DESIGNING A FLEXIBLE AUTOMATED MAPPING SYSTEM FOR MEETING UNIQUE CUSTOMER REQUIREMENTS

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ABSTRACT

The methods used for creating maps have changed dramatically during the past ten years. Most map producing organizations have embraced some form of the automated cartographic technology available today. The map production process consists of several discreet components from an initial design concept through the completion of the map in its final form. Technological development has impacted each of the production process components in different ways and at different rates. The effect of this differential application of automation to the cartographic production process is that some parts of the process are fully automated while others, most notably the design component, lag behind in use of automation. A concomitant effect has been a change in the role of the cartographer.

Historically, large map producing organizations printed a standard set of map products for the public and other customers. Tailoring a product for specific customer needs was an expensive activity. The changing nature of cartography and of producing user-specified maps have brought about whole new map production systems.

This paper examines the characteristics of a flexible automated mapping system design for meeting unique customer requirements. Geographic coverage, content, scale, symbology, design, output media as well as efficiency and expense are examples of basic requirements. The issues involved in developing such a system are considered in a theoretic framework. The position of the cartographer also is considered. This leads to some guidelines to aid in training cartographers and designing map production systems to meet present and future map needs.

INTRODUCTION

Historical

Mapping activities are on the rise as more and more data become available and computer software takes over the tasks of processing and output of the data into maps of high cartographic quality. At the same time an apparent shift has occurred from standard map products traditionally produced by large mapping organizations to more user-specified, oftentimes one-of-a-kind maps. While most map producing organizations have embraced some form of the automated cartographic technology available today, the application of automation to the cartographic production process has been differential with automation of some parts of the process lagging behind others. The implication is that mapping institutions are being challenged by the move from established products with cartographic design to customer-need based mapping. This has challenged not only the mapping

organization's structure - ways in which they do business - but has effected a change in the role of the cartographer.

Historically, large map producing organizations printed a standard set of map products for the public and other customers. Tailoring a product for specific customer needs was an expensive activity. Usually, tailoring a unique product was left to small staffs that specialized in that kind of mapping. The changing nature of cartography and of producing user-specified maps have brought about whole new map production systems.

Current

The current state of map production is one of flux. Traditional map production philosophy is being challenged on all sides by GIS systems capable of map generation, by desktop computer mapping software, by hand held computer based mapping and data capture systems, and so forth; even by virtual reality systems. The whole concept of what constitutes a map and mapping is being reexamined and redefined. This has resulted in an unclear view of what should constitute a mapping system and what kind of training is necessary for a cartographer, or even the role of a cartographer in the map production process.

Future - The Satisfied Customer

The characteristics of a system to satisfy mapping requirements in today's emerging environment must be founded more on customer satisfaction than on production management. This means developing flexible automated mapping systems designed for meeting a customer's unique requirements. There are five words in this statement that are keys to designing a successful system for the future. Each of these words reflects a design issue in the theoretic framework.

Unique (product type) The map content and design are not necessarily the same as that offered by a standard map series. Need is usually immediate and cannot be easily fit into a regular production schedule. Creative design, perhaps even non-traditional design, is required to effectively communicate the data message. The map may require the use of data from data sets that are not easily or commonly related, and indeed may not even be digital.

Customer (product purpose) The product orientation is toward customer-based need and less toward production organization. The customer is the user of the map production function primarily and the user of the product secondarily; though they may be the same. In neither case is it the emphasis on the producing agent or organization.

Meeting (system purpose) The system purpose is to provide the product when, where, and how needed while maintaining quality.

Automated (means of operation) The map product is produced via any of the three automated means: (1) total batch generation, (2) interactive generation, or (3) batch generation with interactive editing. No traditional manual cartographic operations are performed directly on artwork or product.

Flexible (functionality) The system is able to produce many designs, output to many media, and function within many operating environments. It is not a system that is strongly hardware or operating environment

dependent. Nor is the system limited in map design or output media to one or even a few standard formats.

