GIS CARTOGRAPHY FOR TOPOGRAPHIC MAPS SERIES

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Abstract
Cartography is a sophisticated pursuit that is best left in the hands of experts and should be limited to trained professionals. The transition to digital technology had both technical and economic impacts on cartography. On the technical side, it allowed entirely new approaches to map design that escaped the constraints of manual cartography. For example, colour could also be varied continuously, leading to vastly more possibilities in the portrayal of spatially continuous phenomena such as topography.
Automation of cartography, and particularly the thorny problem of automatic generalization, remains a concern of cartographers.
The power of GIS lies in its ability to improve on past practice, rather than to replicate it in a digital environment. GIS packages include support for sophisticated cartographic techniques, such as methods of symbolization and cartographic generalization.
Topographic maps series have common standard symbols are easily designed and stored in GIS library for efficient map symbolization.

***Keywords**: Cartography, GIS Cartography, Symbolization, Generalization, Topographic maps series,Topographic Mapping*

INTRODUCTION

Cartography concerns the art, science, and techniques of making maps or charts. Conventionally, the term map is used for terrestrial areas and chart for marine areas, but they are both maps in the sense the word is used here.

Cartography dates back thousands of years to a time before paper, but the main visual display principles were developed during the paper era and thus many of today digital cartographers still use the terminology, conventions, and techniques from the paper era.

Historically, the origins of many National Mapping Agencies, NMAs, can be traced to the need for mapping for ‘geographical campaigns’ of infantry warfare, for colonial administration, and for defense. Today such agencies fulfill a far wider range of needs of many more user types. Although the military remains a heavy user of mapping, such territorial changes as arise out of today conflicts reflect a more subtle interplay of economic, political, and historical considerations – though, of course, the threat or actual deployment of force remains a pivotal consideration.

Manual methods of cartography to produce paper maps was a time-consuming and exacting blend of art and science undertaken by teams of cartographers using pens, ink, and scribe tools.

GIS CARTOGRAPHY

Modern advances in GIS-based cartography make it easier than ever to create large numbers of maps very quickly using automated techniques once databases and map templates have been built. Creating databases and map templates continue to be advanced tasks requiring the services of trained professionals. The type of data that are used on maps is also changing – today maps often reuse and recycle different datasets, obtained over the Internet, that are rich in detail but may be unsystematic in collection and incompatible in terms of scale. This all underpins the importance of metadata to evaluate datasets in terms of scale, aggregation, and representativeness prior to mapping. Collectively these changes are driving the development of new applications founded on the emerging advances in scientific visualization that will be discussed in the next chapter.

In the last 25 years, digital methods of cartography and a broader range of products many of which are also digital have been introduced. Recent advances in database technology for managing GIS spatial data have been embraced by NMAs worldwide and promise to further revolutionize the way the Agencies fulfils its national mapping obligations. For instance, many of them have produced an object-oriented seamless topographic database for the entire natation and developed tools in ArcObjects™ for the automated pushbutton production of hard-copy maps.

Many NMAs rely on Esri ArcGIS system for map production, from data extraction to data production. First, data is extracted from existing databases. The data is then checked for position against satellite imagery or aerial photography and for attribution against intelligence gathered from a variety of sources including state and local governments; publications; and older, large-scale maps.

Field mapping is undertaken to upgrade the accuracy of roads and other infrastructure features and to broadly check the validity of the data. Formal data validation is undertaken to ensure that the data meets quality requirements as defined in the database specification.

Checks for completeness, positional accuracy, attribute accuracy, and logical consistencies are performed.

On passing validation, the data is checked back into the national database, and a largely push-button approach is undertaken to output print files for color maps.

A map is the digital or analog (soft- or hardcopy) output from a GIS that shows geographic information using well-established cartographic conventions. It is the final outcome of a series of GIS data processing steps Fig. (1) beginning with data collection, editing and maintenance, through data management, analysis and concluding with a map. Each of these activities successively transforms a database of geographic information until it is in the form appropriate to display on a given technology (Longley et. al, 2005).

