Geographic Information Systems, History of

Nicholas R Chrisman, Bellingham, WA, United States

GIS varies in space and time. "GIS" in its original meaning Geographic Information Systems first appeared over 50 years ago. Already in 1967 there were different interpretations and perspectives, showing how different groups and disciplines see the past differently. The Canada GIS project (CGIS), often claimed as "first," grew out of a particular analytical requirement in land evaluation, and launched with an ambitious cross-continent scope. Roger Tomlinson, a key instigator of CGIS, insisted in later accounts that it was an industry-based project for government use, in an attempt to distance it from academic-based innovations at the same time. Other initiatives at that time were focused on urban housing and transportation, landscape planning, and just making maps with computers. The boundaries between academics, industry, and government were thoroughly mixed in most of these cases. In the year 1967, when multiple sources claim the first use of the term GIS, there are hundreds of users purchasing software for computer cartography (from Harvard, University of Kansas, and others), and new professional organizations holding third annual meetings (URISA). For an era of rotary-dialed telephones and huge mainframes with tiny memory capacities (by current standards), the interest was strong.

There were many earlier efforts to build computerized geographic databases, and the software tools to manipulate the data. The US military had launched surveillance satellites a decade earlier, and kept the project firmly in the dark for decades after. The sensors on the first-generation military satellites were still optical, and the processing quite human-intensive. It is not clear how much information or technology filtered out of the secure sector, or when. Yet, the military interest formed a part of a movement for information systems that cut across all sectors. Other efforts to build computer databases for cities or natural resources aimed to build similar capabilities under a range of application-specific titles (Natural Resource Information System, Urban Information System, Land Records Modernization, and so on). It took some time for the different disciplinary groups to see their common thread of shared requirements. As computers surfaced as realistic tools, many professionals around the world began to apply computing power to geographic problems. The diffusion of innovations was not uniform or instantaneous. The next paragraphs will provide some examples.

Geographers played a role in the movement toward information systems beginning in the 1950s, before the term GIS was current. It is important to remember that the academic world of geography, with its talk of revolutions and paradigm shifts, was not isolated from other disciplines and professions living through many of the same transitions.

In this early period, the first concern was access to computers. Equipment was scarce, and often in the hands of more powerful forces not interested in making maps and solving geographic problems. Computing was typically aligned with accounting, and very operational requirements. Edgar Horwood thought that cities would need to send their data to a service center for processing, so his Urban Data Center (at University of Washington in Seattle) was planned to provide the computing as a centralized service (a model that has only recently returned [in the form of cloud computing services] after decades of moving in the direction of dispersion toward the desktop). It is hard for a person living in the current era to conceive of the scarcity of computers in the early 1960s. Horwood's 7094 computer cost $2.9 million (in 1960 dollars) and had a total memory space of 32K (36-bit words). It was the first generation of transistorized computers (long before the integrated chip architecture), 10 times faster than its vacuum tube precessors—but still far beneath the capabilities of the equipment to come.

After attending Horwood's training (and marketing) event in 1964, Howard Fisher foresaw another model, with software being disseminated for use elsewhere, at academic or corporate computing centers. Fisher founded the Laboratory for Computer Graphics at Harvard on this model of software dissemination a few years before the first GIS. The "Lab's" SYMAP package was not a full-scale GIS, but it was sold (or transferred) to at least 500 sites, engaging many students and organizations in the process of displaying geographic facts in a graphic format (at very low resolution using the ubiquitous line printer). Innovators in this earliest period were spread around the World, though computing tended to follow the money in higher income countries. Cook returned from Canada to Australia and built his own topologically structured software for natural resource data, though it remained an in-house resource at CSIRO (the Australian agency for scientific research). Not all followed Fisher's model of a complete stand-alone package of software. For example, Rystedt in Sweden published subroutines in FORTRAN for others to mobilize in their own research. The UK research council funded an"Experimental Cartography Unit" at the Royal College of Art, dedicated to development of hardware as much as software. The first digitizing table was developed by Boyle at Glasgow in collaboration with the Experimetnal Cartography Unit in London. Other countries, including Germany and France had spatial computing software development as well.

