CARTOGRAPHY: GIS AND CARTOGRAPHY (RELATIONSHIP BETWEEN)

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Glossary

Canada Geographic Information System: computer-based system constructed by the Government of Canada in the 1960s, believed by many to be the first GIS

choropleth map: a map depicting statistical data for irregularly shaped reporting zones such as countries, using variations in shading or color

class interval: a range of values associated with a single shade or color on a choropleth map

deconstruction: the scholarly practice of inferring hidden agendas from the content of published material

geovisualization: presentation of geographic information in visual form

Google Earth: an Internet service that allows the user to manipulate a virtual image of the Earth

map scanner: device for converting the contents of a map into a digital image

Mercator projection: one of the most popular ways of distorting the Earth so that it can be shown on a flat paper medium; the Earth is stretched at high latitudes

object-oriented database design: a technique for representing phenomena in a digital database

Synopsis

Cartography as a discipline evolved from the ancient practice of map-making, and its complex set of conventions and techniques. GIS was developed much more recently as a comprehensive computer application for performing a wide range of functions on geographic data. The two fields have converged as digital technology has become more pervasive, and as it provides new opportunities that offer to escape many of the constraints under which manual map-making operated. Cartography is both a science and an art, whereas GIS evolved as a more precise and objective approach to what is observable and measurable about the Earth’s surface, with an emphasis on numerical analysis. While the distinction between the two fields is not as strong as in the past, these nuances remain today.

Introduction

Map-making is an ancient field dating from the first efforts by humans to create pictorial representations of the world around them, by drawing on the walls or mud floors of caves. Cartography, the modern discipline of map design, compilation, and publication, is most often associated with the paper map, a flattened representation of the curved surface of the Earth, but it may also refer to the creation of globes, and increasingly it refers to the use of digital computers to manage the acquisition, manipulation, and eventual display of geographic information on the screens of computers. The advent of digital technology in the 1960s began a transition in the field of cartography that continues today.

Geographic information systems (GIS) are computer applications concerned with the manipulation of geographic information, and today these software packages are capable of the representation, analysis, and visualization of virtually any form of information about the distribution of features and phenomena on the surface of the Earth. The initial developments of GIS occurred in the 1950s and 1960s, as computers became powerful enough to manage the large volumes of data being collected from satellites or digitized from paper maps, and today virtually all geographic information is in digital form, stored in a computer, at some point in its life.

These definitions clearly overlap substantially, and while there might have been a period in the 1960s and 1970s when it was possible to distinguish between a cartography focused on the paper medium and a GIS focused on digital systems, today the distinction is hopelessly blurred. Many cartographers now prefer the term geovisualization, and many GIS professionals consider themselves expert in the design of maps. The following sections explore the many dimensions of the relationship between cartography and GIS, and end with a brief speculation on the relationship's future.

The power of the digital medium

In the 1960s it was not at all obvious that there would be advantages to representing geographic information in digital form. Computers were still regarded as fast calculators, capable of finding numerical solutions to differential equations. They had little memory capacity, and the devices needed to digitize or draw paper maps did not yet exist. When the Canada Geographic Information System (CGIS) was developed it was to serve one specific purpose: to calculate the areas of irregularly shaped features, and to present the results in tabular, numeric form. To do this, a number of historic breakthroughs had to be made. A map scanner had to be built, software had to be designed to perform tasks that computers had never performed before, and methods had to be found to represent geographic features as linear strings of binary digits on magnetic tape.

By the 1970s these breakthroughs had paved the way for the management and manipulation of many forms of geographic data, and for the cartographic production process to begin a slow migration to digital media. Just as word processors allow easy editing of digital text, so cartographers welcomed the ability of digital media to support rapid editing, and to perform the complex numeric operations involved in map projections. Within a decade the entire cartographic process had migrated to digital media, and today it is rare to find any part of the process being conducted manually or in analog form. Geographic data are increasingly digital throughout their life history.

The digital transition, implicit in the development of GIS, had profound effects also on the nature of cartography. No longer were maps condemned to be static once printed, since digital maps could be edited, updated, and corrected at any time. As the graphics capabilities of personal computers grew, it became possible to represent dynamic phenomena, and cartographers began to investigate the potential of animated maps. The acoustic channel, now supported on personal computers with sophisticated sound systems, was explored as a means of augmenting maps, and systems were built that allowed users to interact with maps in both visual and auditory senses. Thus one could explore a digital representation of a wilderness area, zooming to greater detail or accessing textual information associated with specific features, and even hearing the sounds associated with places and their animal inhabitants. Many researchers found the traditional term cartography too limiting as a description of this new, much richer world, and began to describe their field as geovisualization.

