Geographic Information Systems Technology for Business Applications

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Abstract

Geographic information systems (GIS) technology offers the users the ability to query and access information, map spatial data, and perform predictive modeling, for targetting potential markets in a wide variety of industries and businesses. However, investment in the technology is expensive and requires considerable planning, This article presents an overview of the technology in the context of its potential for business applications and serves as a guide to businesses intending to invest in the technology.

Introduction

Geographic Information Systems, or "GIS," is a buzzword that one invariably encounters in the business community, either when attending a seminar or while reading a book or article on the modern marketing research business. In effect, it has become an increasingly important tool in the era of segmented "niche" marketing with significant applications in a wide variety of industries; and to many, it represents a panacea to problem solving and decision making in marketing, resources management and planning.

Unfortunately GIS technology is frequently misunderstood, and its applications often misconstrued. As with most technologies, the effective use of GIS depends on the person using it, rather than the technology itself. Effective use of the technology requires more than mere mastery of the GIS software system, just as mere mastery of a word-processing software does not necessarily make one an accomplished writer. Instead, it requires an understanding of the fundamental concepts of geographic data, map coordinates and registration, data integrity and accuracy, spatial analysis, and database manipulation. However, this frequently has been overlooked by many an enterprising individual fervently eager to embrace the technology. This article is intended to provide the reader with an understanding of the technology, demonstrate its potential as a valuable tool for business applications, and serve as a guide to investment in the technology for business applications.

Comments and questions concerning this article should be sent directly to the authors via e-mail.

Geographic Information Systems

In the late 1950s, the concept of a geographic information system (GIS) arose from the idea of "light-table gymnastics," whereby individual map layers were manually registered and overlaid onto one another for analytical applications. This, therefore, has provided an entire

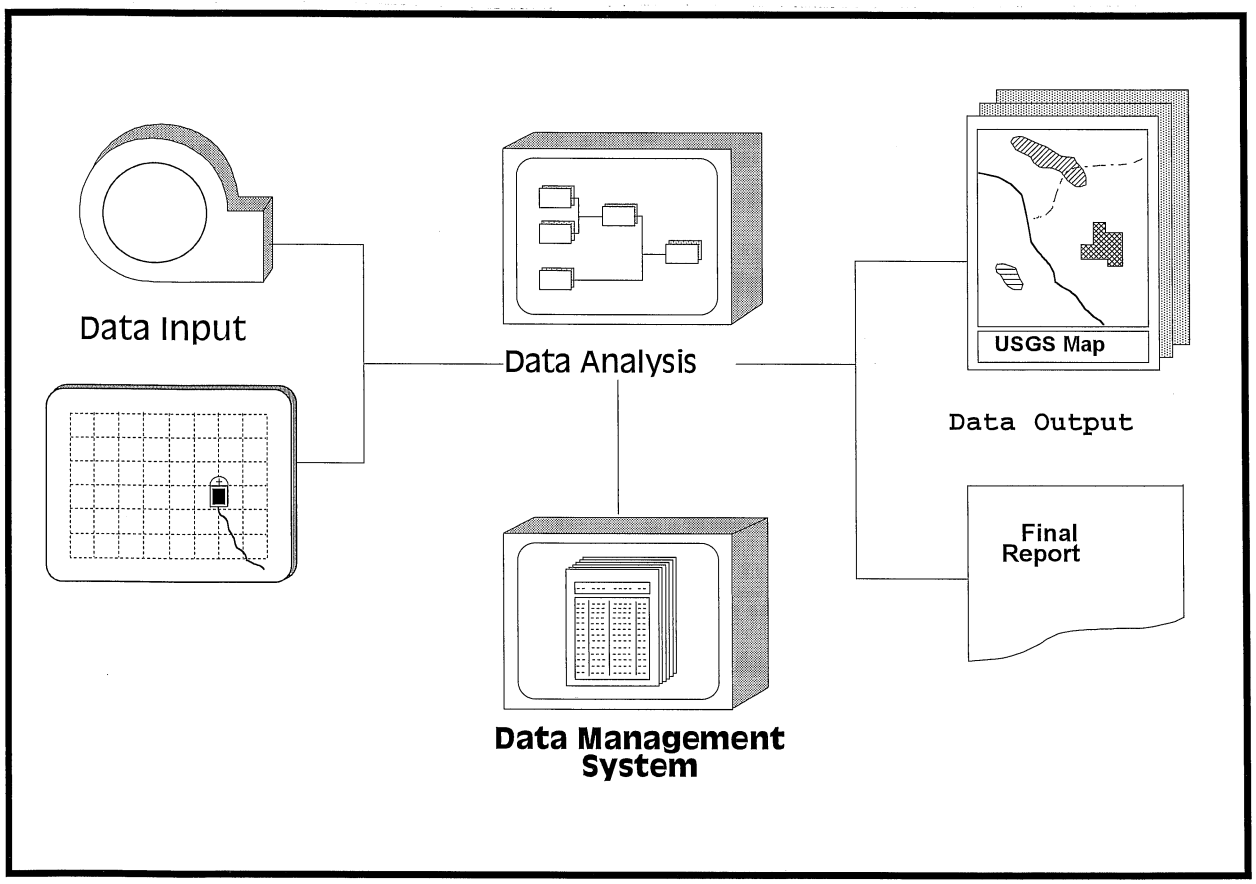
new facet to the application of maps — from a mere descriptive to an analytical medium (Berry, 1987; Parker, 1987).

