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Automated Design in Minneapolis and Hennepin County, Minnesota

Two overlapping government agencies receive significant benefits from automated engineering design and mapping.

ABSTRACT: *The paper describes the engineering design and interactive graphics system called MAPS, jointly developed and used by the City of Minneapolis and Hennepin County, Minnesota. The system was developed to produce automated plan and profile engineering plan sheets. Data for the plan sheets are digitized from aerial photos, processed by the computer, and updated by either hand coded information or interactive graphics. Automation of the engineering plans has increased our productivity by 250 percent between 1974 and 1983. MAPS is now taking advantage of the ability of computers to store and selectively reproduce large amounts of data. A county-wide property basemap tied into state plane coordinates is in final editing. A trial project is now underway with the local gas, telephone, and electric utilities analyzing the benefits of storing each utility's facility information within the property map framework. MAPS is also capable of producing an unlimited variety of planning maps.*

INTRODUCTION

MOST GOVERNMENTAL AGENCIES are forced to get more out of their declining dollars, which leads many to look to the computer for productivity assistance. To improve our productivity, Minneapolis and Hennepin County, Minnesota jointly developed MAPS, an automated mapping and planning system.

Since its initial use in developing engineering plan sheets, MAPS has successfully been enhanced to meet property, utility, and planning needs in both agencies (Figure 1). The explanation of how MAPS assists the functions of those four areas is the purpose of this article.

Hennepin County has a population of one million people spread over 700 square miles, with about half of those people inhabitating the 60 square miles of Minneapolis. Hence, the rationale for joint development and use of MAPS is a common constituency.

ENGINEERING SYSTEM

MAPS is first and foremost an engineering system. Its initial development began in 1970 with the goal of creating an engineering and mapping tool versatile enough to meet our graphics requirements and consistent with the required accuracies. In 1972 a prototype version of MAPS was tested by comparing times to survey and design an engineering project with (1) manual versus (2) automated techniques.

Test results showed three distinct advantages for using automated techniques, which prompted Minneapolis and Hennepin County to automate all appropriate engineering projects. First, the automated plan was produced in half the manhours of the manual plan. Second, it was of a more consistent quality. Lastly, the automated information was usable by any other agency doing design in the same area, giving them a significant cost saving.

Use of the prototype MAPS system identified three problem areas. (1) Originally a contractor digitized our aerial photographs. Substantial time was required to communicate to the contractor what we wanted digitized, which added cost to our projects. (2) Data not visible on the aerial photography had to be added by a command coding process including coding, punching, batch processing, and finally plotting. The problem was the time lag from dealing with the data initially to seeing it plotted correctly. (3) Our existing property maps were in poor physical condition and updates were falling behind.

We recognized that a solution to the first problem was an inhouse stereoplotter. In January 1980 we

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put a Wild B-8 stereoplotter online to our MAPS system.

In 1975 we recognized that a solution to our second problem was being online with interactive graphics to reduce the time lag caused by manual coding, data entry, batch processing, and plotting. The time saved on our engineering plans justified the cost of adding interactive graphics. Additional justification for adding interactive graphics came from a study that showed digitizing to be the most cost effective way of reproducing the property maps. Storing the data in the computer enables updates to be made at one site and reproductions to be made at any size, scale, or orientation at multiple sites. Furthermore, the automated property map data base becomes the framework for a utility inventory and for displaying planning data.

After we decided to implement interactive graphics, we studied available vender supplied systems. We found that no vendor could handle a data base of our projected county-wide size. None of the available systems were designed to handle engineering calculations or accuracies. Futhermore none of the available systems handled the elevation (z) component. All handled horizontal (x, y) data only.

Because, no available system met our needs, we decided to make our own system, MAPS, interactive.

We started using the MAPS interactive graphics subsystem in 1977 with three work stations. We have since replaced the three original work stations with seven new, less costly, but more capable work stations. Each work station includes a 36- by 48-inch high resolution digitizer table tied to a refresh graphics CRT which is in turn linked to a host computer where the central data base resides.

