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A Literature Review on Computer Cartography

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Abstract

Depending upon how we look at it, Computer Cartography can be considered now to be twenty years old (the first contour map was produced about twenty years ago), or a dozen years (the first major project in Computer Cartography, the Canadian Geographical Information System was started in 1963). This is not to say that we started out from scratch twelve or twenty years ago. On the contrary, we had all the tools and all the power from different disciplines, including Computer Science, Geography, Cartography and the Survey Sciences. If we assume that every discipline has some milestones in its development, it has to be said that in Computer Cartography these milestones did not happen or happened virtually unnoticed by the discipline.

Keywords: Computer; Cartography; Advantages; Disadvantages.

1. Introduction

Cartography is a discipline as old as humankind and as young as today's newspaper. Why is this? Cartography is old because as a means of expression the map probably predates many other forms of human communication, and maps survive that are several thousand years old. Cartography is young because it is a discipline that has been subjected to a series of revolutions in innovative technologies. At first, these revolutions came separated by centuries, and in the case of the era following the decline of Greek and Roman cartography most of the cumulative knowledge of map making was forgotten. Since the advent of the digital computer, however, we have become used to cartography as being in a state of almost constant technological revolution.

Why has this technological tool surpassed all others in the history of the discipline? How have cartographers adapted their discipline to this constant state of flux? And what will cartography look like in the years of innovation to come? In this article, we examine the computer revolution in cartography from the standpoint of how cartography has changed, and more important from the standpoint of how it has remained the same. As we shall see, the revolution has shaped a new cartography, in which the specifics of technology appear to be overwhelming.

Fortunately, the revolution has also sent cartography Basic to its historical and mathematical roots and therefore has made the basic principles of cartography as much in demand, if not more so, as at any previous time. When we think of the technology of map making, the centre of activity now lies within computer cartography. In the past, thought of cartographer as scribes with quill pens scratching out maps of the world. This is simply no longer the way it is done. Mapmaking Technologies have come and gone, and the simple Origins are now very distant. Cartographers have changed the way they see the creation of maps and the role of map making self within cartography. This has been the case in both manual and computer cartography, for cartography is a set of skills and a body of theory, and the theory remains the same independent of what particular Technology one happens to use to make any particular map.

This does not necessarily affect the body of theory behind cartography, but rather emphasizes and Re-emphasizes the cartographic lessons of the past. For example, for most map projections, the underlying equations and transformational geometry were worked out, sometimes to projection, in previous cartographic eras. Today the equations still work whether we produce the map by hand construction or by Computer Graphics. A typical laboratory for computer cartography may contain micro computers with graphics card, high resolution color monitors, digitizers, color plotters, and printers rather than drafting tables and sinks.

2. Stages of Adaption of the Computer

Morrison (1980) stated that there are three stages in the adaptation of a new technology. First of all, we have a reluctance to use the new technology; we close our eyes and pretend is isn't there. For example, in word processing Technology, we may characterize this stage with statements such as," I have been using an XYZ brand typewriter for 20 years, and it always work just fine. What are these word processors? I really don't need one, they are just too expensive." This is the reluctance to use stage. In the second stage, it is the replication stage, technology attempts to replicate the previous Technology. If we return to the typewriter example, we might find IBM replacing its electric with a "memory" type writer, with a single line display and some Limited editing capabilities. This uses just a little of the new technology but does not "embrace" it, that is, fully take advantage of all of its features to do new things. We are still using the old Technology, but are simply making it slightly better. We are copying the way of typing was always done, that is, line by line.

In cartography, computer cartography was ignored for some time, as in the first stage, and then was faced by replication, producing pen plotters and table digitizers, which were simply updated electronic versions of the pens and drafting tables we had always used. the plotters were simply mechanical arms with pens fixed to them, and we still fed them pieces of paper and changed their ink. We took a digitizing tablet, much like a drafting table, and instead of using a mapping pen we used a Crusor to draw lines. We replicated the previous Technology, making maps exactly the way we used to, using only some as aspects of the new technology.