In the 1970s, the focus shifted more and more to the data, rather than the computing. Computers got a lot faster, and memories grew, although for the most part they remained in computer centers. The trend was clear that computers would get small enough (first minis, then microcomputers) to escape from behind the counter of the batch centralized model. The data turned out to be a more expensive proposition. Getting data off previously printed maps was not straightforward in an era dominated by the manual keypunch, a tedious medium to say the least. For the 1970 United States. Census, the Census Bureau adopted an innovative topological model for street networks in a bid to automate some of the assignment of census returns from addresses to the collection geography (blocks, tracts, cities, and congressional districts). The technique would support mapping, if the block segments had coordinates. The only method proposed in the early round was the manual keypunch, so many of the 1970 DIME files had the street network topology and address ranges but no coordinates for the points at the ends of the segments. It was just too difficult (and expensive) to make this database fully geographic. Some cartographic agencies started to enter their maps into the computer on digitizing tables (big measurement devices operated by hand). Without access to graphic display, these entry systems were painfully slow and expensive. No computer in this era was interactive, nor dedicated to a single user. CGIS (Canada GIS) had a scanner built by IBM Corporation. It consisted of a drum to mount the map, and a single photosensor paired with a light bulb. The map had to be redrawn as a scribed document with a very controlled lineweight. When rotated in place, the line would be detected as a single pixel. Clearly this was not fast, either, and it depended on complex software to turn the pixels into usable lines around polygons to permit area calculations. This device was made to work, but with a lot more manual intervention than originally conceived. IBM never commercialized this scanner. The potential was clear, but other innovations had to coincide to bring the whole system into place. GIS was not a single technology, but an assemblage of many.

Moving Toward GIS Implementation

The first civilian remote sensing satellites (ERTS, then Landsat and SPOT) created an alluring possibility of masses of data literally falling from the sky. In this period, nearly every state in the US established a "natural resources data center"(or something of the kind) focused on some local (fundable) issue (agriculture, forestry, mining, or any combination). Nearly every one of these efforts failed to establish an enduring geographic information system, but the vision was promulgated, and the actors aligned. In part, the technology was just not ready; the data not as easy to assimilate as expected, and the software just not sufficiently developed.

Although the remote sensing satellites attracted a lot of attention, the world of software development kept the pixel-based remote sensing systems quite distinct from the vector-based GIS developments. It was at least two decades before any reasonable integration became routine practice. Each side of the software world invested in their particular world view, and found it hard to accommodate the alternate data structures. Even today, remote sensing processing is performed on distinct platforms with different objectives.

Perhaps the clearest harbinger of GIS could be detected by the arrival of the commercial consultant industry. Roger Tomlinson, among others, found that the most lucrative part was not doing the work, but telling others how to do the work. He developed this practice into a worldwide operation. Perhaps the most interesting moment was in 1979 when Tomlinson and his collaborator Raymond Boyle (inventor of the digitizing table) decided that there was no software capable of managing a true GIS for Saskatchewan forestry purposes. All proposals were rejected. The competition to pass the consultant benchmark sharpened the software industry to respond to specific requirements developed by the consultants. The next time Tomlinson ran the benchmark for Washington DNR, a small company (ESRI) won the contract, with a software prototype. The symbiosis between consultants and software development led to a flowering of many competing packages in the 1980s, whittled down to a few survivors over the decades. As a consequence, the focus of development moved from university laboratories to startup companies. Some of these survive today as corporate behemoths, others simply as footnotes.

The configuration of the GIS implementations in the 1980s involved a smallish computer serving as time shared host to a number of users. The computer was specially configured for this dedicated use. As the 1980s progressed, professional workstations got sufficiently powerful to provide enough power and storage for each user. These workstations could finally include a suitable graphic display to preview the maps on screen (often in monochrome green of storage display tubes, until color got cheaper). The central requirements to share the data with others made the software get more complicated to match. An industry was born. Software development converted from an anarchic small group of academics to a commercial enterprise with deadlines, deliverables, and benchmarks to pass. In the early days, the marketing department ruled the roost, and made promises that the developers scrambled to deliver.