Today the effects of this transition can perhaps be seen most clearly in the various virtual globe services that are now available, typified by Google Earth. These services provide access to vast stores of imagery and digital map data through a simple interface that a child of ten can learn in a few minutes. The user is able to visualize geography as if looking at and manipulating a globe, with none of the distortions that are introduced when the Earth is flattened for a paper map. The virtual globe can be manipulated by rotating and zooming, from resolutions of 10 km to less than a meter. Information can be merged from a vast range of sources using the techniques now known popularly as mashups, and these extend to three-dimensional representations of buildings and structures. The user's viewpoint can be shifted from vertically above to oblique, and it is possible to simulate a flight over the surface.

Google Earth is in many ways more akin to the traditions of map-making than to GIS. Little of the analytic power of the latter is present; instead the emphasis is on visual representation of the Earth's surface, and an important measure of the service is the degree to which its results resemble the real thing. By emphasizing imagery, and allowing the user to overlay other information on an imagery base, one ensures that the result is familiar, recognizable, and readily understood. By contrast displays generated using GIS tend to be highly abstracted, and while the information they present will likely be precise and in most cases accurate, the GIS lens clearly provides a more analytic and less intuitive view of the world. Indeed, it is common for researchers to combine the two technologies, using GIS to analyze patterns, search for anomalies, test hypotheses, and compute numerical results, and using Google Earth to provide additional contextual information that may not be present in the highly abstracted GIS database.

GIS as threat

Google Earth abandons many of the cherished icons of cartography such as projections, rendering them largely irrelevant, and in this sense can be seen as threatening to a discipline's cherished expertise. Similarly GIS enables anyone equipped with data and a few simple tools to produce a map that previously would have required the expertise of a trained cartographer. While great efforts have been made by developers of the more elaborate GIS packages to include support for sophisticated cartographic techniques, such as methods of cartographic generalization and alternative techniques for assigning class intervals to choropleth maps, nevertheless it is easy to find examples of the misuse of GIS. For example, several recent news stories of the missile threat of North Korea have included maps purporting to show the areas reachable by missiles of a given range launched from Pyongyang – by drawing concentric circles on a Mercator projection. Any cartographer, and hopefully most trained GIS users, would know that the scale of the Mercator projection changes rapidly at high latitudes, and that on this projection the locus of equal distance from Pyongyang is only a circle when the distance is vanishingly small. Unfortunately the result is a severe underestimate of the areas that can be reached (Figure 1).

[Figure 1 about here]

It is sometimes argued, therefore, that GIS, and the popularization of digital geographic information technologies in general, represents a threat to the field of cartography – that "GIS is killing cartography". Map-making, it is argued, is a sophisticated pursuit that is best left in the hands of experts. Maps are often persuasive, capable of influencing opinion and policy; and just as the playing of concert pianos is limited to a few experts, so the creation of maps should be limited to trained professionals. Attempts have been made in several jurisdictions to restrict mapping practice to accredited professionals, in some cases with success.

Another dimension to this argument surfaced in the early 1990s as part of a rapidly emerging social critique of GIS. In the late 1980s Brian Harley had introduced the concepts of deconstruction to cartography, arguing that all maps were social constructions that could be read as texts for evidence about the agendas of their makers. These arguments found ready acceptance, since maps have always been important as tools of power, and map-makers have often followed quickly on the heels of conquerers. The selection of features for maps, and the styles in which selected features are rendered, are part of the process of cartographic design, and clearly open to conscious or subconscious manipulation for purposes that range from visual clarity to more sinister coercion.

At the time, cartographers saw GIS as a new and wildly popular tool that appeared insensitive to these ethical arguments. GIS seemed to be grounded in the naïve assumption that one could achieve a scientifically rigorous description of the world, and store it in precise form in a digital computer – that the contents of a GIS database represented the results of objective, replicable scientific measurement. The ability to compute measures such as area to large numbers of decimal places served to reinforce this view, and it was clear that GIS was being marketed by commercial software developers as a scientifically rigorous approach to geographic problems. To cartographers influenced by Harley, GIS users were the barbarians, sensitized to none of the nuances of mapping practice or to the tension between cartography as science and cartography as art.

