster data in a tightly connected **raster-vector data model**. The features of the real world are depicted in vector data layers as points, lines and areas, and in the raster database as cells or zones of cells. While more spatially approximated than the vector database, the raster representation has the great advantage that various different kinds of hydrologic features can be represented in a single grid rather than having to be separated into different data layers as is the case with the vector representation.

DATA ENTRY

There are five types of data entry systems commonly used in a GIS: keyboard entry, coordinate geometry, manual digitizing, scanning, and the input of existing digital files. Keyboard entry, as its name implies, involves manually entering the data at a computer terminal. Attribute data are commonly input by keyboard. Manual digitizing is the most widely used method for entering spatial data from maps. The map is mounted on a digitizing table and a hand held device, termed a puck or cursor, is used to trace each map feature. The position of the cursor is accurately measured by the device to generate the coordinate data in digital form.

Scanning, also termed scan digitizing, is a more automated method for entering map data. A raster digital image of the map is produced after which additional computer processing is done to improve the quality of the image and to convert the raster data to vector format. Operator-assisted editing and checking is then done to generate the final GIS-compatible data file.

KEYBOARD ENTRY AND COORDINATE GEOMETRY PROCEDURES

Most attribute data are entered by keyboard. In many cases these data can be obtained in digital form from an existing data base into which they were keyboard entered. Field observations can be recorded in digital form by keyboard entry of the data in the field using small hand-held computers. The data files are then periodically downloaded to another computer or copied onto diskette for storage.

Keyboard entry can be used during manual digitizing to enter the attribute information. However, this is usually more efficiently handled as a separate operation in which the attributes are entered with a code to indicate the spatial element (such as the line or polygon feature) that they describe. The attribute file is subsequently linked to the spatial data.

Manual Digitizing

In manual digitizing the map is affixed to a digitizing table and a pointing device is used to trace the map features. Digitizing tables can be as large as 1 m x 1.5m or more. A smaller device, termed a digiizing tablet (usually equipped with a mouse instead of the more precise cursor) is commonly used as a device to operate the GIS. The digitizing table electronically encodes the position of the pointing device with a precision of fractions of a millimetre. The most common table digitizer uses a fine grid of wires embedded in the table. The cursor normally has a crosshair for precise positioning and 16 or more control buttons that are used to operate the data entry software and to enter attribute data. As the map elements are traced, the coordinate data generated from the digitizing table are either processed immediately by the GIS or are stored for later processing. The digitizing operation itself requires little computing power and so can be done off-line, i.e., not using the full GIS.

The efficiency of digitizing depends on the quality of the digitizing software and the skill of the operator. The process of tracing lines is time-consuming and error prone. The software can provide aids that substantially reduce the effort of detecting and correcting errors. Attribute data may be entered during the digitizing process, but usually only an identification number is coded. The attribute information referenced to the same identification numbers are then entered separately. If the attribute data are already in GIS-compatible files, they may be entered directly. Manual digitizing is a tedious job. Operator fatigue can seriously degrade data quality. Work scheduling should limit the hours per day that an individual spends digitizing and suitable quality assurance procedures should be used to ensure that the digitized data and associated attribute data satisfy the required accuracy standards. A commonly used quality check is to produce a verification plot of the digitized data that is visually compared with the map from which the data were originally digitized.

Scanning

Scanning (or scan digitizing) provides a faster means of data entry than manual digitizing. In scanning, a digital image of the map is produced by moving an electronic detector across the map surface. Two scanner designs are commonly used. In a flat-bed scanner the map is placed on a flat scanning stage over which the detector is moved in both X and y directions. In a drum-scanner, the map is mounted on a cylindrical drum. The detector is moved horizontally across the drum as it rotates. The sensor motion across the drum provides the movement in the X direction. The drum rotation provides the movement in the y direction.

The output from the scanner is a digital image. The fineness of detail captured by the scanner depends on the size of the map area viewed by the detector, termed the spot size. Spot sizes on the order of 20 microns (.02 mm) are commonly used. Scanners can record colour information by scanning the same document three times using red, green and blue filters. Usually only a black-and-white image is produced. The raster image is computer processed to improve the image quality and is then edited and checked by an operator. If the data are required in vector format, additional raster- to-vector conversion processing is done. During the editing procedure or after conversion to vector format, each spatial element is tagged and assigned an identification number. The attribute data are linked to the spatial data by means of these identification numbers.