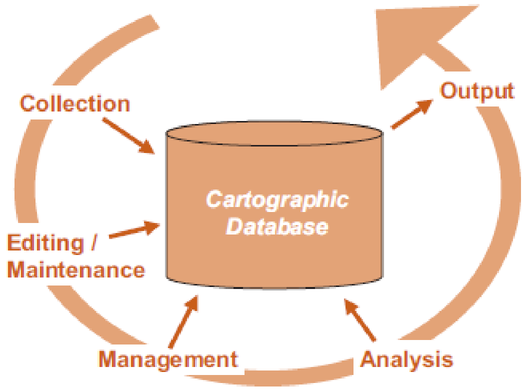

Figure (1) GIS processing transformations needed to create a map(Longley et. al, 2005)

Central to any GIS is the creation of a data model that defines the scope and capabilities of its operation, and the management context in which it operates.

Implementing GIS throughout NMAs enables faster workflow, easier maintenance of data, and cost efficiencies in terms of the ability to generate multiple products—digital and hard copy—from a single database.

GIS also make it easier to attract younger staff who see the potential of the new technology and the broader range of career options it offers them, such as in the fields of analytic GIS, map production, and data management.

GIS enable to automate cartographic symbolization, text placement, and the building of the map surround so that the map technician would be able to publish maps very fast. Since users of topographic maps expect a high caliber of cartographic quality and content, there were several challenges to overcome.

The territory interpretation and analysis can be developed with the support of the cartography, unavoidable tool for modern world. The growing needs for using the cartography has experienced a wide and important impulse nowadays.

Paper maps remain in widespread use because of their transportability, their reliability, ease of use, and the straightforward application of printing technology that they entail. They are also amenable to conveying straightforward messages and supporting decision making. Today mapping must be capable of communicating an extensive array of messages and emulating the widest range of 'what if' scenarios.

Both paper and digital maps have an important role to play in many economic, environmental, and social activities.

The visual medium of a given application must also be open to the widest community of users. Technology has led to the development of an enormous range of devices to bring mapping to the greatest range of users in the widest spectrum of decision environments. In-vehicle displays, palm top devices, and wearable computers are all important in this regard. Most important of all, the innovation of the Internet makes 'societal representations' of space a real possibility for the first time.

Maps fulfill two very useful functions, acting as both storage and communication mechanisms for geographic information. The old adage 'a picture is worth a thousand words' connotes something of the efficiency of maps as a storage container. The modern equivalent of this is 'a map is worth a million bytes'. Before the advent of GIS, the paper map was the database, but a map can now be considered a single product generated from a digital database. Maps are also a mechanism to communicate information to viewers. Maps can present the results of analyses (e.g., the optimum site suitable for locating a new store, or analysis of the impact of an oil spill). They can communicate spatial relationships between phenomena across the same map, or between maps of the same or different areas. As such they can assist in the identification of spatial order and differentiation. Effective decision support requires that the message of the map is readily interpretable in the mind of the decision maker. A major function of a map is not simply to marshal and transmit known information about the world, but also to create or reinforce a particular message. Maps are both storage and communication mechanisms.

GIS has fundamentally changed cartography and the way maps are produced, used, and thanked about. GIS cartography of frees map-makers from many of the constraints inherent in traditional (non-GIS) paper mapping.

TOPOGRAPHIC MAPPING

Topographic mapping is defined as the art, science and technology to locate points near the earth surface, to derive geometric structures from these points and to monitor a set of static and dynamic attributes associated with these structures. Points form basic and complex geometric structures such as lines, polygons, areas, parcels, surfaces, etc. These points are necessary to map the entire earth surface or a part of it (Hatzopoulos, 2008).

Currently topographic maps are mass produced from GIS databases include roads, hydrography, contours, boundaries, cultivation cover, structures, geographic names, worldwide topographic map series is the 7.5-minute series, published primarily at 1:25,000 scale

Common cartographic scales: For Topographic Maps, 1:25,000 (7.5 ' x 7.5 ' quads), 1:50,000 (15 ' x 15 ' quads), 1:100,000 (30 ' x 30 ' quads), 1:250,000 (1.5° x 1° quads), 1:500,000 (3° x 2° quads) and for World Maps 1:1,000,000 (6° x 4°).