It was a period of heady expansion; user numbers expanded rapidly from a few dozen to hundreds in a few short years. The focus was on the future, with new releases and more marketing around the corner. Very little attention was given to history in this era, though many crucial decisions were made by development teams with very little background in the range of applications.

The first publications that reflected on history were six articles in a special issue of *The American Cartographer*, published in 1988. These articles were first-person accounts invited by Barbara Petchenik and Roger Tomlinson. They included accounts of early developments in United States, Canada, and United Kingdom on the theme of the "technological transition" of cartography from analog to digital. This kind of insider retrospective continued in a larger volume published in 1998, with Tim Foresman as Editor. Retrospectives tend to be written by the victors in technological battles, so these accounts need to be verified by careful documentation and scholarship. There are still important early developments that remain obscure because they did not persist or the actors moved on to other pursuits.

Computers were unevenly distributed around the world, certainly in the 1970s and 1980s. It is no surprise that GIS developed faster in areas with sufficient penetration of the underlying technology. In each country, pathways of development depended on local factors. While the early phase in United States was quite decentralized, the United Kingdom saw a big increase in activity following a House of Lords report. Central government agencies played a significant role in France, Finland, Sweden and many other European nations. Eventually, European Union regulations brought a degree of transnational integration, focused on environmental issues due to the mandate of the Union. There were various initiatives to bring GIS training to developing countries, but few of those projects led to continuing sustainable indigenous installations. By contrast, Brazil was motivated to build their own in-house capacity to report on deforestation (with a remote sensing and GIS capability). As China built up universities and research capacity in the late 1980s, GIS developed quickly through the 1990s, including a local software market. GIS has a different flavor in each country but it has become widespread.

Simultaneously, the widespread GIS has also become more diverse, as it has become specialized for specific uses and users. There is no longer any sense of a single toolkit to cover a water utility, a package delivery service, or a hiker in the wilderness. Each application employs maps and geographic data to make calculations and to track their spatial footprint. Perhaps in a while none of them will call what they do "GIS" anymore.

A History of Data

While it is common to trace history as a story of people, it is also useful to consider that the world of GIS is also framed by changes in the expectations about data. The Canada GIS of the 1960s was justified as a means to automate the calculation of land area in various suitability classes. The alternative was an army of people running planimeters, much as the US Census Bureau had employed in the 1930s. The central object in the CGIS database was the polygon. In their full form, polygons were calculated from the overlay of different themes, each from an exhaustive set of polygon coverages. Ian McHarg is often credited with this emphasis on polygon overlay as the basis for rational landscape planning, although the core problems he described also involved locating paths through a set of constraints. In the simplest form, a stack of transparent maps were superimposed on light tables; the areas that remained transparent were the suitable areas not excluded by some factor. This overlay mentality pervaded the first round of GIS implementation, with many versions of a "stack" diagram to explain the GIS database. The first round of commercial software had to pass strict testing on the calculation of polygon overlay. While much of the marketing talk described GIS as an integrated database, the individual layers in the stack often represented the different participants in the project. Each contributed their own data resource, motivated by the access to the richer shared potential.

The early era was also a period of data scarcity. It took substantial organizational effort to plan the data conversion process and to pay for it. In the early 1980s, many cities embarked on GIS projects that only accomplished their pilot goals before they folded. As mentioned above, every state had a "natural resource" database project that failed. Only a few projects were carried to completion, so much had to be made of what was available. The big potential would come later as the investment in data resources eventually made new applications possible at a lower entry cost. The first clear example was the public investment in a nationwide street network for the 1990 Census, built by US Geological Survey, called TIGER. Though full of data quality issues, the nationwide coverage permitted innovations such as MapQuest to mount web-based address matching and rudimentary street maps at low cost.

While processing of polygons remains a more difficult test, many other kinds of data emerged as equally important. Networks took a place as their own distinct problem, particularly for utilities like gas and electricity, but also for roads and addressing. The commercial sector absorbed the street network data generated for the 1990 US Census and rushed to provide street maps on the early web. The lack of similar (low cost) coverage in the United Kingdom led to the OpenStreetMap initiative that then propagated across the planet at record speed. Data on streets and highways became an expected infrastructure, part of the framework for a modern connected society.