Scanning Versus Manual Digitizing

Scanning has been adopted by many organizations as the principal means of spatial data entry, yet the subject is controversial. One reason for the controversy is that rigorous trials are few and of necessity are specific to the organization and application. Another organization will face a different situation that could completely change the cost-benefit trade-offs.

Maps normally must be re-drafted before they can be scanned. Re-drafting is often considered to be a major disadvantage of the scanning option. However, though re-drafting may be an additional step in the digitizing process it does not necessarily add to the overall cost. In fact, re-drafting can *reduce* the total cost of *both* scanning and manual digitizing. While a scanning system is for the most part automated, and so requires less highly trained personnel for some tasks, more complex equipment must be maintained, more sophisticated software must be written or purchased, and there are more steps in the process. Scanners are more expensive than digitizing tables.

Scanning works best with maps that are very clean, simple, and do not contain extraneous information, such as text or graphic symbols. It is most cost-effective for maps with large numbers of spatial elements (such as 1,000 or more polygons) and maps with large numbers of irregularly shaped features (such as sinuous lines and irregular-shaped polygons). The volume of production is also a factor; the higher equipment cost is more easily justified if the sustained production of large numbers of maps is needed.

Manual digitizing tends to be more cost- effective when there are relatively few maps that are not in a form that can be scanned. Maps that contain a lot of extraneous information require interpretation or adjustment during the encoding process or have a small number of features to be encoded are generally not worth scanning

REGISTRATION

Image data commonly need to be rectified to a standard projection and datum. Registration or rectification is a procedure that distorts the grid of image pixels onto a known projection and datum. The goal in rectification is to create a faithful representation of the scene in terms of position and radiance. Rectification is performed when the data are unprojected, need to be re projected, or when geometric corrections are necessary. If the analysis does not require the data to be compared or overlain onto other data, corrections and projections may not be necessary.

There are two commonly used rectification methods for projecting data. Image data can be rectified by registering the data to another image that has been projected or by assigning coordinates to the unprojected image from a paper or digital map

Image to Map Rectification. Unprojected images can be warped into projections by creating a mathematical relationship between select features on an image and the same feature on a map. The mathematical relationship is then applied to all remaining pixels, which warps the image into a projection.

Ground Control Points (GCPs). The procedure requires the use of prominent features that exist on both the map and the image. These features are commonly referred to as ground control points or GCPs. GCPs are well-defined features such as sharp bends in a river or intersections in roads or airports. The minimum number of GCPs necessary to calculate the transformation depends upon the order of the transformation. The order of transformation can be set within the software as 1st, 2nd, or 3rd order polynomial transformation. The equation identifies the number of GCPs required to calculate the transformation. If the minimum number is not met, an error message should inform the user to select additional points. Using more that the minimum number of GCPs is recommended.

$(t + 1)(t + 2)$ = minimum number of GCPs 5-12
Where t = order of transformation (1st, 2nd, or 3rd).

To begin the procedure, locate and record the co-ordinate position of 10 to 12 features found on the map and in the image. Bringing a digital map into the, image processing software will simplify co-ordinate determination with the use of a co-ordinate value tool. When using a paper map, measure feature positions as accurately as possible, and note the map co-ordinate system used. The type of co-ordinate system used must be entered into the software; this will be the projection that will be applied to the image. Once projected, the image can be easily projected into a different map projection.

After locating a sufficient number of features (and GCPs) on the map, find the same feature on the image and assign the co-ordinate value to that pixel. Zooming in to choose the precise location (pixel) will lower the error. When selecting GCPs, it is best to choose points from across the image, balancing the distribution as much as possible; this will increase the positional accuracy. Once the GCP pixels have been selected and given a co-ordinate value, the software will interpolate and transform the remaining pixels into position.

Positional Error. Most software program generate a least squares or "Root Mean Square" (RMS) estimation of the positional accuracy of the mathematical transformation. The RMS estimates the magnitude transformation. The estimate will not be calculated until three or four GCPs have been entered. Initial estimates will be high, and these should decrease as more GCPs are added to the image. A root mean square below 1.0 is a reasonable level of accuracy. If the RMS is higher that 1.0, simply reposition GCPs with high individual errors or delete them and reselect new GCPs. With an error less than 1.0 the image is ready to be warped to the projection and saved.

Re-sampling Methods The location of output pixels derived from the ground control points (GCPs) are used to establish the geometry of the output image and its relationship to the input image. Difference between actual GCP location and their position in the image are used to determine the geometric transformation required to restore the image. This transformation can be done by different resampling methods where original pixels are resampled to match the geometric coordinates. Each resembling method employs a different strategy to estimate values at output grid for given known values for the input grid.