MAP SERIES

A map series is a collection of map pages (also known as map sheets) built from a single layout that represents a geographic area. The most common type is a spatial map series where each map page displays a portion of the larger geographic area based on a feature's geometry.

For example, a spatial map series might contain an individual map for each county in a state, each country in a continent, or each parcel in a new subdivision. Each page, or sheet, in a map series also typically contains map elements such as the map title that change to reflect the name of the area shown in the particular map sheet.

Map series gives you the ability to generate a set of output pages by using a layout and iterating over a set of map extents. The extents are defined by the features in a layer and are sometimes called tiles, sections, or areas of interest (AOI). The layer that defines the extents is referred to as an index layer. Any feature layer can serve as the index layer.

A single layout defines the map composition for each map series page. Only dynamic parts of the layout change with each page; static elements stay the same. Any changes made to static elements of the layout will be reflected on each page of the map series.

For example, a map series can be based on a regular grid of polygons with a town parcels. Using an index layer representing a grid, a series of pages of equal area can be produced that cover the town as shown in Fig. (2) below:

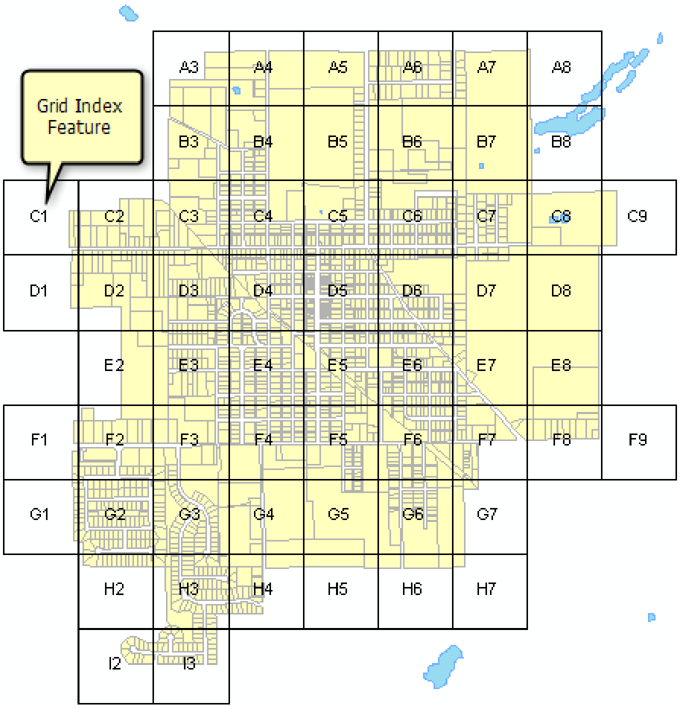

Figure (2) A series of pages of equal area.

The features in the index layer can be non-contiguous, overlapping, and represent various shapes and extents. The features can be points, lines, or polygons. The extents for line and polygon features are based on the feature's spatial envelope. For example, a polygon layer representing political boundaries can be used to drive the extents for each map sheet. Points can also define an extent when a scale is provided. Non-feature layers, such as raster layers, cannot be used for the index layer.

MAP COMPOSITION

Map composition is the process of producing a map comprising several closely interrelated elements (Longley et. al, 2005):