Since then, the GIS technology has progressed in step with the advent and development of computer technology. In its present form, GIS technology represents a software/hardware system designed to capture, manage, manipulate, and analyze geographic data. A typical GIS software, therefore, will provide the mechanisms to capture, encode, edit, analyze, compose, and display spatial data organized as a GIS database; these functions are categorized as the four major components of a GIS: data input, data analysis, data management, and data output (Figure 1) (Aronoff, 1989; Star and Estes, 1990).

The most crucial component of a GIS is the database, which contains map layers representing geographic features organized in a digital format (Marble and Peuquet, 1983). These map layers, which are referenced to a standard coordinate system such as the Universal Transverse Mercator (UTM) or State Plane Coordinate systems in use today, may be conceptualized as a stack of floating maps tied to a common map base (Figure 2) (Avery and Berlin, 1992). Each map layer can be independently accessed, and when combined, information and related attributes from individual layers can be correctly referenced to one another from a spatial standpoint.

In addition to the map layers, a GIS database also includes data file(s) containing attribute information associated with each map feature. For instance, a map layer of the road network of an area may include such information as road name, road type, physical distance, class type, and address range. Through a relational database management system the attribute information for each map feature in the database can

Figure 1
Components of a GIS include Data Input, Data Analysis, Data Management, and Data Output



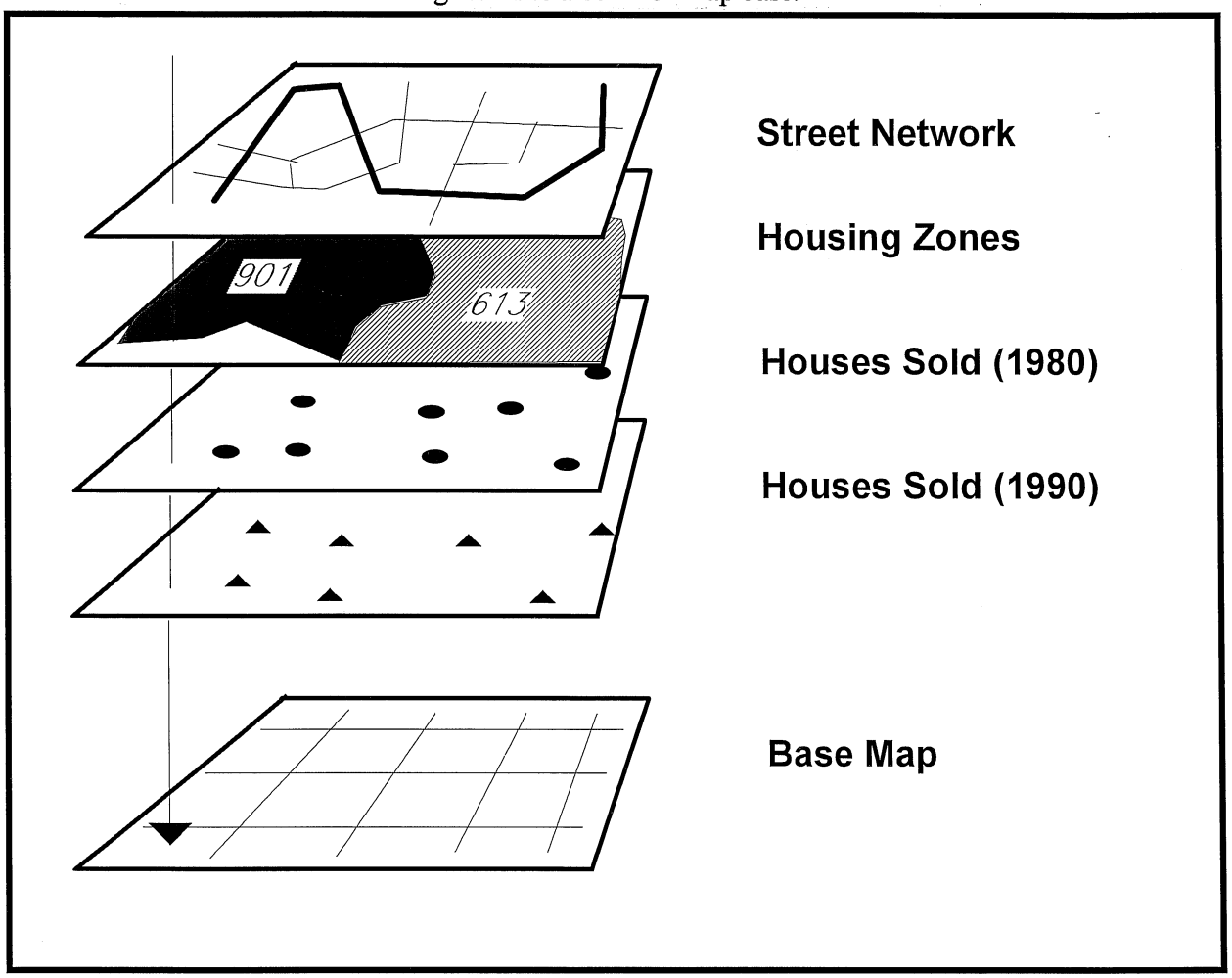
be queried or accessed for manipulation.