MAPS Features

Since its inception, MAPS has differed from other available mapping systems in at least three ways. First, the central data base can easily store enough information to map the largest metropolitan area with a storage technique that allows MAPS to efficiently get at any needed data.

Second, MAPS has always used refresh, as opposed to storage, CRT technology. The lower cost storage

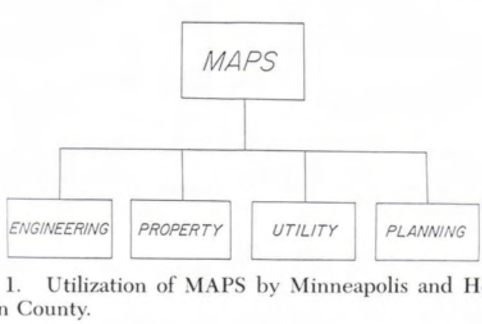

Fig. 1. Utilization of MAPS by Minneapolis and Hennepin County.

CRT "paints" a high quality image on the screen once. Interactive graphics implies that the operator is interacting with the image on the screen. To do that, the operator needs to look at a portion of a file at a large enough scale to see the results of adding, correcting, or deleting data items from the file. Changing scale, and viewing different areas of or deleting information from the file requires "repainting" of the image on the screen. Storage CRTs take several minutes to repaint the screen, which can seem like an eternity to the operator. Refresh CRTs repaint the screen at 40 times a second, which gives the illusion of instantaneous scale changes and data deletions. Venders supplying work stations with storage tubes "solved" their problem by adding a second CRT for a second image at a different scale. Our experience is that one refresh CRT is less costly and far more productive in an interactive environment than two storage CRT.

Third, MAPS stores its 3200 data symbols in a hierarchy which allows the user to efficiently create automated plots of any and all symbol combinations. Contrast this with manual maps where there is no flexibility of symbol selection; what you see is what you get. Contrast it also with other automated systems that store like symbols in rigid pre-defined groupings called levels. The user can mix and match these levels but he does not have the unlimited symbol selection capability of MAPS.

Plan Sheets

I will now briefly describe the engineering subsystem to explain the features of MAPS.

An automated plan sheet is the typical final product of the MAPS engineering subsystem.

The first step in producing the plan sheet is using a stereoplotter to digitize visible points on an aerial photo, giving each point a coordinate and symbol name. The computer transforms the digitized data into a meaningful collection of points, curves, and areas.

Digitizing simply means giving a ground point a state plane coordinate. A coordinate defines distance over (x) and distance up (y) from a reference point. Every point in space has a unique coordinate. An analytical stereoplotter can measure x, y, and elevation (z) coordinates of photo points.

The second step is to define any shape of boundary and any combination of our 3200 symbols. MAPS then generates a plot of any size, scale, and orientation. Normally, we first request a 100 foot per inch plot of an entire project to check for any obvious large errors. Next, we request 40 foot per inch area plots to note any additions, corrections, or deletions. Usually the alterations will be made with interactive graphics, unless high precision is required, in which case they are made using a command coding language.

Lastly, we break the project into plan sheet plots.

On the top quarter of the plan sheet we request a 40 foot per inch plot of all the symbols making up the present plan view. Directly below it on the plan sheet is positioned a plot of the same geographic area with a different grouping of symbols that represent the proposed plan view. The plot has all the lines neatly truncated, all the text rotated for easy reading, and an accumulation in English or Metric units of all point, line, and area items by symbol name which forms our quantity list.

The profile on the bottom half of the plan sheet illustrates that MAPS stores the x, y coordinate and the z elevation of its data. Numerical ground image surfaces can be generated from field data or fom stereoplotter cross-sections or by digitizing contour maps. Subsurfaces can be generated by soil boring data or by roadway design data. Each surface is defined by cells down to 1/2 metre by 1/2 metre. After the system generates the proposed road design surface, earthwork quantities between subsurfaces are computed.

Profile, cross-section, and perspective plots can be generated with underground structures such as sewer lines shown in their correct x, y, z orientation.