These critiques came to a head in the early 1990s, and led to a series of meetings in which each side slowly achieved an understanding of the other's position. Today, the social context of GIS is one of the major themes of GIS research, and many developments have addressed the issues raised by Harley and others. The notion of objective truth, reflected in the use of such terms as accuracy and error, has been replaced by concepts of uncertainty and of the relationship between truth and power, in the realization that many aspects of GIS practice are not replicable, that many of the key definitions are inherently vague, and that seemingly objective technologies can be molded to the agendas of their owners and sponsors.

GIS as science

GIS is an attractive computer application, combining the visual and the numeric, and it is not surprising therefore that it has captured the attention of many professionals with backgrounds in science and engineering. Cartography may indeed be part art and part science, but to these scientifically minded GIS users the new world of GIS offers the opportunity to escape the constraints and vagueness of the past, by developing new ways of describing the world that are indeed replicable and objective. Science has always attempted to sweep away the vague and subjective, replacing terms such as cold, warm, and hot with replicable measurements on standard scales – why not, therefore, replace the vague and partially subjective classifications of a soil map with measures of soil properties that are both replicable and useful to farmers? From this perspective the power of GIS lies in its ability to improve on past practice, rather than to replicate it in a digital environment.

The transition to digital technology had both technical and economic impacts on map-making. On the technical side, it allowed entirely new approaches to map design that escaped the constraints of manual cartography. For example, line widths could be varied continuously, rather than being constrained by the width of a nib or scribe tool. Shading and color could also be varied continuously, leading to vastly more possibilities in the portrayal of spatially continuous phenomena such as topography or temperature. In short, the new technology helped to underscore for the first time the degree to which cartographic practice had been constrained by the technology of manual map-making – by the marks a human could make with a pen and ink.

Nowhere is this more evident than in the debates over interval-free choropleth maps. These maps are used to portray statistical information, such as population density or average income, for irregularly shaped reporting zones such as countries or postal-code areas. The attributes of each area are shown using color or shading, each color or shade corresponding to a defined part of the range of observed values. The relationship between value and color or shade is usually shown in a legend on the map, and the set of possible shades or colors is usually limited to less than ten, reflecting the difficulty of generating many different shades or colors with traditional tools. There is a vast literature in cartography on alternative methods of partitioning the range of values – of defining what are often known as class intervals.

In the late 1970s Waldo Tobler had suggested that in the digital world this use of a finite set was no longer necessary, and that one could instead establish a continuous relationship between observed value and color or shading density in what he termed interval-free choropleth mapping. This would have the advantage that the information lost during classification would be preserved, since it would no longer be necessary to lump a range of values into each class, and as a result the map would show a more accurate picture of the data (note, however, that choropleth maps also distort the spatial aspects of data by averaging or lumping spatially continuous phenomena within discrete, irregularly shaped areas). Accuracy and the avoidance of information loss are clearly close to the heart of scientifically trained professionals.

The response from the cartographic community was overwhelmingly negative, and today it is difficult to find mention of this technique in textbooks, or implementations in software (ESRI's ArcGIS, the leading GIS software, supports many strategies for defining class intervals but does not support interval-free choropleth mapping, or allow the number of classes to exceed 32). Many cartographers argued that the assignment of class intervals was a vital part of the cartographer's art, and an essential tool in using the map to tell his or her chosen story about the data (Figure 2).

[Figure 2 about here]

Today there continues to be a strong association between GIS and science. The term geographic information science was coined in 1992, and serves two somewhat distinct purposes: first, to describe the set of fundamental scientific questions and principles that underlie GIS, and second, to describe the use of GIS in a scientifically rigorous context. Cartography as a discipline clearly overlaps strongly with both interpretations of GIScience, but while there have been efforts to emphasize the scientific aspects of cartography, most notably in the analytic cartography pioneered by Waldo Tobler, the artistic underpinnings of the field remain as important as ever.

Current research

Both cartography and GIScience have developed and published strongly overlapping research agendas in recent years, and a comparison makes interesting reading, for both the similarities and the differences. Both emphasize representation, and the need for continuing research on how to extend existing methods to capture phenomena that are complex, dynamic, and three-dimensional. Automation of the map-making process, and particularly the thorny problem of automatic generalization, remains a concern of cartographers, as does the design of user interfaces, particularly in devices such as mobile phones that offer only limited area for visual display, and the role that cognitive science can play in helping to address such issues. Both fields are concerned about uncertainty, and how to convey what is known about it to the user; and both fields are concerned about the rapidity of technological change, and the abilities of researchers and developers to exploit innovation.