Nearest Neighbor The simplest strategy is simply to assign each corrected pixel, the value from the nearest uncorrected pixel. This approch has the advantages of simplicity and the ability to preserve original values in the altered scene, but it may create noticeable errors, which may be severe in linear features where the realignment of pixels is obvious.

Bilinear Interpolation The strategy for the calculation of each output pixel value is based on a weighted average of the four nearest input pixels. The output image gives a natural look because each output value is based on several input values. Some changes occur when bilinear interpolation creates new pixel value.

GIS DATA TRANSFER STANDARD

A data transfer standard is necessary to facilitate the transfer of the geographic data between computer systems. For example ASCII data are acceptable in Windows to the Unix platforms. Few commercial data formats that are widely accepted as data transfer standard are DXF, e00, ERDAS GIS etc.

DXF: This is a data format that writes the vector data in ASCII. This was developed for transferring the engineering drawings (Cassettari 1993).

Arc exchange format (e00): This format is data transfer format used in Arc/ Info. The geographic data are written in ASCII.

ERDAS GIS, LAN and IMG: These are widely used data format for raster data. The data are in binary.

CAPABILITIES OF GIS

The power of GIS lies in its ability to analyse spatial and attribute data together. The large range of analysis procedures can be divided into four categories:

1) Retrieval, reclassification and measurement,
2) Overlay,
3) Distance and connectivity,
4) Neighbourhood
5) Interpolation

Retrieval, Reclassification and Measurement Operation:

In these functions retrieval of both spatial and attribute data are made and only attribute data are modified. New spatial elements are not created.

Retrieval operations:

These involve the selective search and manipulation and output of data. Retrieval operation includes the retrieval of data using:

- Geometric Classifications
- Symbolic Specifications
- A name of code of an attribute
- Conditional and logical statement

- Retrieval operations on the spatial and attribute data involve the selective search and manipulation, and output of data with out the need to modify the geographic location of features or to create new special entities. Retrieval operations include:
- Retrieval of data using geometric classification. Specifying the spatial domain of a point, line or area, retrieve all spatial entities and nonspatial attributes contained in the entire or in position of that spatial domain.
- Retrieval of data using symbolic specifications.

- Retrieve data using a name of code of an attribute. Retrieve using a name or code of an attribute. Example, retrieve effective depth and dominant texture of a given soil.
- Retrieval of data using conditional and logical statements. Retrieve data that satisfy alphanumeric conditions using logical expressions. Example retrieve all soil series with a pH range of 6.0 to 7.5 and silty clay texture.

Reclassification Procedures:

This procedure involves the operations that reassign thematic values to the categories of an existing map as a function of the initial value, the position, size or shape of the spatial configuration associated with each category, for instance a soil map reclassified into a permeability map. In a raster based GIS, numerical values are often used to indicate classes. A cell might be assigned value to indicate a class. For example a cell might be assigned the value 1 to indicate an agriculture land, 2 for forest land, and so on. Classification is done using single data layer as well as with multiple data layers as part of an overlay operation.

Measurement Functions:

Every GIS provides some measurement functions. The measurement of spatial data involves the calculation of distances, lengths of lines, area and perimeter of polygons. The measurements involving points include distances from a point to a other point, lines or a polygon enumeration of total number as well as the enumeration of points falling within polygon.

Overlay Operations:

Overlaying of maps results in the creation of a map where the values assigned to every location on that map are computed as a function of independent values associated with that location on two or more existing maps. Overlaying operation creates a new data set containing new polygons formed from the intersection of the boundary of the two or more sets of separate polygon layers. Arithmetical and logical overlay operations are common in all GIS software packages.

Arithmetical overlay includes operations such as addition, substraction, division and multiplication of each value in a data layer by the value in the corresponding location in the second data layer. Logical overlay involves the selection of an area where a set of conditions are satisfied.

Neighbourhood operations:

Neighbourhood operations involve the creation of new data based on the consideration of 'roving window' of neighbourhood points about selected target locations. They evaluate characteristics of an area surrounding a specified target location. In all neighbourhood operations it is necessary to indicate one or more target locations, the neighbourhood considered around each target and the type of function to be executed on the attributes within the neighbourhood. The typical neighbourhood operations in most GIS are search function, topographic function and interpolation.

Interpolation Point

Nearest neighbor: This technique gives horizontal surfaces around each point. This technique is generally used for interpolation of the rainfall data. This provides weight to be used for the rain gauge stations, for finding average rainfall over a watershed.