Productivity

The MAPS engineering subsystem has been successfully implemented by the Minneapolis street design section, as the productivity chart in Figure 2 shows. Between 1974 and 1983, Minneapolis productivity, as measured by miles of plan produced per person, increased over 250 percent. Whereas in 1974, 90 people were required to produce our paving plans, in 1983, 30 people produce the plans plus do all data base creation, system development, and system maintenance work. Factoring in computer costs gives street design a 1983 "adjusted" manpower of about 36 people.

While this productivity improvement is impressive, we have not yet received the greatest benefit of automation, which is the elimination of redundancy.

Consider that each section of each department of every level of government and each private utility independently maintains and draws its own records

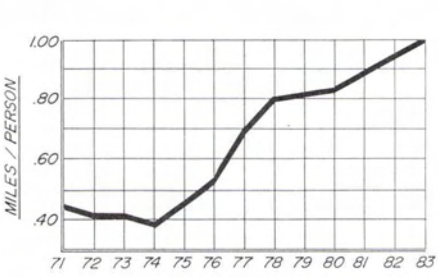

FIG. 2. Increase in productivity after implementation of MAPS in 1974.

and plan sheets using unique scales and symbols. Also note that 60 to 90 percent of any one map's lines represent features common to every other map of that geographic area. Not only is this redundant mapping process wasteful but also it greatly increases the potential for errors by using data that are not current.

Our solution to the redundancy problem is using MAPS to build an automated x, y, z utility inventory data base. Each user updates only its own data, with viewing access to the rest of the data base. The common data base greatly reduces each individual agency's map production costs while giving each user better up-to-date information.

Property Maps

To build the utility inventory, a framework is needed within which to fit the utilities. Minneapolis and Hennepin County decided to build a one county-wide basemap by digitizing all 1400 Hennepin County half-section maps and mathematically transforming them to fit field measured and adjusted control points. In the process obvious map errors have been corrected and map dimension information has been input to allow English or Metric output.

Obviously, large amounts of data are included for Hennepin County's 325,000 parcels and all associated information. But because the data base is geographically oriented, data in storage can be accessed extremely quickly.

While digitizing the property maps the old plat-parcel number is being replaced with a new *P*roperty *ID N*umber. The new PIN number that appears on all new maps incorporates section, township, range, quarter-quarter, and unique parcel number. The ability of MAPS to know the location and boundary of every PIN number automatically links an address to a geographic location. The property data in the computer are now going through final editing. When editing is complete, one site, the county surveyor, will update the property data base with the approximately 75 parcel splits, combinations, and new plattings that occur per week. Figure 3 shows the relationship of basemap information flow from the source to all the interested users. The automated property basemap is updated at the source and all users immediately have access to it rather than independently updating their own manual maps.

Up-to-date property map information will be available on computer generated microfilm on a two week distribution cycle, on CRT for immediate viewing, and on hard-copy plot.

As a comparison of different drawing speeds, we estimate about 700 minutes to hand draw one of our engineering plan sheets, 7 minutes to have the computer drive a mechanical plotter to draw it, and 7 seconds for the computer to generate a comparable

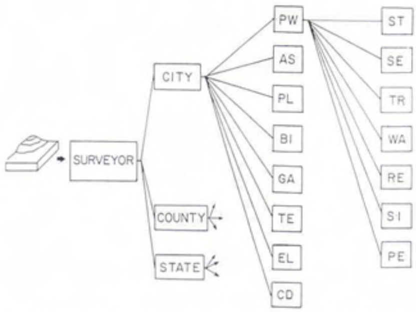

FIG. 3. Hierarchy of basemap users. PW—Public Works, AS—Assessment, PL—Planning, BI—Building Inspection, GA—Gas, TE—Telephone, EL—Electricity, CD—Community Development Agency, ST—Street, SE—Sewer, TR—Traffic, WA—Water, RE—Real Estate, SI—Sidewalk, PE—Permits.

plot onto microfilm. The volume of property basemap updates requires high speed microfilm plotting.

