NATIONAL CAPITAL URBAN PLANNING PROJECT: DEVELOPMENT OF A THREE-DIMENSIONAL GIS MODEL

Lawrence G. Batten
U.S. Geological Survey
521 National Center
Reston, Virginia 22092

ABSTRACT

The U.S. Geological Survey (USGS), the National Capital Planning Commission (NCPC), and the U.S. Bureau of the Census (BOC) are cooperatively developing a three-dimensional model of the Monumental Core in Washington, D.C. The overall goals of the project are to extend two-dimensional GIS techniques into the third dimension and to illustrate the potentials of a three-dimensional GIS model for use in urban planning, review, and evaluation processes.

The major components of the study are the two-dimensional and three-dimensional models of the current urban setting including USGS Digital Line Graph (DLG), BOC Topologically Integrated Geographic Encoding and Reference (TIGER) system, and NCPC data sets; linkages to move attributes, spatial information, and analytical results between the two models; view-shed analyses of existing and proposed new buildings; and network analysis for urban transportation simulation modeling.

The ability to quickly and efficiently produce perspective plots from various view positions, to update the cartographic and (or) attribute data bases subsequent to design changes, and to model transportation patterns before and after construction of a new structure has made the planning review process more efficient and precise. New techniques developed during this project will also apply to the broader field of solids modeling including three-dimensional geologic, ground-water, and geophysical studies.

INTRODUCTION

Recent advances in computer technology have given researchers new tools for natural resource and socioeconomic analysis. Most notable of these advances are the development of workstations suitable for both three-dimensional Computer Aided Design (CAD) and two-dimensional Geographic Information System (GIS) software. Combining GIS and CAD technologies depicts urban and natural environments in a fashion more understandable to the lay person.

The following paper describes the creation of a three-dimensional data base for the Monumental Core of Washington, D.C. (fig. 1). The project is part of a

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cooperative effort by the U.S. Geological Survey (USGS), National Capital Planning Commission (NCPC), and the U.S. Bureau of the Census (BOC) to develop computer tools for urban planning applications. Important considerations in the design of this project will be discussed and preliminary results shown.

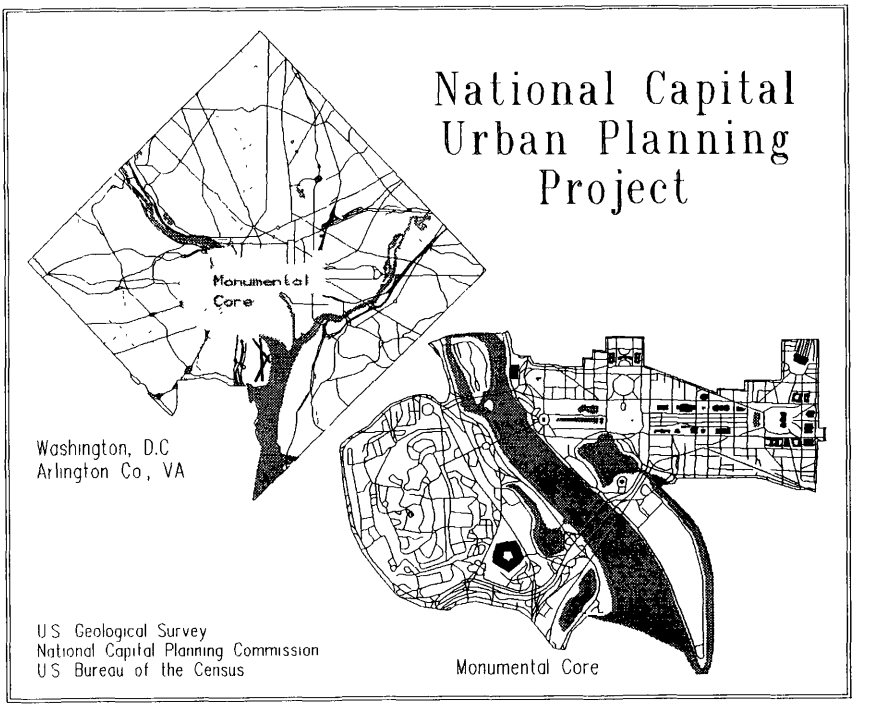

Figure 1.--The Monumental Core extends from the Capitol Building in Washington, D.C., to portions of Arlington County, Va., across the Potomac River, and encompasses major national monuments and landmarks such as the Lincoln Memorial, Jefferson Memorial, White House, and Pentagon.

