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Reinventing Local Government With GIS

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MAPS and data associated with locations have been used throughout history by city and county governments for delivering public services, managing public resources, and setting public policy.[1] Most of these information resources are still stored in file cabinets and map drawers and used as paper records and products in small cities and rural counties. The property tax and other financial data that have been computerized during the past 20 years only acquire meaning when they are used with a map as a reference, and these data will often have to be manually transferred to maps for further review, display, and analysis. Huxhold[1] opened his recent book on Urban GIS with the following quotation: We have for the first time an economy based on a key resource that is not only renewable, but self-generating. Running out of it is not a problem, but drowning in it is. (Naisbitt, p. 24)[2]

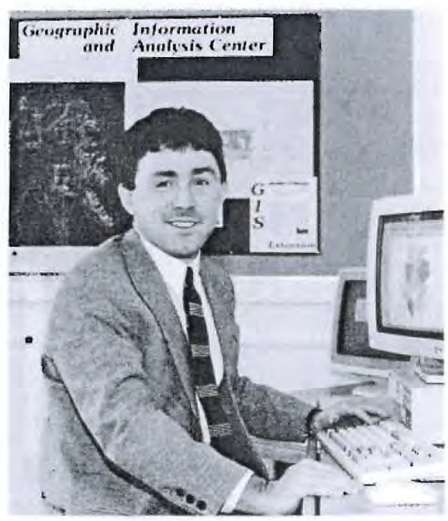
This state of affairs indicates how information can (and should) be viewed as a resource by an organization (similar to people, money, and equipment) and why automation and careful management will be required if it is to improve the effectiveness and efficiency of local government operations. However, the rate of innovation in computer hardware and software is so rapid that local governments must choose between an ever-increasing number and variety of potential automation solutions when starting down this path.

Geographic Information Systems (GIS) represent one option and offer a computerized database management system for the storage, retrieval, analysis, and display of spatial (map) data.[3] These systems can be distinguished from other computer mapping and computer-aided design (CAD) tools because they: 1) use modern coordinate systems to define the positions of features on the earth's surface so that they can be accurately represented in the database, 2) fully integrate map and attribute data, and 3) provide spatial analysis tools unavailable in most other software packages. This article will describe these features and some of the ways in which they can be used to automate local government operations.

Modern Coordinate Systems

The locations of the features stored in the database must be accurately recorded in terms of their real-world positions to perform most spatial operations. These locations can be recorded in global coordinates (latitude, longitude) or planar coordinates (State Plane feet, Universal Transverse Mercator (UTM) meters, etc.) although both types of system imply the existence of a survey control network and the ability to convert measurements (distances and directions) to locations measured in at least one of these coordinate systems.

This requirement is often a problem for small cities and rural counties because they have traditionally used a local coordinate system and they lack a survey control network.[4] A substantial effort may be required to establish a control network



and record the locations of important features in some modern coordinate system before GIS implementation in these instances.

Database Integration

GIS software combines map and attribute data and affords local governments new opportunities for integration in that these data can be processed together as a single product with little manual intervention (Figure 1). Hence, these systems can be used to integrate information from many different sources (engineering, finance, and planning departments) and at many different levels of responsibility (operations, management, and policy levels) in an organization. This integration is possible because **geography** is a common reference used by virtually every activity in local government, whether it be to find a water main valve, set property tax assessments, or begin a new solid waste recycling program.[1]

Most GISs store attribute data in a series of relational database tables. Records can be combined so long as a common item exists in two or more tables. A property tax identification code is often used for this purpose in local government GIS applications (Figure 1). The spatial data are usually stored in some proprietary format, although these data can be linked with the tabular data based on a common item as well. There are two choices: 1) adding an item to the spatial data, or 2) adding one of the items from the spatial data to one of the tables with your attribute data. The first option is illustrated in Figure 1, where an item representing a property tax identification code *(PPTAX_ID)* has been added to the four default items generated by PC ARC/INFO[6] when topology was constructed. The presence of these common items means that the records in two or more tables can be permanently or temporarily joined based on the values of the common item. This capability means that database queries can be implemented via the spatial features or tabular database items. Hence, we can query the attribute data to identify all the land parcels with delinquent property taxes and color a map of land parcels accordingly. Alternatively, we could point to one or more features (land parcels) in the spatial database and obtain key information such as the name, address, and telephone number of the landowner(s).