- The main map body, which is the principal focus of the map. It should be given space and use symbology appropriate to its significance.
- Overview map may be used to show the general location or context of the main body.
- Title. One or more map titles are used to identify the map and to inform the reader about its content.
- Legend. This lists the items represented on the map and how they are symbolized. Many different layout designs are available and there is a considerable body of information available about legend design.
- Scale. The map scale provides an indication of the size of objects and the distances between them. A paper map scale is a ratio, where one unit on the map represents some multiple of that value in the real world. The scale can be symbolized numerically (1:1000), graphically (a scalebar), or texturally (‘one cm equals 250 m’). The scale is a representative fraction and so a 1:1000 scale is larger (finer) than a 1:100 000. A small (coarse) scale map displays a larger area than a large (fine) scale map, but with less detail.
- Direction indicator. The direction and orientation of a map can be conveyed in one of several ways including grids, graticules, and directional symbols (usually north arrows). A grid is a network of parallel and perpendicular lines superimposed on a map. A graticule is a network of longitude and latitude lines on a map that relates points on a map to their true location on the Earth.
- Map metadata. Map compositions can contain many other types of information including the map projection, date of creation, data sources, and authorship.

A key requirement for a good map is that all map elements are composed into a layout that has good visual balance. On large-scale maps, such as 1:50 000 national mapping agency topographic maps, all the contextual items (everything listed above except the map body) usually appear as marginal notations (or marginalia).

SYMBOLIZATION

Symbols graphically describe, categorize, or rank geographic features, labels, and annotation in a map to locate and show qualitative and quantitative relationships. Symbols are one of four types—marker, line, fill, or text—depending on the type geometry they draw. They are generally applied to groups of features at the layer level, but graphics and text in a layout are also drawn using symbols. Symbols can be created and applied directly to features and graphics, and they can be optionally stored, managed, and shared in collections called styles Fig. (3).

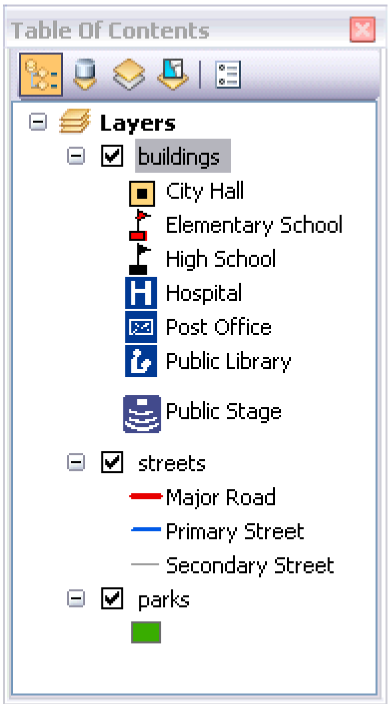

Figure (3)Symbols categorize and draw features in a layer.

The data to be displayed on a map must be classified and represented using graphic symbols that conform to well-defined and accepted conventions. The choice of symbolization is critical to the usefulness of any map. There is not a single universal symbology model applicable everywhere, but rather one for each combination of factors. Again, cartographic design is a compromise reached by simultaneously optimizing several factors.

Good mapping requires that spatial objects and their attributes can be readily interpreted in applications. attributes were classified as being measured on the nominal, ordinal, interval, or ratio scales, while spatial objects were classified into points, lines, areas, and surfaces. We have already seen how attribute measures that we think of as continuous are actually discretized to levels of precision imposed by measurement or design. The representation of spatial objects is similarly imposed – cities might be captured as points, areas, mixtures of points, lines, and areas Fig. (4) or 3-D 'walk-throughs', depending on the base-scale of a representation and the importance of city objects to the application. Measurement scales and spatial object types are thus one set of conventions that are used to abstract reality. Whether using GIS or paper, mapping may entail reclassification or transformation of attribute measures.