Several of these design issues are present in today's mapping systems. Unfortunately, smartly devised demonstrations coupled with customer imaginations have combined to create an impressive panoply of mapping options that appear to say that the needed mapping systems are here today. This has led to high customer expectations of systems that, in fact, cannot meet their mapping requirements. Customers familiar with traditional map production operations appreciate what can truly be done by today's systems. The experienced customer knows how to test the precise capabilities of systems by asking simple questions such as, "Will you demonstrate how to...?" When this happens, the stark truth of any system's automated flexibility to meet customer's unique requirements is revealed.

MAP PRODUCTION MODELS

At the core of all mapping systems is the map and the operations needed to produce it. In the world of today and tomorrow, the traditional view of what is a map and the terminology applied to map production operations must change. When one examines textbooks and articles about cartography, one is able to find numerous map classification schemes but few definitions of a map. Robinson and Petchenik (1976) described the difficulty of defining a map. Thrower (1972) and Raisz (1938) and others have all attempted to define a map, while acknowledging the difficulty in doing so. Previous definitions, when examined in the light of today, seem hopelessly inadequate and unnecessarily restrictive.

A map is not merely a visual phenomenon. Rather, a map may be considered to exist at the moment that it becomes a unique entity, distinctly separate from the sources and materials needed for its production. Much in the manner that a cognitive map is said to exist, a map today can exist as a series of computer commands that a display device acts upon to produce a visual image.

To a person viewing a map, selected data and their spatial relationships are seen presented in a manner designed to communicate a message. The message may be as mundane as a catalogue of data locations or as complex as a traffic flow map representing vehicle flow-volumes at peak hours. The marginal and other supporting information, such as scale, source note, date of creation, accuracy diagram, graticule, legend, and so forth, are part of the map and add to clarify information in the map image area.

Thus, a map is defined as an entity consisting of a collection of selected data and their spatial relationships, and of marginal and other supporting information, all designed to communicate a specific set of understanding through presentation.

Fundamental Cartographic Operations

Implicit in the definition of a map are the cartographic operations necessary to produce one. Basically, the operations are conceptualizing a design to fulfill the map's purpose, evaluating and gathering source data, manipulating the data to prepare the geographic and thematic map components, map preparation including marginal and other support

information, and map production to the desired media and form; each of which is appropriate in both the manual and automated systems.

Conceptualizing a design to fulfill the map's purpose The cartographer relies on experience and skills to conceive of a design that fits the map's purpose. This usually is arrived at by sketching and reworking the basic layout and content of the map. From this is developed a list of what is needed to execute the map and a plan for the production.

Any future systems should allow for just such free-form design work. And the system should be able to identify what sources, symbol libraries, and so forth will be needed to execute the design; or at least assist in the identification.

Evaluating and gathering source data This activity involves an analysis of the content and data relationships of available digital databases. Future systems should have a way of "cruising" through different geographic and thematic databases so the operator can make reasonable judgements as to a database's applicability and difficulty of use for this design. An example from both traditional manual and automated production would be:

Manual - deciding if a base map must be re-scribed to show only some general background information for use in the final map.

Automated - deciding if selected items must be extracted from a digital geographic database and processed through a generalization operation for use in the final map.

Manipulating the data to prepare the geographic and thematic components Here the cartographer performs the "drafting" operations. These include operations related to, but not limited to, symbolizing, projecting, layout, and so forth. This is the preparation of the basic map image area.

Preparing the map This is where the final touches are added to the layout, where the legend, scale, marginal information, accuracy or quality statement or diagram, source notes, and so forth are added.

Producing the map to the desired media and form This activity includes printing, storage on CD-ROM, display on a screen, or whatever the map's purpose requires.