Weighted average: A weighted average is taken of point elevation falling within a specified radius from the interpolation point. Weight is an inverse function of a distance between the point of unknown value (interpolation point) and that of known value (data points).

Weighted surface: Weighted surface fits a surface of n-degree using the elevations at points within a specified radius from the point of interpolation.

Trend surface: Trend surface fits an overall surface with the input data. It provides the global direction in which the variable changes.

Kriging/ geostatistical method: Kriging is a mathematical technique developed by D.G. Krige for application in mining industry in South Africa. The experimental semivariogram is calculated from the data. A standard semivariogram equation is fitted to the experimental data using regression technique. This fitted curve is used in the interpolation. For groundwater data the spherical theoretical semivariogram model is best suited.

DIGITAL ELEVATION MODEL (DEM) OR DIGITAL TERRAIN MODEL (DTM)

DEM or DTM deals with the topographic elevation of the ground surface. Conventionally, the ground elevations are available in the topographic maps as contours, spot heights etc. In GIS, the information is available similar to this conventional form as vectors or points. Apart from this the data are also represented as raster and TIN model. Since, water flows under gravity from higher elevation to lower elevations, the DEM are very important input in hydrological studies. Using DEM, the surface is routed from upstream points to the catchment outlet. Other physical variables e.g. slope, aspect, drainage network, subwatersheds are also derived from DEM automatically.

The raster and TIN forms are useful input to hydrological models. Thus, the conventional forms of DEM such as vector, point are required to be converted to these forms. This is done through the interpolation techniques in GIS.

Triangulated Irregular Network (TIN): In this a network of triangles is created by joining point with techniques known as Thiessen polygons. At each apex of the triangles the height is known. The ground is represented as a plane surface with in a triangle. Input data to the model are spot height and contour data of the topographic maps. The triangles are so drawn such that sides of the triangles are the lines of slope or aspect change and the apex are the points where spot height is known.

TERRAIN VISUALIZATION

Many techniques are used to represent the terrain on VDU. The techniques use simple representations such as contours to sophisticated representations in which observer feels as if he is part of the scene such as virtual reality.

Contouring and hypsometric representation: The techniques have been in use in topographic maps, physical maps etc. A contour is a line of equal elevation. In hypsometric representation, the areas between contours are shaded with different colors. In GIS contour data are represented by vector model and the hypsometric data are represented by vector or raster models.

Hillshading: The illumination on objects is calculated. A light source is assumed over an object. The tone or color of the object is calculated using DEM. This type of shading has been in use with conventional paper maps and is also available in many GIS.

Perspective view: A perspective view involves calculation of hidden points. The technique involves specifying location of the observer, look direction, vertical exaggeration, angle of view or panorama etc. In The flat areas the height is exaggerated for a better perspective view.

A perspective view is created using wire net or profiling techniques. The adjacent profiles of the terrain are joined together to produce the perspective view. Over the perspective view, optionally, the GIS layers can be draped.

Fly through: In this technique, many perspective views are generated with several points as observation points. These views are animated to create an impression of the flying over the terrain. The direction and the speed of the flight, height etc. can be defined interactively.

True three- dimensional view: In a true three- dimensional view, by changing the height or the distance between viewer and the objects, the details visible are also changed.

Perspective cartography and texture mapping: In the perspective cartography and texture mapping, an image or symbols for important buildings, bridges, built up areas are overlaid on the perspective view.

LINKING SPATIAL AND NONSPATIAL DATA

GIS use raster and vector representations to model location, but how they must also record information about the real-world phenomena positioned at each location and the attributes of these phenomena. That is, the GIS must provide a linkage between spatial and non-spatial data. These linkages make the GIS "intelligent" insofar as the user can store and examine information about where things are and what they are like.

The relationship can be diagrammed as a linkage between:

- Location <<< >>> What Is There
- Spatial Data <<< >>> Non-Spatial Data
- Geographic Features <<< >>> Attributes

At the most abstract level, this is a relationship between:

A Locational Symbol <<< >>> Its Meaning

In a raster system, this symbol is a grid cell location in a matrix. In a vector system, the locational symbol may be a one-dimensional point; a two-dimensional line, curve, boundary, or vector; or a three- dimensional area, region, or polygon. The linkage between symbol and meaning is established by giving every geographic feature at least one unique means of identification, a name or number usually just called its ID. Non-spatial attributes of the feature are then stored, usually in one or more separate files, under this ID number. In other words, locational information is linked to specific information in a database. The relation in the GIS is a method of relating the same spatial entity to different non-spatial entities based on a link key.