The power of the visual

In the mid-1960s design of the Canada Geographic Information System there was no support for visual output or for map-making, and although the database included full representations of the contents of maps, the only output was tabular and numeric, in the form of summary measures of area (Figure 3). Even today a tension continues between visual and numeric output in GIS, and one still finds the occasional pejorative use of phrases such as "merely making a map", implying that numerical analysis is the true purpose of GIS, whether it be the inductive search for pattern and anomaly or the deductive testing of hypotheses. Recent advances in data modeling, particularly the adoption of object-oriented techniques of database design and CASE (computer-assisted software engineering) tools, have made it possible to represent phenomena in GIS that were never suitable topics for map-making, including events and transactions, flows, and fine-resolution time series.

[Figure 3 about here]

At the same time maps and visual displays remain a central part of all geographic information technologies, and provide much of the attraction that draws new recruits to the field of GIS. Maps are in many ways visual trophies that can be incorporated to great effect in presentations and posters, and hung on walls for purposes that go far beyond the objective representation of information. GIS is still explained to the uninitiated using the metaphor of maps, and students are still judged in GIS classes in part on the visual quality of the maps they produce. Students are trained to be sensitive to the degree to which maps can mislead and even lie, and to the importance of careful visual design in telling a desired story.

The relationship today

The past few decades have seen a steady convergence of cartography and GIS, as the former has become more embedded in the digital age, and as GIS professionals have grown more sensitive to the issues that cartographers address. Both fields have made strong efforts to emphasize the principles underlying their techniques, and to show that dealing with spatial information, particularly information about the surface of the Earth, requires a special perspective based on special concepts. The question “What is special about spatial?” has been asked many times, and has been addressed very effectively by recent research.

Nevertheless significant differences remain, and it is possible to identify different flavors in the ways geographic information technologies are used. To a cartographer the primary means of communicating the results of investigation is through the map. To GIS users, however, the map is only one way of communicating information, which may also be presented in the form of text, numbers, sounds, and images or illustrations that would not qualify as maps in the normal sense of the term. Maps are compelling, but other media may be more appropriate in a given context. The definition of a map is changing also, and there is increasing interest in maps that distort the geometric world in specific ways; in animated and three-dimensional maps; and in maps of spaces other than the geographic.

Cartography has much older roots than GIS, even though analog precursors of many GIS functions can be found dating from hundreds of years ago. This tends to give cartography a more scholarly flavor, and it will be many years before society accords the same value and significance to historic applications of GIS as it does to historic maps. Maps are accorded places in libraries that GIS databases are not, and often used as decoration; and the English language assigns a single word to a practitioner of cartography but not yet one to a practitioner of GIS (GISer can be found in some of the critical writing of the early 1990s but was not widely adopted).

The legacy of Brian Harley lives on in the general perception that cartography is the more artistic, subjective side of geographic information technology, and GIS the more scientific, objective side. Scientists using computers to make maps are more likely to call what they do GIS than cartography, and more likely to assume that the information they work with is the result of scientific observation and measurement.

To the outside world, however, these nuances are largely invisible. The general public is by now well aware that important things are happening in geography, whether it be as a result of a GPS-enabled navigation system in a car, or exploring the world through Google Earth, or geotagging a photograph. In this world the concepts and principles in which both cartographers and GIS professionals are trained are largely invisible, and it is possible for entire books to be written on the subject of map-making with Google Maps that make not a single reference to the literature of either field. Formal training in what it means to think and express oneself spatially remains the preserve of a few, in contrast to formal training in thinking numerically or in the use of language.

Further reading

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Figure captions

1. A circle centered on Pyongyang and superimposed on a Mercator projection. Similar maps appeared in several newspapers and magazines to illustrate the threat of North Korean missiles with 10,000 km range. However the locus of points 10,000 km from Pyongyang is not a circle on the Mercator projection, and includes the North Pole and much of the continental US.

2. Two choropleth maps of Milwaukee census tracts, showing percent black. (A) uses five classes following the Jenks natural breaks method of class interval selection. (B) uses 32 classes, and approaches the Tobler interval-free technique.

3. An analysis of the relationship between vegetation cover (each green area is a different vegetation cover type) and elevation (the black and white image). The results of such a GIS analysis are more likely to be presented in numeric form in a table (the column headed MEAN shows the average elevation for each SPECIES).