BACKGROUND

As the central planning agency for the Federal Government in the National Capital region, the NCPC is responsible for the analysis of urban conditions, the review and approval of all new Federal buildings and projects in the Washington metropolitan area to ensure that they meet the long-range planning objectives of the Federal Government and are compatible with local plans, and the preparation of plans for future development. Detailed site analyses are produced for all proposed buildings to determine their effect on existing structures, public lands, and surrounding areas. Products include perspective views of the proposed building set in the midst of existing facilities, three-dimensional axonometric maps, and traditional maps at various scales and resolutions. Maps and graphics used in this process are currently being produced manually. The original data include USGS maps (normally 1:24,000 scale), aerial photographs, building construction documents, and local planning documents.

The USGS has developed numerous GIS data bases by combining disparate analog and digital data layers for subsequent modeling and program analysis. The USGS GIS Research Laboratory in Reston, Va., has vector and raster GIS software co-located in the same facility, which allows for the development of analytical techniques that utilize both storage systems. Hardware resources include three-dimensional graphic devices and GIS workstations.

The USGS and BOC are cooperatively preparing geographic data in support of the 1990 Decennial Census of Population and Housing. The resulting TIGER files offer a detailed description of the population for urban areas. To date, however, no GIS project has been applied to the study of the use of these data for urban planning. Both the cartographic and socioeconomic attribute portions of TIGER data are being used in the NCPC project to model this complex environment.

METHODOLOGY

The project was designed to develop three-dimensional GIS capabilities for use in architectural, urban design, socioeconomic and natural resource studies in an urban planning environment. A two-dimensional data base was prepared for traditional GIS applications and storage of detailed building attributes. A three-dimensional data base was constructed for maintaining structural details and producing perspective views. The development of two-dimensional to three-dimensional linkages for passing analytical parameters was a crucial part of the study.

Data Compilation

Review of the various types of data needed by the NCPC for the digital data base preceded the actual data collection tasks. Data included USGS digital topographic and cartographic data, BOC statistical and geographic data, urban planning data, and architectural drawings. The various scales and resolutions of the data were defined at this point. It was decided that the three-dimensional data base should contain enough detail to capture general building design but not to maintain specific details, such as ornamentation or brickwork. These fine details are more appropriate for a building-specific study rather than a citywide program.

Development of GIS Tools and Techniques

The second phase of the project involved development of the appropriate hardware/software environment for the two-dimensional and three-dimensional data bases. The NCPC and USGS had different equipment requirements because of their respective applications. A two-dimensional vector GIS system (ARC/INFO) was chosen by both groups to maintain the building-specific information such as number of employees, date of construction, and amount of office space. ARC/INFO was also used to generate cartographic products. Two three-dimensional CAD software packages were tested for solids modeling applications. The USGS installed Medusa on a Prime minicomputer, while NCPC used the Architect and Engineering Series software on an IBM RT personal computer.

Techniques for passing information between the two-dimensional and three-dimensional systems were written and implemented at this time. Unique feature codes were developed for all the structures within the project area. These codes were added to the two-dimensional data as an attribute in the INFO file. The same codes were then used as object identifiers in the three-dimensional data base. Typical GIS queries are then used to identify a subset of features that are of

interest. The codes for those features are passed as a file from the two-dimensional software to the three-dimensional data base where a perspective view can be generated showing those features in a different fashion. An example might be displaying a perspective view of buildings built in 1950 in red and the others in gray.