Large, traditional map production systems have very formal procedures for achieving the steps outlined above. They organize, and schedule them in ways that are quite efficient for the production of large quantities of maps of a standard design. Smaller cartographic units go through the same types of steps, but usually with fewer time consuming formal procedures. Today's automated cartographic software and systems are capable of bringing many of these activities together into even fewer formal, externally managed steps. Indeed, that is one of automation's strengths.

A MAPPING SYSTEM FOR TOMORROW

Automation has witnessed a revolution in output media. Magnetic tape slowly slips to museum displays alongside paper tape and punch cards while CD-ROM, electronic communication of images, and even virtual reality move to the forefront. Crude monochrome display screens are now replaced by ones with much higher resolution and mega-color capability.

The impact of output media on map design limits options and capabilities more than any other component of an automated mapping system. Maps are designed for the final output device (as they were designed for the final print media characteristics in the past). The output media now are plotters, display screens, and printing presses. Digital map files are embedded with the peculiarities of the intended output device. A map file used on multiple output devices carries with it design embellishments and flaws of the primary device for which it was designed.

Design issues

The design of tomorrow's mapping systems must be guided by several key concerns. The three most significant address issues related to learning, using, and map quality.

Ease of learning The software, and whole production system, must be easy to use (intuitive). Having a system that requires the user to read volumes of manuals or attend expensive mandatory training classes is not only user unfriendly, but counter productive to producing quality maps.

Labor dependence of software The number of systems designed around interactive mapping activities far exceeds the number of systems using a batch method for map production. The software tool has replaced the manual pen and scribing tools, but at what benefit? Without question, automation is the better alternative in most situations and by its very nature provides vast opportunities for map production and cost savings. The number and variety of maps produced by automation surpasses those previously produced by conventional methods. The time required to construct the map and the labor and materials costs associated with conventional map production contributed to the push into automation. The issue is to reduce the dependence on human interaction within mapping systems.

Many of the software packages today can and do place text on maps. Few, if any, place the text in cartographically appropriate and ascetically pleasing positions. Most require extensive intervention on the part of the human operator to handle situations such as overlap, rotation, and leader line or arrow placement. Not only are these operations not handled automatically by the systems with only limited human intervention, they are not even recognized by the systems as needing human action. This means humans must search for text placement problems. Exasperating as this is, many systems then require a difficult series of commands that must be executed just to adjust even a single piece of text.

Map quality Future systems must be able to ensure quality to the point where the map message is communicated accurately and clearly. The systems must be able to warn the user when a fundamental cartographic rule is being violated, even if the software cannot automatically fix the

problem. The system must be capable of providing alternative solutions to poor design decisions made by the user.

Components

Parts that comprise the entirety of the mapping system extend beyond the mere combination of hardware and software that form the working tools of the map production process. There are distinct program modules, and systems within systems that interact in complex ways to effect a simple solution (procedure). Examples of components include: user requirements (specifications); various mapping program modules; symbol libraries; editing functions; education and training mechanisms; computer hardware; and a production control system.

User requirements Those characteristics that satisfy the customer are the user requirements. The user has a purpose for the map. User requirements are stating how these will be fulfilled.

Mapping program modules Generally, the more modular the mapping functions, the more flexible the mapping system. Mapping programs perform the functions necessary to access and process the data, including any required links with internal and external data sources such as symbol libraries and statistical data sets respectively. Mapping programs prepare the data for cartographic output. Chaining together data that share the same cartographic symbolization is an example of data preparation. Maintaining intelligence about each of the component parts of the chain for future processes exemplifies higher-level programming modules.

Symbol libraries. Symbols are graphic representations assigned to classed data and, if designed well, contribute to the map readers' understanding of the map message. Previously, symbols were designed and produced based on the emphasis of the data item as well as the interaction with other symbols. This action oftentimes is a function of map scale.

Today, symbol design is further complicated by the limitations of the output device. The same dot size and density of an areal screen on a high resolution plotting device is very different on a low resolution screen. Conversely, symbols differentiated by a 256 color palate monitor loose their discriminating meaning on a monochrome laserwriter.