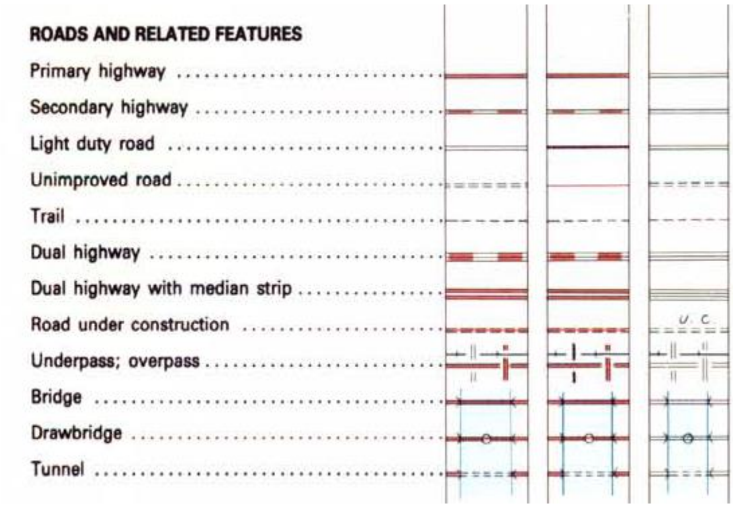

Figure (4) The representation of spatial objects by symbols

The process of mapping attributes frequently entails further problems of classification because many spatial attributes are inherently uncertain. For example, in order to produce a map of occupational type, individuals' occupations will be classified first into socioeconomic groups (e.g., 'factory worker') and perhaps then into super-groups, such as 'blue collar'. At every stage in the aggregation process we inevitably do injustice to many individuals who perform a mix of white and blue collar, intermediate and skilled functions by lumping them into a single group (what social class is a frogman?). In practice, the validity and usefulness of an occupational classification will have become established over repeated applications, and the task of mapping is to convey thematic variation in as efficient a way as possible.

Attribute Representation and Transformation

Humans are good at interpreting visual data – much more so than interpreting numbers, for example – but conventions are still necessary to convey the message that the map-maker wants the data to impart. Many of these conventions relate to use of symbols (such as the way highway shields denote route numbers on many US medium- and fine-scale maps; Fig. (2) and colors (blue for rivers, green for forested areas, etc.), and have been developed over the past few hundred years. Mapping of different themes (such as vegetation cover, surface geology, and socio-economic characteristics of human populations) has a more recent history. Here too, however, mapping conventions have developed, and sometimes they are specific to particular applications.

Attribute mapping entails use of graphic symbols, which (in two dimensions) may be referenced by points (e.g., historic monuments and telecoms antennae), lines (e.g., roads and water pipes) or areas (e.g., forests and urban areas). Basic point, line, and area symbols are modified in different ways in order to communicate different types of information. The ways in which these modifications take place adhere to cognitive principles and the accumulated experience of application implementations. The nature of these modifications was first explored by Bertin in 1967, and was extended to the typology illustrated in Fig. (4) by MacEachren. The size and orientation of point and line symbols is varied principally to

GENERALIZATION

Within cartographic circles automatic generalisation is one of today buzzwords but yet remains one of the most difficult goals to achieve and is hence a subject of intense research activity.

NMAs the need of automatic generalisation is of significant interest. With automatic generalisation NMAs are able to not only improve and streamline their map production lines but also save important resources such as time and money. It is for these reasons that many NMAs are either in the process of, or have already introduced automatic generalisation.

Sometimes GIS data contains an excess of detail or spatial information than what is needed for the scale of the map being prepared. Generalization is the method used in GIS to reduce detail in data. For example, a small scale map of the United States does not need detailed coastlines or a map of California does not need to show every road in the state.

Generalization can be achieved by removing detail, such as only showing major roads, showing only the boundary of a state instead of all the counties. In GIS generalization is also used to smooth out lines, removing small detail such as the nooks and crannies of a coastline or the meanderings of a stream.

Since detail about a geographic feature is simplified during generalization, generalized data is less spatially accurate. Those using generalized data to calculate length, perimeter, or area will incur errors in the calculations.

Depending on whether you are generalizing vector or raster data, there are different tools for generalizing GIS data using ArcGIS.

There is a toolset in the Spatial Analyst toolbox in ArcGIS that allows for several different methods of generalization on raster data. The generalization tools in the toolset are grouped into three categories: Aggregating zones of data (Nibble, Shrink, Expand, Region Group, and Thin), smoothing data edges (Boundary Clean and Majority Filter), and reducing the resolution of a raster (Aggregate).