GIS Spatial Analysis and Business-Related Applications

The analysis component, the most critical function of a GIS, involves the manipulation of map layers, individually or in combination, to identify locations that satisfy a set of given criteria. The operations in this function include: a) map reclassification; b) map overlay; c) neighborhood characterization; and d) connectivity (or network) analysis (Berry, 1987). A typical GIS software, therefore, will provide a specific number of commands that can be selectively combined to perform these tasks, whereby various analysis models may be implemented by the user.

In the 1980s, niche marketing, whereby consumers were targeted based on demographic and socio-economic characteristics, was introduced to the business community. The ability of GIS to "layer" spatial information within a neighborhood or other predefined geographic region made it the ideal tool for such application. Using the technology, an entrepreneur can quickly identify potential market areas, based on spatial coincidence among various geodemographic data -- age, sex, income, and racial background, etc. Neighborhoods could be "clustered" into categories and defined by demographic data and lifestyle surveys. Additionally, through the relational database management system, the user can rapidly access attribute information about mapped features, and more impor-

Figure 2
A GIS database may be conceptualized as a stack of floating map layers
rgistered to a common map base.



tantly, query the database and selectively identify features or regions that meet a set of given criteria.

Environmental scientists, planners, and resource managers have long utilized GIS as a research and planning tool (Goodchild, 1987; Burrough, 1989; Antennucci, *et al.*, 1992). Today, this potential is being increasingly recognized and capitalized upon in the business community, and its ability to provide solutions to "what-if" scenarios may be the most effective GIS analysis strategy for business applications.

Predictive modeling allows sets of geographic information to be overlaid to identify regions or locations based on spatial coincidence of factors that meet given conditions. For instance, in urban landuse planning, potential sites for proposed development may be modeled based on analysis of the interactions of developmental objectives, environmental, economic, and political factors. The greatest advantage of predictive modeling is its ability to pose "what if" scenarios concerning environmental, demographic, and political factors. For example, GIS can be utilized for a site suitability analysis, such as identifying locations suitable for a proposed development or business (e.g., housing, agriculture, factories, shopping malls, etc.) or to predict the impact of proposed urban development on the surrounding environment and population (Aronoff, 1989; Lo and Shipman, 1990).

Other GIS functions with extensive potential in marketing are the address-matching and network analysis applications. Given a street address, an address-matching operation will pinpoint its precise location using the beginning and ending address range on the identified street segment. The basic requirement for address-matching is a map layer of road networks, with each road segment identified: road name, road type, and the beginning and ending address range. This function allows businesses to locate essential facilities and properties on a map.