Symbol use also is affected by automation. The order and sequence of applying cartographic symbols are more complicated as the rules of computer systems are fixed, even where multiple iterative attempts are allowed and applied. The result is a stringent interpretation of encoded rules whereas a cartographer, even in an interactive mode, applies "cartographic license" based on what is known, perceived, and felt.

Editing functions In order to accommodate map requirements that exceed the built-in capabilities of the mapping system, or to adjust the map image to maximize quality, editing functions enable the user to improve those capabilities or to alter the map image. Ultimately, the less editing required, the more effective the production capacity of the mapping system.

Education and training Intuitive use of a system is most desirable. As more complex functions are added to systems, there is a tendency to

complicate the learning required to simply use the system. Regardless, a mapping system should provide users with whatever information (and examples) are needed to maximize its use. Weeks and months of training should not be a prerequisite for use.

Computer hardware An assumption for current and future mapping system development is open architectures. Systems that are device dependent are doomed to fail over the long term. Both software and hardware must be portable in order to serve the greatest number of users. A user of a mapping system should not have to write a program to convert anything. Those conversions should be embedded as a function of the system. This does not mean a pull-down menu of choices in which the system inevitably fails to support the user's requirement. Rather, the system should recognize the data structure, process the information correctly, and import the map data.

Production control system The creation of multiple maps usually warrants a system that monitors the mapping process. The system not only reports the whereabouts and status of the production flow, but it also reports map errors via automated editing procedures implemented throughout the production cycle. Production control is an excellent weather vane on the efficiency of the mapping system. Automated checks on the process contribute to future development requirements.

THE CARTOGRAPHER'S POSITION

The dramatic change in methods for creating maps has effected a change in the role of the cartographer. Not only has the availability of commercial mapping software given everyone with a desktop computer access to make their own maps, but even in larger map production facilities, the power of automation has increased the number of map makers who are not trained in cartography or related fields. This begs the question, "What is the position of the cartographer in future map making operations?" There are several possible answers.

Possibility 1. Designs, initiates, implements, and uses automated cartographic systems in one or more of the following ways: determines requirements; specifies content and system functionality; writes computer program modules; tests system effectiveness; provides mapping and system development expertise to support staff; instructs mapping system users; and designs, compiles, and produces maps using the system. (This is the most proactive role for the modern mapmaker in which the knowledge, skills, and experience of the cartographer direct and guide mapping system technology and assure it is founded on sound cartographic principles).

Possibility 2. Involved in developing and implementing cartographic design rules within the software. (This is a participatory role in mapping system development but it leaves aside many valuable skills that the cartographer can contribute to the map production operation. An example of a skill in early phases of mapping is a knowledge of source materials and how to integrate them into the final product).

Possibility 3. Developer of guidelines for software users to apply when evaluating the quality of their final map product. (The cartographer is on the outside looking in and is passively participating in a manner which

depends heavily upon the software user to take the extra step for quality, an action not common to human nature).

Possibility 4. Withdraw from the active production of maps and deal only with research into the meanings, messages, and methods of cartography, that is, make it an abstract academic research specialty that provides professional criticism of mapping systems. (Cartographers become observers and drop out of the mapping process. This seems to be the line of least resistance, but ultimately costs the most. Inevitably, this could reduce cartography to a sub-topic under graphic arts within the fine arts department).

Possibility 5. Increase the involvement of cartographers in more aspects of education at all levels, even non-geographic fields of study, so that future users will have or understand the need for cartographic principles and quality. (This requires an extensive effort on the part of the field. It also demands a long term commitment. However, the payoffs are highest, indeed greatest, to both the discipline and users of maps as a means of communication. The involvement should be implemented regardless of which position the cartographer assumes in future endeavors).

TRAINING TOMORROW'S CARTOGRAPHERS

Fundamentals, Fundamentals, Fundamentals
Cartography, as art and science, mandates a renaissance approach to a diverse discipline.

