Cartographic Design Process: Artistic Interpretation With the Geodatabase

An ESRI® White Paper • July 2004

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The Direction of Cartographic Design in GIS

Map production companies seek to answer the call for high-quality maps that must be turned out in a short time frame with low production costs. Customers want traditional cartographic paper maps as well as vector and raster data products. The Internet is influencing product demand as well, so large mapping companies are seeking Web-enabled geographic applications that can access data and publish maps. Traditional computer-aided drawing packages do not meet the rigors of the fast-paced, dynamic industry. Innovations in geographic information system (GIS) technology are underway with the goal of meeting the criteria of quality-oriented mapmakers who have high production requirements. ESRI is combining database driven automation and cartographic functionality that support fast map production and high-end cartographic design.

Cartographers who use typical computer drawing packages appreciate their level of map quality. Unfortunately, because these packages are in file format rather than database driven, they have limitations in setup, automation, data sharing, and data accessibility. The restrictions of traditional drawing programs interrupt the mapmaker's work flow and productivity. ESRI understands the cartographer's high standards and is working toward producing a solution that has the quality of a cartographic drawing package while bringing the advantages of GIS functionality to the mapmaker's table.

ESRI® ArcGIS® 9.x software provides essential cartographic capability. Its enterprise solution uses a centralized geodatabase as the repository for spatial data, thereby avoiding the fragmentation problems of traditional drawing packages. With GIS the cartographer is not encumbered with tile edges but rather works smoothly with continuous data in an open relational database. The newly added world leading Maplex text placement engine significantly reduces labor-intensive tasks of generating and positioning text for cartographic clarity. The Production Line Tool Set (PLTS™), which layers on top of ArcGIS, optimizes the cartographic work flow and the day-to-day tasks of operators of bulk loading, error correction, and job tracking. It has representation styles, layouts, and marginalia for common mapping formats and style models designed for creating defense maps and nautical and aeronautical charts. At ESRI, cartography and map production continue to be integral parts of the development of its software.

Cartographic capability will be further refined in the next generation of ArcGIS software. Through research and development, ESRI has produced prototypes that expand the

cartographer's levels of free representation and deploy the database's ability to model, share, and automate updates.

Mapping: The Constant Human Endeavor

ESRI Commitment to Cartography

Numerous mapmakers use popular computer-aided drawing packages that provide freedom of artistic interpretation for making high-end map products. They differ from GIS because limited information about attributes is kept in separate files that are difficult to access. GIS has the benefit of providing analytical capabilities of sophisticated database modeling systems.

GIS is database-oriented and, therefore, handles data in a single seamless database. Because GIS has always had the capability of managing data over a wide geographic extent, it includes many tools for map projections and for handling large data volumes. GIS can have different data requirements and behaviors (business rules). The functional elements of GIS include data input, storage, management, retrieval, manipulation, analysis and modeling, output, and display.

The GIS model is helpful to users because it sets up a template and helps a variety of industries quickly implement their system. This schema can be as simple or complex as the user's needs require. Once in place, the model, implemented in a smart database, will self-enforce data consistency and data relationship rules established by database management. Without a smart database in place, data consistency is dependent on data entry operators and their understanding of the conventions used by the organization.

ESRI's next innovative step is to develop a cartographic drawing package within ArcGIS that delivers the high-end quality of sophisticated cartographic packages. This paper presents the vision of how ESRI's cartographic drawing package will harmonize cartographic drawing tools with GIS capability.

Throughout the ages, the mapmaker has inspired people by creating representations to help them understand the real world and then to manage and sustain it. Maps are a central device for linking geographic knowledge, management, and sustainability. Geographic knowledge (knowing where things are and what they are like) is the basis for making effective decisions about sustaining, protecting, or improving the quality of an area.

Database and Graphics

GIS geoprocessing is needed for a large portion of the entire mapping process. The remaining portion of the process requires the cartographer's art of design, which brings in detailed representations of the final map. The technical resolve must allow the cartographer to be both artist and engineer, to have the freedom of drawing precise detail, and to deploy high powered GIS technology to develop a polished and professional map product.