Spatial Analysis Tools

Most successful GIS applications utilize geographically-referenced data as well as non-spatial data and include operations that support spatial analysis. Two database models are commonly employed: 1) the raster GIS divides the world into a series of pixels or cells, and 2) the vector GIS represents the world as a series of points (nodes), lines (arcs), and areas (polygons). The latter database model will usually be required for GISs that are constructed from land records and applied to city and county government. However, it is the ability of GIS to perform spatial operations (address matching, buffering, overlays, etc.) rather than the choice of database model that distinguishes GIS from the other computer programs (spreadsheets—Lotus 123, Quatro, etc.; statistical packages—Minitab, SAS, SPSS, etc.; drafting packages—Easy-CAD, etc.; and drawing packages—Coreldraw, MacPaint, etc.), which also utilize spatial data.[4] Address matching, buffering, and overlay capabilities are found in many different GIS software packages and they are used here to illustrate how some of the spatial operations could be applied to local government projects.

Address matching is the process of linking data from separate data files by means

of a common attribute, such as a street address or ZIP code.[7] For example, a dBASE file containing street addresses (Bozeman Sign Permit Data) and an arc attribute table created as part of an ARC/INFO street network coverage (Attributes of Downtown), are linked. The street addresses in the dBASE file are compared with the range of addresses in the ARC/INFO file and an interpolation is performed to locate and assign real-world coordinates when a match occurs.

The street network attribute file contains address ranges (L-add.from, L-add.to, R-add.from, R-add.to) and these values are used to define the end points of each line (street) segment and the bounds for the interpolation. These address matching tools are important to spatial analysis because: 1) most of the information resources used by cities and counties are referenced by address (sign permits, tax assessment/parcel ownership, sewer/water hookups, etc.), 2) street networks can be obtained from TIGER (Topologically Integrated Geographic Encoding and Referencing) System[8] files or some other data source relatively quickly (and cheaply), and 3) many of these data only acquire meaning when added to a map for further review and analysis.

Buffering is the process of constructing new areas around the points, lines, or areas in a vector GIS, which enclose the buffered objects. Some GISs require the user to specify the width of the buffer and others give the user the option of using one of the attributes of the object to determine the buffer width. Hence, the type of street (major, secondary, tertiary, etc.) might be used to buffer residential buildings away from a street network (using setbacks of 600 ft for a major street, 200 ft from a secondary street, 100 ft from a tertiary street, etc.). Buffers can help with numerous local government tasks; for example, they can be used to find the names and addresses of all the property owners who own property that is located within a certain distance of one or more land parcels. The owner of these parcels may have applied for a zoning variance and the city may have a legal obligation to notify surrounding landowners of a public meeting and/or comment period in these circumstances. GIS can speed up and/or reduce the likelihood of errors in this application so long as the buffer and subsequent queries are properly formulated and the appropriate databases are regularly updated.

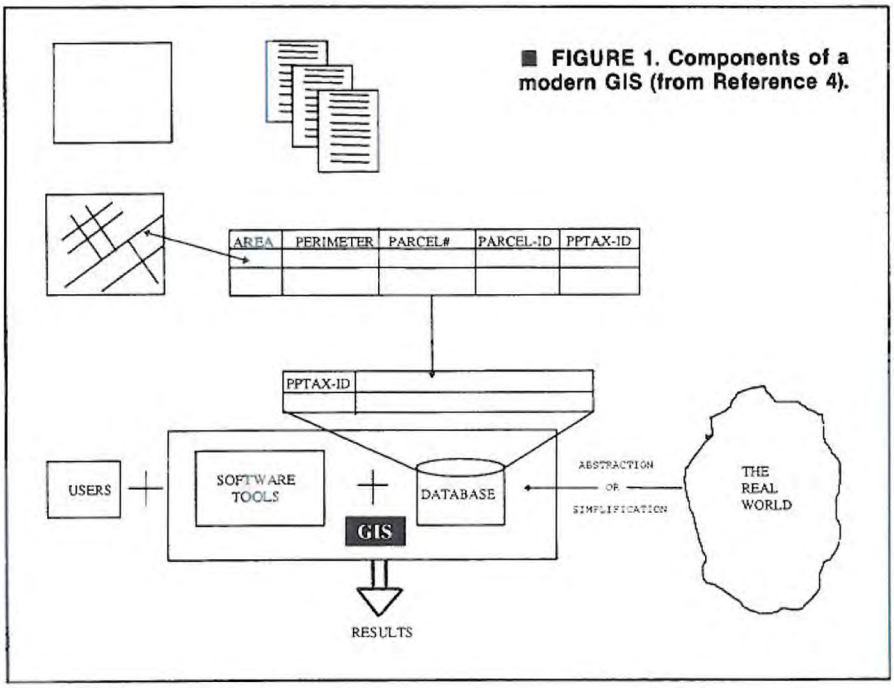
Topological overlay is the general name given to the procedure in which two or more data layers are combined and then planar enforced. The rules of planar enforcement are required in most vector GISs and mean that new intersections are computed and created wherever two lines cross and that lines crossing area objects create at least two new area objects when overlays are performed. These rules ensure that the relationships between the different geographic features and their non-spatial attributes will be updated for the new, combined maps, which are created when one map is overlaid or superimposed over another map.