Network analysis enables the user to determine optimum routing, as well as resource allocation along predefined routes. The former provides a solution to the classic "traveling salesman's dilemma", and the latter provides a solution to resource distribution and identification of potential markets in terms of accessibility to business locations.

A number of businesses have, in recent years, begun using GIS frequently as a planning and decision-making tool. Hilton Corporation, for instance, made use of GIS technology for locating suitable casino sites by identifying local population-base gaming markets through analysis of demographic, socio-economic, and psychographic information (Wendelken, 1995). In another successful use of the technology, Sylvania employs GIS to provide market performance information as a service to its distributors (Wendelken, 1994). Lichliter, Jameson & Associates, a Houston-based consulting engineering firm, effectively employed GIS to assist in their transportation planning and engineering projects, such as the construction of a 200-mph passenger rail system serving Houston, Dallas, Austin, and San Antonio (Lang, 1994). With the help of GIS, the Wolfgang Puck Cafe chain identified potential customers for its Cafe located in Universal City, California, using 1990 census data and five-year projected information overlaid on geographic zip code boundaries (Specht, 1996).

GIS Database Sources

The development of a GIS database is the most fundamental, and perhaps the most critical stage in a GIS operation. It is a very time-consuming task, and represents approximately 80% of the effort in any GIS operation. The task involves the generation of map layers in a digital format compatible with the GIS software to be used. The required information may have to be digitized from available maps or aerial photographs, or may be purchased from government organizations or commercial sources.

The two most commonly used street and highway databases are produced by the U.S. government. These are the Digital Line Graphs (DLGs) produced by the U.S. Geological Sur-

vey, and the Topologically Integrated Geographic Encoding and Referencing (TIGER/line) files from the U.S. Bureau of the Census (USBC). Additionally, census/demographic data based on county and census tracts are also available from USBC.

Commercial companies are important sources of geographic, demographic, business, and natural resource and environment data. EtakMAP, for instance, provides highly accurate, large-scale digital basemaps of roads, addresses, ZIP Codes, Metropolitan Statistical Area (MSA) Boundaries, and related map features. Other commercial sources include Claritas, Geographic Data Technology, DataMap, SMI, EarthInfo, and MapInfo.

Before the data can be entered into a GIS database, they must be transformed or encoded to a format compatible with the GIS software being used. Most data sources will provide the necessary interface for the conversion. Likewise, most GIS software also provides the option to convert data from a variety of recognized formats. This not only provides an avenue for capturing data from a variety of sources, but also the possibility of acquiring output data from other GIS software using a different format from that employed by your system.

GIS Investments: How and Where To Begin

Although much has been written about the usefulness of GIS, little has been published to help businesses embrace the technology. A number of questions relating to software/hardware investments, data sources and database development, degree of expertise and training needs, and personnel requirements need to be addressed.

Involvement in GIS applications includes a wide spectrum of options, and commitment to such an undertaking depends on the needs and scope of the enterprise's objectives. At one end of the spectrum are businesses or corporations whose day-to-day activities require "in-house" GIS with a full range of GIS capabilities. This will require large investments in a comprehensive GIS software (e.g. ARC/INFO), the appropriate hardware (computers and peripherals), and employment of trained personnel to operate the system. At the other extreme are those businesses that will certainly benefit from GIS, but whose infrequent needs for the technology may not justify such an investment.

The majority of businesses are in between the two extremes, and will require frequent use of the technology, but do not have the need for a full range of GIS capabilities. In such cases, the users are typically the managers, who require instant access to GIS analysis and querying capabilities to assist in their decision-making process. For the most part, they are not and will not be involved in the tedious data capture or editing tasks. One solution to this requirement is an investment in the so-called "Managers' GIS" software (e.g. ARCVIEW), designed primarily to provide GIS analysis and output capabilities. The advantage to this solution is that it requires minimum training, providing the users the capabilities to perform complex GIS and map design operation. Because it provides neither data capture nor editing functions, these operations cannot be performed "in house", and required data will have to be either purchased or developed through contracts with commercial enterprises.

Depending on the nature and scope of the business, the level of investment in the technology will vary among individual businesses, and therefore, the initial step should be to identify one's needs. The process of identifying one's needs involves confronting a host of questions, the most pertinent of which include: The frequency and volume of usage, the nature and amount of data required, possible sources of data, and how much of the data is already available, and most importantly, the availability of trained personnel to operate the system. The answers to these questions will indicate the level of investment needed, and once these issues have been resolved, one must investigate the appropriate software/hardware system in which to invest. This can be a rather difficult step because of the variety of systems available in the market, and the numerous sources of information giving so

many conflicting impressions.