From the maps of the 17th century, the world received a new perspective about combining measurement and representation. For centuries, the discipline of cartography

has been a marriage of art and science similar to the art of sculpture and the science of architecture, and the art of design and the science of engineering. Cartography is used in many scientific disciplines such as epidemiology, oceanography, agronomy, and other fields.

The appeal of GIS is that users can create good thematic maps with minimum effort. But cartographer users have felt this automation has been restrictive. Technology, however, has risen to the level that now cartographic tools can work compatibly within GIS. ESRI's technical researchers are making this a reality. The artist can be exact in craft while using the speed and precision of an automated system.

Artistic Interpretation Possible

Interpretation of Data

At the beginning of the computer-generated map era, cartographers rarely referred to a computer database to create maps. Georeferenced data was unavailable and expensive to obtain. But the recent booms in data technology, brought on by remote sensing sciences of satellite imagery and global positioning technology, have made geospatial data easily available. This has changed the cartographer's approach to using the database. Today, nearly every cartographic agency, in some manner, relies on a geodatabase.

Efficient access to geographic data requires geodatabase management; therefore, the cartographer becomes responsible for setting graphic rules and enlisting GIS applications to represent data according to these rules. The three essential components of this process are data management, which is the rigors of organizing, defining, capturing, and cleaning data; technical mechanism, which is the computer program development and application for managing the database, publishing the basic map, and performing automated functions; and interpretation, which is the art of presenting the finished product for a professional, high-end map. A cartographer is most concerned with the interpretation of this data and, by using a computer-generated map will present an artistic rendering useful to the final map reader.

The art of the cartographer's interpretation of a GIS-created product is similar to a musician's interpretation of a composer's score. Figure 1 shows how the Canadian pianist Glenn Gould annotated a composition by Johann Sebastian Bach so that the player could present his professional interpretation of the work to the listening audience. The data is the musical score, the technical mechanism is the piano, and the interpretation comes from the pianist's training and craft.

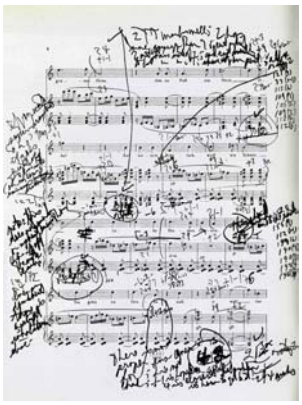

Figure 1

Like the pianist, the cartographer annotates the GIS product to present a professional and artistic interpretation that makes the map come alive for the map reading audience (Figure 2).