Formal cartographic training A well-rounded education in map design and production processes (both historical and modern) provides a sound foundation for map-related work, particularly mapping applications. The evolution of an effective map from creativity of the map theme through the visualization of a symbolized image carries terms that are subjects unto themselves: source; perception; point, line, and area; scale; color; font; ink; file; resolution; printing; accuracy; plot; software; geographic; dimension; projection; label; paper; symbol; placement; (tele)communication; interpretation; and others. Skill in each of these areas is necessary.

Geography Map subjects are infinite. Cartographers should learn basic facts about the map theme in order to design it appropriately. General knowledge of geography complements facts, content, and the map purpose and improves the effectiveness of imparting the map message.

Logic and mathematics The ability to solve complex problems (usually without formulas, theorems, and equations) is a normal mapping responsibility. Identifying a problem and/or a system shortcoming followed by a problem-solving, step-by-step approach that leads to a solution, is a required staff trait for mapping system development. Efficiency also is important but is secondary to problem-solving. Problem-solving at this level is based on the ability to deal with individual details while keeping in view the "whole."

Computer science Automation is the tool. A cartographer must know, appreciate, and respect the capabilities and limitations of the mapping environment. Computer programming skills in one or a variety of forms is highly desirable. Knowing basic functions such as how a machine draws a

line or links two discreet elements aids in understanding how those same machines perform what appears to be more complex actions. It allows the cartographer to speak intelligently and effectively about the automation of cartographic operations.

Communication skills. Most of what has been described requires exchange of information, ideas, concepts, plans and so forth. Customer-based cartography, by its very nature, requires extensive interaction on the part of the participants. Effective written and oral communication ability is important. The term "effective" includes the ability to draw out of the customer the map requirements without the user having to learn cartographic technology.

Automation Awareness

Technology continues to evolve. Ten years ago, the computing environment was very different from today, and with time, more options will become available to users and customers. Technology has improved at an increasing rate which limited the scope of specialization on the part of developers.

Cartographers are affected by the same technical pressures. In order to be effective in automated cartography today a cartographer does not necessarily have to be an expert in programming. Rather, it is important that the cartographer knows enough about programming and the capabilities and limitations of different working automated mapping systems. For example, knowledge of the advantages and disadvantages of particular output (display) devices is desirable to make intelligent symbol choice decisions and recommendations. Likewise, a cartographer should know enough about database operations and capabilities as well as how to examine a digital source for content or be able to assess a database's value for a particular cartographic operations.

Cartographers in the traditional mapping environment were skilled in the use of multiple tools and methods for producing artwork. In order to be functional today, cartographers should be skilled in the use of two (2) or more mapping software packages. These skills do not replace formal cartographic education. The intent is not to train cartographers to be operators of two or more packages, but rather to allow the cartographer to experience firsthand how cartographic concepts are executed by the software packages as a result of initiating the program commands. Each package has been designed to perform specific functions, and do so with variable rates of success. The goal for today's cartographer is to design, using the best functionality of systems, an automated mapping system that meets customer demands.

SUMMARY

Designing automated mapping systems is challenging. Altering the goal to include the design of flexible automated mapping systems to meet unique customer requirements causes a rethinking of traditional approaches to current mapping software. The greater the degree of automation, the more complicated the implementation of technical development. Meeting customer requirements is not a static exercise. Continual reassessment of the mapping functions are, and will continue to be necessary.

The field of cartography is experiencing a second wave of change in automation. The shift from traditional mapping techniques to those which used computers was the first phase. A redefinition of the role of cartographers in a world where mapping capabilities are available to users at their desktops currently challenges a profession and an industry in which each is struggling for identity and excellence. This should not be a struggle for dominance, but one of cooperation for quality. The various aspects presented here of an automated system should be the basis of a balanced design that leads to cooperation. Together they provide promise for development of user-friendly, customer-based systems that produce high quality, accurate maps on demand.

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