The third stage is the full implementation of the new technology, in which we forget the previous technology, and the new technology becomes the current Technology. Cartographers first had a reluctance to use computers all together, then they replicated the previous Technology. Finally in the full implementation of the technology we have to ask you questions all together. This is a sign that a Revolution has taken place because new ideas are necessary to organise the new approach. We may ask, for example, if maps actually have to be on paper. New media are now available, such as micro film, Video, Broadcast images, and Holograms. Perhaps, more simply, we now have to ask ourselves just what a map actually is.

A characteristic of a developing technology is that we move through these stages. Al so, however, we find that all stages usually exist at the same time. We still have both an ignorance of and a reluctance to use this technology. We have replication of the previous Technology, but fortunately we also have some full implementations, and there are some good examples of people who have completely adopted Computer technology and made a success of it.

More recently, Morrison (1993) has argued that the impact of the computer has gone even father and is eroding the boundaries of the organizations that conduct and control cartography. The flexibility of computer networks, the increasing collaboration between Universities, Government and industry, and the new highly portable Technologies have made the formal cartographic organizations at least partially obsolete. Such institutional changes are likely to significantly impact the way cartographic data, expertise, and mapping problems are assembled to make Maps with future making systems. The inevitable result will be a more spatially literate population making use of the Tools and techniques of cartography in new and exciting ways.

3. The History of Computer Cartography

Computer cartography in the United States really dates back to a single article written by a graduate student at the University of Washington, waldo Tobler. The paper "Automation and Cartography, was published in the geographical review in 1959. At the time, plotting devices were simple cathode-ray tubes, and input and output were normally by punched cards. During the early years, the 1960s, the accent was on the creation of algorithms, that is, the creation of expressions of ways of doing things mechanically that had previously been done by hand. Because programming these algorithms was difficult, many remained and unimplemented. So in the past, contour lines had been drawn by a cartographer using knowledge about the lay of the land and perceptions about how the map should look. Later, the computer gained ability, giving the cartographer the role of deciding how best to represent the lay of the land rather than how to draw contour lines.

The first problem that had to be solved was how to make a computer draw cartographic lines. The way to do that was to examine how the cartographer had made the decision, what methods were in use, and how they could be automated. In fact, many of those decisions are made on a very simple mathematical basis, and their is often a simple algorithm that will replace the method the cartographer has been using.

Cartographers devised a plethora of different algorithms, at first implemented as stand-alone computer programs and later consisting of program packages, peaking with the production in 1968 of the SYMAP package at the Harvard University. The 1970s two major changes. First of all, the implementation of new algorithms brought innovations in producing new types of maps that had previously been impossible, certainly computationally, to produce. Within five years, most cartographic techniques are automated, even some complicated methods such as his shading and cartograms. Computer programs were created that could produce almost all the various types of cartographic Representation.

The second change, during the 1970s, was the people began to realize the application of computer cartography had potential commercial value, just as a whole first generation of graduate from the Universities that fire specializing in computer cartography provided in small group of trained students for the job market. Many small companies started during this period, employing the new cartographers and using software engineering practice is to produce some really effective and cost competitive cartographic software. Most of the software was made available for those who wish to make new maps are those who wish to replace manual mapping systems. Federal, state, and local government frequently took the initiative in producing mapping software. This phase continues today and in fact is gaining Momentum as the industry matures and as the microcomputer and workstation penetrate smaller and smaller drafting office environments.

Some of the first programs were for the types of computers that are around in the 1970s; large mainframe computers, mostly IBM product that used existing languages such as FORTRAN and simple Proprietary graphics plotting in systems such as CALCOMP and tectonics PLOT-10. In keeping with the times, most applications programs ran in Batch Mode and frequently used the line printer as the primary display device.

4. The Computer's Influence on Cartography

What have been the implications of these technological changes, and what has happened to mapping? First of all, cartography is now fast, or at least faster. The compilation time for a 7.5 minute quadrangle, with field surveys and checking in the 1940s, when most of the series was made, was on the order of 5 years. To update the map now, we use photogrammetric methods, and the survey and field work plus and the cartography takes about two years. As we move to fully digital maps, we obviously decrease the time spent in making and remaking the map.

At the time extreme, consider instead the daily weather maps distributed by NOAA over the computer networks. Every hour, a new image of North America, admittedly at low resolution but showing up to date atmospheric conditions is posted on the Internet. Weather stations, television weather forecasters, Pilots, and even recreational boaters can download the image and have access to cartographic data within just minutes of the image have been recorded by the satellite. Mapping speed has been increased substantially by computer mapping systems.