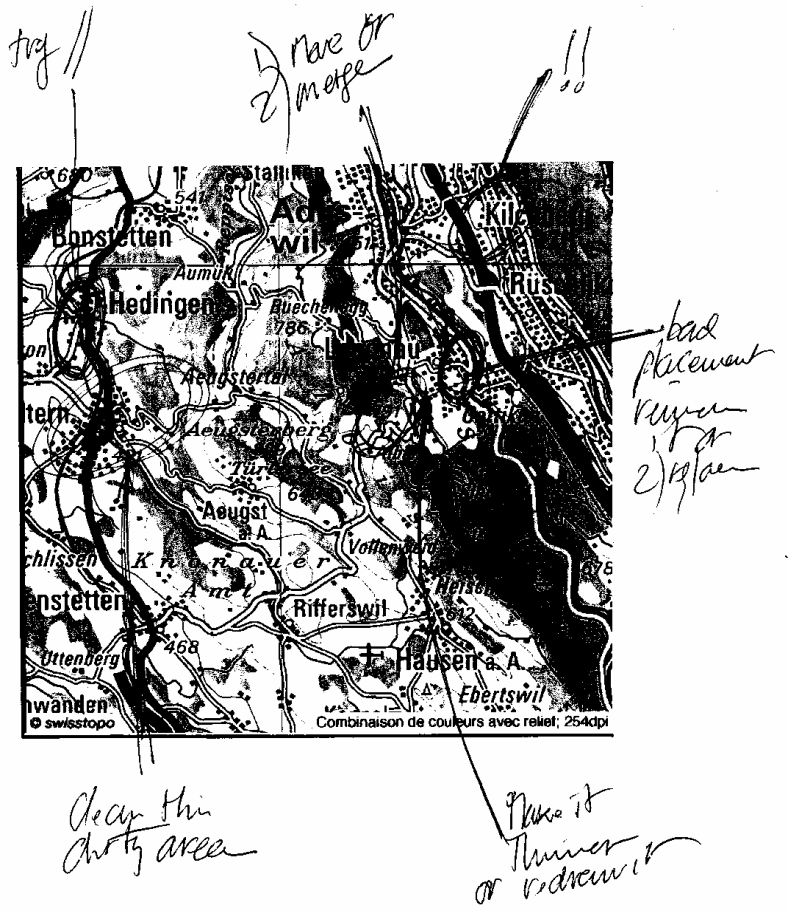

Figure 2

This analogy between musical performer and cartographer is straightforward.

- If the artist begins the interpretation process with good data, the final presentation will be excellent.
- If the artist accesses a high-quality technical mechanism, the final presentation will be rich.
- If the artist's interpretation is created with professional craft and intelligent interpretive judgment, the presentation will be successful in meeting the audience's expectations.

For cartographers to succeed, they must bring all components of data, technical mechanism, and interpretation to their craft. ESRI is seeking ways to technically enable the cartographic industry to succeed with all three aspects: data manipulation, GIS functionality and cartographic tools, and development of professional craft.

Graphic Tools and Geodatabase Side by Side

Real World Represented at One Scale

Cartography represents the real world through appropriate objects and graphic rules according to the scale in a digital landscape model (DLM) database.

ESRI's GIS cartographic system vision is to design cartography technology built on GIS that delivers the same high quality as current cartographic system drawing packages (Figure 3). It uses database technology that will not spoil the map's fine features. ESRI is working toward a system that combines DLM and the digital cartographic model (DCM). This interrelationship allows both the rigor of data management in a seamless database and the freedom of graphic applications to work side by side on the map designer's desk.

Figure 3

Different Approaches to a Cartographic System

Cartographers vary in the way they approach technology. Consider two different cartographic approaches to working with data in a GIS cartographic system.

- The graphic image approach: The cartographer is graphic oriented and uses only basic and simple GIS technology. In this case the cartographer uses a computer application that keeps track of the project graphic files in the database and accesses data from the drawing itself.

- The database feature approach: The cartographer uses skills for database driven technology and accesses the database with a GIS application to automate cartographic processing and map finishing. The GIS cartographic system must accommodate both user styles to meet the demands of varied cartographic methods. It must provide for the essential needs of both styles and be as intuitive as current cartographic drawing packages, but more powerful.

DLM and DCM can be stored together in the same geodatabase, allowing the cartographer access to geospatial data manipulation and automated applications while offering freedom for artistic graphic interpretation.

The Database Driven Map Process

Software that stores map graphics in a geodatabase provides cartographers a complete system that includes data surveying, cartographic data processing, and map update processing. This solution offers the foundational components for developing multiscale editing functions in a seamless database that facilitates automated updates.

Having a seamless database and storing each DCM/scale are particularly valuable for multiscale editing updates. For example, for a cluster of polygons (buildings) represented at scale *a,* a single polygon is represented at scale *b.* The update process must recognize the relationship between the two representations and has to be able to (1) trigger the update, (2) analyze the propagation of the conflicts, and (3) issue resolution options. This type of update resolution is only possible if the geodatabase is able to drive it.

Basic Tenet

The foundations of a multiscale edition from a single seamless feature database relies on a simple tenet: The database must store the DLM and DCM side by side to allow both freedom for the cartographer and automation for production and update processes.