Point-in-polygon, line-on-polygon, and polygon-on-polygon overlays can be performed in a vector GIS like ARC/INFO. A point-in-polygon overlay procedure is used to: 1) combine the point features in a point coverage (water wells) with a polygon coverage (showing county boundaries), and 2) add the polygon attributes (county names, areas, etc.) to the point attribute table. A line-on-polygon overlay will split the line features (road network) at polygon (county) boundaries to produce a new line coverage. The polygon attributes (county names, areas, etc.) will be appended to the appropriate records in the arc attribute table (one record per road segment). The polygon-on-polygon overlay procedure is used when one area object layer (watershed boundaries) is to be combined with another area object layer (county boundaries). The boundaries are broken at each intersection and the number of output areas (watershed/county combinations) that are produced will usually be greater than the total number of input areas (watersheds and counties) with this procedure.

The following example illustrates how the overlay and buffering tools in PC ARC/INFO can be used with street and stream data layers to choose the location for a new city park. First, buffering is used to identify areas that are easily accessible from major highways and yet not too close to cause noise or safety problems, and a line-on-polygon overlay is performed to identify natural streams that are located within the desired distance of the highways.

This example is useful because it illustrates several additional features of GIS. First and foremost, establishing objectives and criteria for analysis, preparation of data for spatial operations, and then performing spatial operations show how GIS operators must translate the objectives specified by the city or county commissioners into a series of criteria that are used in the GIS analysis. This part of the analysis demonstrates how the elected officials specify what kind of park is needed and the GIS is used to accelerate or improve the chances of finding one or more sites that satisfy their criteria. The GIS staff can only do their job if they find or generate the appropriate data and perform the spatial and tabular database operations that will be required to identify one or more sites.

The implementation of GIS makes it much easier to 1) track the rationale and method that was used to make a particular decision, and 2) vary the criteria and perform the analysis again in those instances in which no "suitable" sites were identified the first time. And finally, a good GIS can also be used to produce multi-colored maps and tables for final reports once the analysis is completed.



■ **FIGURE 1. Components of a modern GIS (from Reference 4).**

Final Remarks

A GIS is a particular type of information system that can be applied to geographical (spatial) data. It is not surprising, therefore, to find that GIS is commonly applied to help with the management of land and other resources, transportation, retailing, and other spatially-distributed entities, and that the connection between the elements in the system is geography (location, proximity, spatial distributions, etc.). The observations by Huxhold and others that geography is im-

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H. Nagel, senior product manager, disinfection products, Fischer & Porter, Lancaster, Pennsylvania. Public Works, March 1995.

"Membrane Stripping: Effects of Pretreatments." Low-pH and low-chlorine waters are good candidates for membrane air-stripping. By Kevin Castro, project engineer, Stearns and Wheeler, Cazenovia, New York; and Amy K. Zander, assistant professor, Department of Civil and Environmental Engineering, Clarkson University. Journal AWWA, March 1995.

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"Work Ethic Alive and Well, Approach Just Different." A study of total quality management was undertaken by Metro Water Services, Nashville, Tennessee in 1991; several positive changes have resulted. By Elmer D. Young, assistant director, Metro Water Services, Nashville, Tennessee. Opflow, February 1995.

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Reinventing Local Government

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portant to 80 percent or more of the information managed and utilized by local governments indicates how and why this technology is suited to local government applications.[1] The number and variety of local government GIS applications can be increased as more and more data are brought into a GIS format and its analytical tools are applied to these data. □□□

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9. Modified after *Introducing ArcView* course materials with permission of Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373.
10. Extracted from *Introduction to PC ARC/INFO* course materials with permission of Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373.