The computer has also increased the potential map accuracy, although accuracy is more difficult to discuss, because most people confuse accuracy and precision. If someone were to ask me that time, I replied that it was 4:12:15.783, I would be very precise. I might be completely wrong-the time would actually be 5:31-but I would be very precise. If I were to say about 5:30, then I would be fairly accurate, although imprecise.

Has computer mapping made maps more accurate? It has certainly made them more precise. We are able to store and use many more numbers now and can compute lengths and areas with more significant digits than before. A surveyor can calculate the area of a new subdivision plat to the thousandth of a hectare. Are these numbers more accurate? It certainly seems that we have taken the old causes for inaccuracy, smudgy lines and shaky hands, and replaced them with other things, such as digitizer's neck and grid interpolation error. I would argue that perhaps, in the very long term, computers have made maps more accurate. More important, however, is that our accuracy levels are now measurable against the truth, or at least against other maps, and we have therefore made our maps more accountable. Much recent cartographic research has focused on the accuracy of digital maps, and some important findings have already found their way into cartographic theory.

A major innovation in surveying is the implementation of a system involving geostationary satellites in Orbit around Earth, whose location are very precisely and accurately known because the orbits are very predictable. The system is called the Global positioning system (GPS). This means that if you have a receiver that receives and decodes the signals coming from the satellites, you can fix your location very precisely by three dimensional triangulation from a set of three satellites. It is not unknown now for a system with some microcomputer post processing to give your latitude, longitude, and elevation to within about 10 millimeters. That is so accurate and precise that it is good enough to measure continental drift: in fact, the technology has contributed a great deal toward figuring out that the continents are moving around and by how much. The contributions of the satellite system to the mapping sciences of geodesy and surveying are already apparent, and Measurement from GPS can now be sent directly to mapping software.

This new technology allows us to resurvey things with a new level of accuracy, and sometimes we have found that we have gotten things wrong, in some cases really wrong. A good example would be the Pacific Islands, totally out of sight of every other piece of land in all directions, so that locations could only be fixed by astronomical measurements of latitude and longitude. With a GPS receiver we have found out that our maps show the islands in some cases tens of kilometers off their correct locations. In many senses cartography has a long history of islands that appear and reappear, and move around with changes in mapping Technology rather than having anything to do with Atlantis, the Bermuda Triangle, or plate tectonics. A whole new promontory was discovered in Antarctica the Washington monument was found to have been isolated state by several meters, and probably the most famous Instance is that Mount Everest spent a short period between measurements as the second highest rather than the highest mountain on earth.

The digital computer allows us together cartographic data that is both precise and accurate. Unfortunately the implication of quality that comes with accuracy and Precision has not always being justified. When the source material for a digital map is sheet map, the digital map can become a faithful exact Reproduction of all the errors involved in putting the original map onto the paper. It is important to retain a "fitness for use" criterion when considering the accuracy of digital cartographic data.

5. Benefits of the Computer to Cartography

What are some of the benefits of using computers in cartography, and has the computer made mapping more cost effective? It is rather expensive to produce maps, and in the initial stages it was believed that computers would make it incredibly inexpensive to produce maps. In fact, in the long run, computer produced map seem to cost about the same, with a few expectations, as handmade maps. On the other hand, it probably will not remain that way. If we think about the stages of adopting a new technology, much of the cost of computer cartography is due to replication of the previous technology. People still use figures such as the cost of digitizing a sheet map for a single mapping project, normally a one-time fixed cost. For lower variable costs per map are possible by reusing the digital map base.

The level of output of maps has increased using computers. Most of the fixed costs of computer cartography are in preparing a now base map, and after this step it is both easier and less costly to produce maps from the base. For example, we may spend a great deal of money producing a new census tract base map after every decennial census, but in doing so we are ensuring that we can make on that base for numerous other derived maps and analysis. Only the data, the symbolization, and map types change.

This implies that we can increase output. What this means is that mapping projects that were previously not possible are now cost-effective, even inexpensive, perhaps affordable by overseas countries and local governments, which were previously excluded by cost from the making business. These completely new applications have the greatest potential for computer cartography, for these users have no previous technology to waste time replicating and they can reap the benefits of other people's experience.