Data Base Development

After the proper GIS tools and techniques were determined, methods for entering nontraditional data (blueprints, building elevations, etc.) into the chosen GIS systems were developed. Manual digitizing was used to enter detailed data. Scan digitizing was used to enter data from planimetric maps and site plans. Rasterization of aerial photographs may be investigated later in the project.

The two-dimensional and three-dimensional data bases were treated as separate entities during this portion of the project. Each was different in the manner in which features were represented. For example, roads were entered as line coverages in the two-dimensional file and as polygons with x,y,z coordinates in the three-dimensional version. Creation of the two-dimensional data base followed well-defined routines from previous GIS studies; available two-dimensional analog and digital data, NCPC building attributes, and BOC TIGER files were registered to form a planimetric two-dimensional data base.

The major research product of this project was the creation of a three-dimensional model for the pilot area. The various buildings within the area were depicted as abstract geometric blocks or detailed structural entities depending on the application needs and graphics devices used. Most data were entered into the data base through turnkey operations available from the vendors. However, some computer code was written to enter data not routinely used in CAD systems (such as digital elevation data). Data sources included NCPC building "footprint" maps, low-altitude aerial photographs, digital elevation models, and building elevations.

Applications

Early in the project, a pilot area was chosen for testing modeling techniques. The site was representative of the urban design issues faced by NCPC. Accepted routines will be applied to the expanded area currently under investigation by the NCPC.

A proposed new Supreme Court building and associated changes within the pilot area offered the opportunity for real-world examples of the types of questions to be answered by the completed system. Perspective views of the study site before and after erection of the proposed new structure were identified as an important capability. The two-dimensional to three-dimensional linkages were crucial for querying the two-dimensional attributes and depicting the solutions in three-dimensional space.

Network analyses of the transportation environment within the pilot area were also conducted. Time-of-travel information was added to the attributes for the TIGER and DLG data. By using this variable, routes were computed to show the shortest travel time between various sites. Currently, methods are being developed for modeling the effects of increased commuter traffic from new buildings during rush-hours. Commute-to-work information maintained by NCPC and BOC will be used in this effort.

Socioeconomic analyses of the greater Washington, D.C., area are currently being conducted. Attribute data from the 1980 census have been combined with the

1990 TIGER files to produce a model depicting the cultural makeup of the region. Future applications of these data include cooperative studies with urban development, health, emergency, and law enforcement agencies.

Demonstration and Project Review

Demonstration and review of techniques and products developed are important aspects of the project. Presentations of the findings, techniques, and recommendations for follow-on studies will be made to NCPC and USGS staff and management representatives. Additionally, a number of Federal, State, and local agencies have shown an interest in this work for applications in urban planning, natural resource analysis, and data visualization.

CONCLUSIONS

The overall project goals were to:

- Design tools and techniques to assist the NCPC in planning the development of the National Capital region.
- Develop NCPC and USGS skills in the areas of three-dimensional analysis, graphics, and network studies.
- Illustrate the potentials of a three-dimensional GIS model for use in urban planning, review, and evaluation processes for cities throughout the Nation.

Project results demonstrate that using a combination of three-dimensional CAD and GIS is a better method for preparing the graphics used by the NCPC for their work. The ability to quickly and efficiently produce perspective plots from various view positions, update the cartographic and (or) attribute data bases subsequent to design changes, model transportation patterns before and after construction of a new structure, and enter engineering and design analyses (i.e., building height, infrastructure) will make the planning review process more efficient and precise.

This research has given the USGS, NCPC, and BOC experience in the new field of three-dimensional investigations. Results are more readily understood when viewed in a three-dimensional context. The new techniques developed during this project apply not only to architectural siting, but to the broader fields of solids modeling (including three-dimensional geologic, ground-water, and geophysical studies), view-shed analysis, and data visualization.

The new techniques also could be used by other cities as tools for urban planning. The ability to combine disparate data sets by using merged GIS and CAD technologies will provide researchers a better, more realistic view of the total urban environment. Future developments in automating data capture tasks, better transportation algorithms, and true three-dimensional graphic displays will further promote this technology for programmatic operations throughout the Nation.