Work Flow

Many cartographic production organizations have a strategic goal of building a digital landscape model in a central database and deriving a range of cartographic products from that. In practice, a single, scale-free DLM with 100 percent automated generalization is usually beyond current technology, so the preferred model has a small set of DLMs of increasing coarseness and a set of associated digital cartographic models. Change data flows from the finest DLM through a set of derivation processes to DCM and the ultimate product.

The schema in Diagram 1 shows how a database driven architecture creates and automates a complex multiscale/representational map process within the geodatabase in a current work flow that, by its architecture, involves the ability of automated updates.

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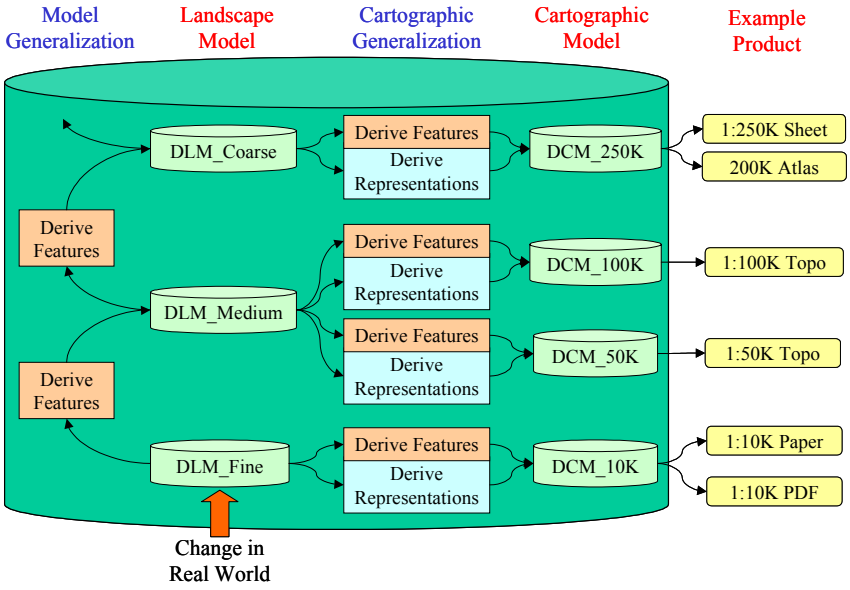

Diagram 1

Meeting Cartographers' Needs

ESRI is working to meet the needs of today's cartographic artisan by improving ArcMap™. This new cartographic system offers the user *freedom* from the database when needed, *interaction* with the database through graphics, *recognition* of features that bridge the DLM and DCM representations, *automation* of high-end map processes and updates, and *customization* capabilities so that the system can be tailored to the rules of DCM.

Freedom to Design Using Traditional Drawing Package Functionality

Freedom to Play With Graphics

Cartographers want to control their drawings. The GIS cartographic system allows the cartographer to change the graphic attribute of one feature, whatever the model constraints are—for instance, to minimize the width of one segment of a road (Figure 4). This would change the look of the road to better fit the placement of structures (Figure 5).

Figure 4

Figure 5

Freedom to Move Representation of Features

The GIS cartographic system allows cartographers to change the place of a feature and the type of model constraints. The mapmaker can move buildings to avoid conflicts with roads.

Freedom to Change Geometry

Cartographers want to redesign objects, simplify them, and make them fit with the scale of the neighborhoods (changing the look of Figure 6 to the look of Figure 7). The GIS cartographic system tool should

- Activate a smoothing function that does not lose the former geometry.
- Allow the cartographer to alter the smoothing both automatically and by hand.
- Maintain geometry versions of the feature.

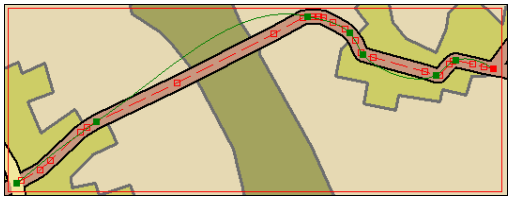

Figure 6

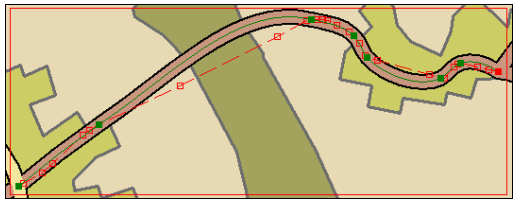

Figure 7

Freedom to Change Density of a Grid

Cartographers want freedom to vary representation. For example, a map's orchards can be represented in various ways. The cartographer must be able to modify the grid's orchard angle to fit with graphic context or to change the density of the trees (Figure 8).