In the choice of an appropriate software/hardware system, the critical question to address is the nature of the work, or project, with which the system is to be used. Are you interested only in map production, or does your requirement go beyond cartographic output? One obvious source of information are the vendors of the systems themselves, as they will be the most well-versed in their own product. However, one should be wary and may not expect an objective opinion from a vendor. Since a vendor will stand to gain by persuading you to invest in its products, a "discussion" may quickly turn into a sales pitch, geared towards persuading rather than informing.

Another option is to communicate with other businesses that are already involved in the technology. One can certainly profit from their experiences, and avoid any pitfalls they might have encountered. However, their decisions have already been made, and most are not likely to be knowledgeable on all aspects of what is available, even if they are technically proficient in the software they use. Additionally, a system that may work well in someone else's operation may not necessarily be applicable to your own operation.

Universities or colleges that have GIS programs are important alternative sources of information. These programs, usually housed within the geography department, are usually equipped with complete GIS software/hardware systems, with excellent faculty resources supporting the institution's academic and research programs. Such a facility will be an invaluable source of information and advice, able to address all your questions objectively, help identify your needs, and provide useful advice on the level of investment to meet your requirements. One can even schedule a tour of their facilities, and obtain "hands-on" knowledge about the type of systems in which one might be interested. In this instance, one is not dealing with a salesperson, and will not be subject to any sales pressure.

Establishing contact with an educational institution can be beneficial beyond information gathering. For businesses that intend to invest in an in-house GIS, the faculty and the department can provide the necessary training, personnel and technical support during the early stages of their endeavor into the technology. Such support, provided either by the faculty, or students under the supervision of the faculty, is invaluable in helping to alleviate the "growing pain" that usually accompanies a new technology. One can certainly capitalize on their experiences and resources to ensure a smooth and quick transition into the new technology with a minimum of difficulty.

For those businesses that do not want to invest in "in-house" GIS, an educational institution can also be of service. Such businesses may contract with the institution to undertake the GIS analyses as research projects. Under such a contract the institution and the facility involved will undertake the GIS analysis to meet the business's criteria, and provide the end-products agreed upon. This is analogous to having your car fixed by a specialized mechanics, without having to do it yourself, and invest in a workshop, tools or training. The institution will undertake the necessary research, perform the needed analysis, and produce the results. Very often, it also involves a close working relationship with the responsible investigators or individuals to ensure that the research, analysis, and output conform to your requirement.

To those businesses that do not intend to invest in a complete in-house GIS, but do require GIS analysis and querying capabilities, the institution is the best source of technical, resource, and data support, particularly if the data required are not commercially available. One can easily contract with the institution to undertake the laborious tasks of data capture to develop the appropriate GIS database. Since the laboratory in such an institution is already equipped with the necessary software/hardware systems, and trained staff to undertake the tasks, it provides a very cost-effective means to obtain the required data, freeing the GIS user to allocate his/her time

more efficiently in performing the critical decision-making tasks.

Business certainly can benefit from establishing a good working relationship with educational institutions, and most institutions will welcome the financial support for their students. Therefore, it certainly will be a smart move to investigate such facilities, to assess their capabilities, and to ensure that they can adequately serve your needs.

Conclusions

Geographic information systems have been increasingly accepted as a potential decision making tool in the business community. Its applications for database query, predictive modeling, address matching, and resource routing and allocation can be effectively applied to offer solutions to businesses to help formulate developmental and investment policies. However, investments in the technology have to be carefully considered. While hardware and software may be the tangible components of a system, one should not overlook the need for investments in database development, and most importantly, trained personnel. Governmental agencies and commercial enterprises may be critical sources of data needed for the development of a GIS database. However, when the required data are not readily available and need to be captured, businesses may also capitalize on the expertise and resources of universities and institutions of higher education to assist in these tasks. Additionally, they can provide technical and data support in their day-to-day operations.

Suggestions For Future Research

This paper provides a starting point for the understanding of GIS as a technology, and its potential for business applications. For businesses who are interested in embracing the technology, future research along the lines proposed in this paper would do well to (1) critically investigate the need for the technology, and (2) its investment costs. As stated in the paper, educational institutions are invaluable sources of information and assistance to address these issues. Apart from commercial software/hardware vendors, GIS-related trade shows, conventions, and training workshops could also provide attendees avenues to achieve greater understanding and appreciation of the investment needs.

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