Utility Inventory

With the MAPS property basemap intact, it becomes the framework for a utility inventory. Street outlines along with sewer, water, gas, telephone, electric, traffic lines, and conduit can be stored in *x, y, z* format at one site. Such maps exist in coordinate form for about one-third of Minneapolis's residential streets as well as an appreciable number of the County roads.

To illustrate the practicability of eliminating mapping redundancy, our principal telephone, gas, and electric utility companies are now using MAPS for a trial project. They are digitizing their facility information into the MAPS database to analyze the cost benefit of generating a utility map and as an ongoing map record system.

To input their facilities, each utility started with a digitized half-section map. The map was replotted at 40 feet per inch with minimal lines and text for a map upon which to draw and digitize their facilities. After all the data are input, each utility generates output tailored to its specific format. MAPS has been designed to allow each user to view the data base but to only be able to update its own data to maintain data integrity.

Potential benefits to the utilities include (1) cheaper one time map production costs; (2) complete automatic quantification of any part or all of their system; (3) *x, y, z* data; (4) location of other utilities and structures relative to theirs and; (5) future decreases in lost service time.

Planning Data

With the property basemap complete, planning data can be displayed by MAPS. To plot planning data, the data must be (1) automated and (2) related to a geographic position. Many governmental jurisdictions have already automated and linked their data to address or parcel number. In Hennepin County, MAPS knows the coordinates of every parcel number. Hence, as is shown in Figure 4, the user requests a MAPS planning map by (1) supplying automated data tied to an address or property ID; (2) telling MAPS what color, symbol, or shading pattern to use to display each type of data; and (3) defining the geographic boundary of the entire planning map in question. MAPS then plots the correct information in the correct parcel.

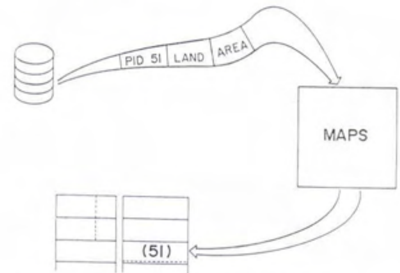

FIG. 4. The flow from the request for a MAPS planning map through the plotting of that map.

MAPS has been used to plot data per parcel, per block, per census tract, city-wide, and county-wide. Data have included day-care centers relative to kids under 5; assessed land value per square foot by parcel; use code, zoning, and tax exempt property per parcel; average building value per block; and county-wide population shifts, to name just a few.

Equipment Configuration

The data base is presently stored and processed in a large machine, an IBM 3081. Our seven refresh work stations and two storage plot preview stations are tied into the IBM 3081. Plot files are sent downline to a PDP 11/780 VAX to be plotted on either our drum plotter or our COM unit. The 11/780 also runs our stereoplotter, our 60 word processing and data entry terminals, and acts as an RJE device for processing on the 3081.

By spring 1985, MAPS will be fully operational on Super-Micro equipment.

Summary

In summary, Minneapolis and Hennepin County have jointly developed MAPS, an automated *m*apping *a*nd *p*lanning *s*ystem. MAPS is capable of efficiently storing and disseminating large amounts of information be it engineering, property, utility, or planning data. Each data item is stored in *x, y, z* format and can be retrieved easily because of its geographically oriented data base design.

The engineering product has proven itself successful. Using the system, Minneapolis has greatly increased its productivity while going from a staff of 90 to less than 30.

A county-wide basemap is being created (1) digitizing property maps, (2) mathematically transforming each map to meet field measured and adjusted control points and (3) editing the map data. Steps 1 and 2 have been completed.

With the property maps tied together, the framework exists for a county-wide utility inventory. A trial project is now testing the practicability of multiple agencies storing sewer, water, telphone, gas, and electric information in x, y, and z data base.

Distributed processing will allow each agency to store and retrieve map data at its own site with complete flexibility in symbol selection and independence of operation.

The potential uses of planning information—be it crimes, accidents, services performed, etc.—is limited only by an agency's interest (and budget).

The MAPS system has the capability to include data for a regional or even state-wide area because it was designed to handle large as well as small jurisdictions.

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