The overall effects of the computer on the discipline of cartography are many. Cartography in the 1950s was much of a service discipline. A cartographer would be attached to a Geography or geology program academically, or isolated in a map department commercially. A cartographer’s function was as a technician, a producer of maps, rather than as a producer of systems for making maps. Wolter (1975) argued in the Emerging Discipline of cartography that cartography has evolved, through it self-examination as a result of the computer age, all the requirements to become a distinct academic discipline in its own right, the distinctiveness of the discipline and its new role are clear.

Certainly, if one examines the literature that is evident. Much that is published in cartography journals these days is clearly analytical cartography, although there are other approaches to the discipline (Moellering, 1991). One could argue that this is just a return to the preeminence of cartography, a return to the role that cartography held under the ancient Greek or during the age of Discovery. Many more people outside the discipline new encounter and eventually study cartography. As a result of this scrutiny from outside, we have been forced to define the cartographer's domain of interest very precisely. We have had to define in detail exactly what cartographer's do, how they do it, exactly what the information they deal with is, and what its limitations are. And we have had to model the flow of this information through the mapping process.

The computer has relieved the cartographer from tedious production tasks. Anyone who has experience with manual cartography knows how much hard work goes into a manually produced map, even a poorly designed or inexpertly drafted one .The focus of cartography used to be on the production technology. If the computer is doing the minor production tasks for us. We can worry about other things, such as design- which is ultimately what a cartographer is trying to perfect. For one thing, the computer has allowed us to set up a design loop. The manual equivalent is to work on a series of separations one at a time, incorporating a single map design for each map project. We finally get to produce a map proof, and for the first time after perhaps 100 hours of work, get to see what the map looks like. What if we don't like what we see? More commonly, we might say, "if only this text were slightly smaller" or "If only this red or green". It is too late to change the map, in other words, we have no design loop.

In design loop, the finished product can be interactively modified to make all the changes we may wish to incorporate. In fact, we can use the design loop to produce experimental maps that will help us to learn better design; for example, to see why a map with 12 font and 30 shade classes really does look bad. This changes the emphasis from the technology to the design and further to the principles that make this a good design regardless of the technology. In this way, we can make maps look better-which is not a bad definition of what it is that cartographers now do.

The computer has produced a whole series of new capabilities. The ability to manipulate colour is a good example of this. The computer has given us new types of maps and new media for their display. The field of scientific visualization has produced maps that can be worked around, manipulated and perceived as three dimensional objects. Cartographers are now beginning to exploit the tools and methods of the new interactive media, multimedia, and animation to show spatial distributions over time and space(Andrews & Tilton, 1993). Similarly we can use cartographic techniques to map new types of data beyond the traditional domain of cartography, such as statistical distributions, the ocean floor, mars, or a molecule (Hall, 1992).

6. Disadvantages of the Computer for Cartography

The computer has had some negative effects on cartography. For one thing, the amount of technical training that a cartographer has to acquire has increased enormously. The cartographer of the 1990s must be a database expert, a user-interface designer, and a software engineer. He or she must also retain a sense of map aesthetics, be familiar with diverse computing environments, and still produce maps. Cartographer ideally need training in image processing, Remote Sensing, photogrammetry, land information systems, geographic information systems, surveying and geodesy, and computer programming.

Another disadvantage of the computer for cartography as a discipline is that those not trained in cartography can now easily produce maps. Although in many cases this is a popularization of the mapping process, in the early days of computer cartography it led to a renewed need for good design and esthetics. For a time, in replicating the previous Technology mapmakers threw out the quality standards that the previous technology had contributed to cartography as a whole. For about 20 years computer cartography produced rather inferior products, which were accepted not because they were better but because they were new and different. Today, digitally produced maps are usually superior esthetically to those we can make by hand.

7. Conclusion

Computer Cartography has gone through many changes during its short life. This article tries to document some of the results of the development. The major conclusions are:

Whereas the application of computer mapping is flourishing, conceptual development is slow; as a result, the applications are simpler than they could be, given the development of computer science, and brute force reigns over elegance.

To exemplify these points, the main types of Geographic Information Systems are discussed with respect to their recent achievements: Cadastral mapping, thematic mapping, Topographic mapping, Resource Information Systems, and Digital Terrain Models.

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