For vector data, ArcGIS has a Generalize tool in the Editing toolset which uses the Douglas-Peucker simplification algorithm to simplify lines. For additional generalization methods, the Generalization toolset found in the Cartography toolbox offers a range of tools for simplifying and reducing resolution of vector data for cartographic purposes Fig. (5).

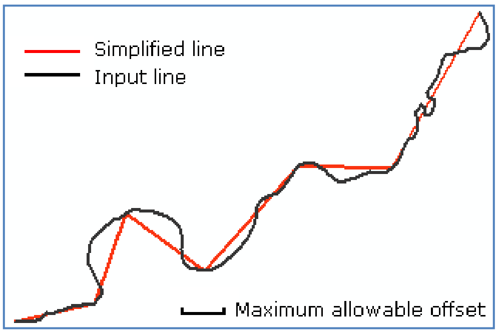

Figure (5) Smoothing a line using the Generalize tool in ArcGIS. Image: Esri.

The Cartographic generalisation plays a key role in producing topographic map series – particularly in today digital cartography, where generalisation tools are an essential part of any Geographic Information System (GIS) (Weibel, 2004). At the present time the amount of spatial data is increasing rapidly. Therefore, new solutions are needed to innovate the map production process of topographic maps in order to save valuable resources. So helping to ensure efficiency and maintain update cycle without suffering any loss of quality. Therefore, the automation of generalisation is a subject of intense research activity and one of the most discussed topics at present (Burghardt et al., 2014).

Brassel and Weibel already stated in 1988 that "generalisation is a fuzzy concept and is not well defined". Due to this fuzziness and the importance of the topic, there has been a significant amount of research done to provide and improve possibilities of automating the most critical and repetitive tasks in map production. Since the second half of the 20th century a number of different rules and approaches have been defined for coping with the problem of automatically generalising small scale maps from a large scale base (Weibel, 2004).

For many NMAs the need for automated generalisation is from significant interest [(Duchêne et al., 2014) in (Burghardt et al., 2014)]. With automated generalisation NMAs are able to improve their map production lines and so save important resources such as time and money. This process leads to the other big advantage of being able to derive their smaller scale datasets from a single maintained database (Foerster et al., 2010). For these reasons many NMAs have already introduced automated generalisation and for all the others it can only be a matter of time before they will follow down this path.

The NMAs are responsible for the national survey of their nations and production of the national maps. Many NMAs already use automatic generalisation in their map production, are however constantly seeking new approaches and methods to further increase their efficiency. At present the final quality control of all mapping products is still done manually by the skilled cartographic workforce.

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BIOGRAPHY

Dr. Elsayed Ammar, acquired his PhD in Surveying engineering (Surveying and Photogrammetry), from Benha University, Egypt in 2010. He was working in the Egyptian Military surveying Department in the period from 1987 to 2009 in the mapping group and GIS centre. His published research on GPR remote sensing has appeared in top scientific conferences such as the Regional conference on Surveying and Development, and the 14th International Conference on Civil Engineering and Geotechnical. Dr. Ammar is currently a lecturer of surveying subjects in the Department of Civil Engineering at Thebes Higher Institute for Engineering, Thebes Academy. Dr. Elsayed Ammar research interests in the domains of geomatics sciences and technologies; remote sensing, photogrammetry, geographic visualization, spatial thinking, and disaster recovery.

Prof. AbdelHalim Mohamed Behairy, acquired his PhD in civil engineering from the City University, London UK in 1986. Since then he joined the Surveying Engineering Dept. as a lecturer then assistant professor and then professor in 1999. He was on a leave teaching in the Civil Engineering Dept., ElMargeb University, Libya from 2007 till 2010. Co-supervised many MSc. and Ph.D students in both Cairo University and Benha / Zagazig Universities in the areas of analytical and digital photogrammetry and remote sensing. He has been on a sabbatical leave in the second half of 2015 to both Carleton and Ottawa Universities, Ottawa, Canada. Prof. Behairy's research interest lies in digital close range photogrammetry, GPR and remote sensing applications.

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