Figure 8

Add as Many Graphic Layers as Needed

The GIS cartographic system should allow the cartographer to add as many layers as needed to display all graphic components of a GIS feature.

Figure 9 shows three graphic image layers displaying the road features.

- Line
- Direction (marker)
- Name

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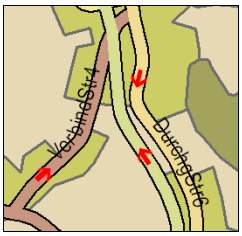

Figure 9

Interact With Database Through Graphics and Tools for Symbology

Use Graphic Tools to Interact With One Feature

Cartographers commonly use graphic tools such as pipette, warp, magic wand, and so forth. These tools must be available to perform standard graphic artwork (Figure 10). Intuitive tools easily help the designer interact with a single feature. For example, a multifield tool interacts with rotation, an *x,y* offset, and the site of the specified feature.

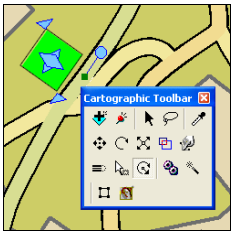

Figure 10

Interact on Pair of Features Using the Drag and Drop Tool

Next, the user wants to display the attribute's label by entirely masking the orchard's trees without clipping. The drag and drop tool should allow the user to drag the text layer on the orchard's multipoint layer and redesign the masking geometry as needed (Figure 11).

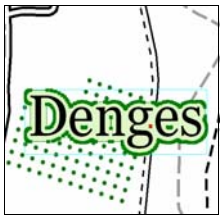

Figure 11

Figure 12

To change the orientation of a grid, cartographers want drag and drop tools that automatically reorient the feature. For example, an orchard is represented at one scale and is aligned on a grid whose angle is along a road. The drag and drop tool should allow the user to drag the road and drop the orchard and then automatically reorient its grid (Figure 12).

Recognition of DLM for Creating Graphics

Figure 13 shows a pair of escarpment line captures drawn with Swisstopo DLM (from the Swisstopo Web site, www.swisstopo.ch). A GIS cartographic system must understand this and allow the drag and drop tool to create the correct symbolization such as triangles whose size is otherwise constrained by DLM lines (Figure 14).

Figure 13

Figure 14

A GIS cartographic system should provide cartographers with symbolization that can be edited manually (Figure 15). In addition, once samples and adjustments are completed, the user can then perform automatic edits for all like features on the map.

Figure 15

Edit Processes to Create Cartographic Features

In many cases, cartographers have to create their own objects to represent some of the attributes contained in other features. For example, the cartographer drawing freeway overpasses in Figure 16 would like to automatically process the design of parapets and perform masking by manually using the drag and drop tool (Figure 17) to represent "upon–below" relationships between the two roads at the intersection.

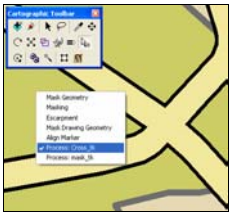

Figure 16

Figure 17

Based on the information about road attributes stored in the database, an edit process will be triggered to design parapets and masking that create nice looking overpass symbols (Figure 18).

Those intermediate objects must be in relationship with parent features such as roads. If they are updated, by either representation or geometry, overpass representations must be triggered through the link they have with their parents (Figure 19).

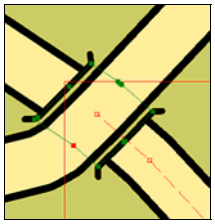

Figure 18

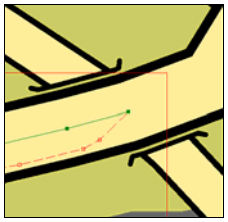

Figure 19

Automated Map Processing

The cartographer wants to use the freedom of cartography tools to draw and design and then use the automation of geoprocessing tools to create the map. Every hand tool available in the GIS cartography system must have a complementary GIS tool to ensure the automation of map finishing.

Graphic Conflict Detection and Resolution

Once the map finishing process is complete, cartographers want tools that easily resolve graphic conflicts with all the layers they have built for one map series at one scale. This resolution should be repeated continually for all the maps included in the work flow.

Maintain Map From DLM Updates

Map publishing companies want to maintain map information by using DLM updating processes. Because the digital cartographic model is placed beside the digital landscape model in ESRI's geodatabase, geoprocessing functions can naturally update all the representations linked to one feature for the entire map. This is a tremendous advantage, especially for large mapping agencies. DCM saves the cartographer's manual drawing effort even during the update process.

Customize Program Functions

Cartographers want to customize or create cartographic tools. A software development kit (SDK) tool is used to create program functions in Visual Basic (VB). Because all graphic and drawing geometry attributes are in the database, SDK will offer VB programmers a simple way to solve cartographers' customization needs. For example, a team of cartographers can use the SDK tool to develop drag and drop tools that apply to graphic rules they have set (e.g., make the angle of the orchard's grid the same as the angle of the nearest road).

Natural Relationship of Cartographic System

System Implementation

Geospatial data management technology improves with each new release of ArcGIS software. The ArcGIS 9 release adds more capability to the database such as annotation of graphics that is described entirely in fields.

The beauty of the GIS cartography system is that the cartographer has a drawing package that easily avails itself to a host of GIS capabilities. This includes, for example, the ability of an enterprise GIS that is integrated with the standard architecture of the company, making shared geospatial data accessible to many users. This means the cartographer can store graphic work (art) beside data features (structure) so the graphics can be shared and updated along with other geospatial attributes in the database.

The cartographic system has a natural relationship with GIS that allows the user to have override options, thus giving authority to the user to freely read and write on the work. The override function would not destroy the data feature, and the user would still be able to deploy automatic update mechanisms such as DLM feature updates.

ESRI software designers are working toward developing strong cartographic GIS tools. These designs are forged from a larger context of architecture that allows for adding to and customizing a program's functionality. ESRI has a policy of building products with scalability, extendability, and interoperability into its software. This makes it possible for these products to accommodate future innovative technologies that will serve today's cartographers.

ESRI's Continued Support of Cartographers

ESRI is dedicated to helping cartographers meet their goals of developing high-end maps by enhancing the process with the speed and precision that GIS offers. This next step of development provides a cartographic system that will be the first cartographic database driven solution that includes artistic symbolization capability.

The cartographer's work should easily flow from one task to another, freeing the artisan to efficiently move back and forth between drawing functionality and database update automation. This places the authority of the final refinement of interpretation with the artist. High-level cartographic automation interaction with a database can produce high-end maps.

Because of the low cost and high availability of data, the current trend is to use geospatial data in a database. Mapmakers need both the artistic skills of interpretation and design

and the technical skills required by GIS. In addition, they will most likely be responsible for the entire mapping project. As with all professional industrial technologies, cartographers must be equipped to meet the demands of information technology systems. Cartographers who add GIS to their working skills may also want to consider adding skills that allow them to work at the level of a graphic database administrator. ESRI provides professional development training by offering a wide range of learning opportunities and access to an experienced support community. Educational programs will be available to those needing to acquire the knowledge to be a company's representative database administrator.

ESRI seeks the help of the cartography community in realizing the vision for a database driven cartographic design processing system. This insight is invaluable to software designers for creating a highly useful, real-world solution. ESRI representatives attend conferences at national and local levels and are advocates of shared geographic system technology. User group meetings provide a venue for sharing ideas and creating professional networks. ESRI is committed to meeting the needs of the cartographer in the present technological age and to fulfilling the needs for meeting cartographic demands of the future.