The core problem with a network is not overlay, but routing. The street map applications added more and more data, becoming more and more connected to the real-time feeds of traffic and weather. Now much of the population expects to have estimates of arrival time on optimal routes recalculated based on current traffic speeds. Routing is not an easy computation, but the servers respond to the demand.

Also, the mass adoption of social media has generated substantial volumes of data represented as simple points in time and space. The GPS sensors embedded in mobile devices provide streams of data tracking vehicles, people and any other object that attracts commercial interest. Points are so simple in themselves that it takes a lot more processing to extract anything of value. In the current era, there are so many data feeds that much of the stream is filtered, not preserved. In the short time span of modern GIS, the expectations about data scarcity have reversed. The kinds of data have diversified, and the promise of a single unified database has melted away.

In effect, the history of data is also a history of users. In early initiatives, the need had to be carefully articulated and the data assembled to respond to a particular funding source. One application could determine what was collected. For example, the mandate for a soil erosion plan in Dane County, Wisconsin (mid 1980s) was used as a means to demonstrate the potential for a multipurpose system, under the premise that the same data sources could support additional applications. As the collection of data became more common, there was a dream of a single unified infrastructure to support many applications. These initiatives were put in place around the world (under the banner of "spatial data infrastructure" or something similar), but the uptake was not as convincing as expected. The "authoritative" data sources were just not that much better, and often not as up-to-date. The logic of a single comprehensive centralized database depended still on the idea that data were scarce and therefore valuable. The established national mapping organizations retained the illusion that they were central to technological advance. At one point, they may have monopolized the employment of mapping personnel, but mapping was headed toward a radical change as millions of citizens carried sensors that could communicate into repositories in real-time. As more and more data streams become available, it should be apparent that no particular source is central, and that the core problem is to filter out the noise.

A History of Critique

Rapid expansion in the 1980s also expanded the attention paid by many critical voices. Up to this point, it was perhaps too small and idiosyncratic to notice. As GIS moved toward implementation, it was the appropriate moment to consider alternatives and implications. The marketing narratives were relentlessly positive, but not everybody agreed. In the academic realm, many questioned the expectation of "progress" and positivist logic. It was an era described by many labels, many starting with "post-" (post-modern, post-structuralist, etc.). Brian Harley opened up a debate about cartography, pointing to the inherent politics in the development of maps. This critique extended from the historical maps of Harley's attention to the nascent GIS world. It is easy to demonstrate that government-funded databases were related to an expression of power. Even a database for soil erosion planning implements a political agenda, and favors certain parties over others. There was also a general wariness as academic cartographers saw a transition as untrained citizens were empowered to make their own maps, perhaps in awful color combinations or with total disregard to established procedures. Cartography was changing, often faster than observers imagined.

By the 1990s, criticism of GIS was much more nuanced and sophisticated. The academic world was no longer focused just on GIS pilot projects. GIS specialists were increasingly concerned with appropriate technology—matching the tool to requirements rather than just disseminating the next round of technology. Some critics went further to examine the fundamental assumptions that made the technology function. Each step in geoprocessing depends on coordinates in some simplified geometry (like a map projection). The Newtonian or Euclidean view of space was challenged as incomplete. At first, the critics were concerned with the implications of technology on society, with a key moment recorded in the chapters contributed to *Ground Truth*, edited by John Pickles in 1995. Some set out deep suspicions that the fundamental assumptions of GIS developments were flawed. Others sought to design alternative means to engage fuller participation in GIS developments, in circumstances of power differentials such as third world or Indigenous communities. As the field of Critical GIS evolved, the development process was no longer seen as just a one-way path (technology impacting on society), but complemented by a "full circle" as the technology responds to certain societal pressures and requirements differentially. It is quite clear that GIS development is not just a technical matter to deliver the highest quality at the lowest cost, but also to consider ethical issues and protection of societal values (including privacy, safety, and social equity).

Academic geographers have begun to build a richer view of the history of GIS, including a deeper look at changes in philosophical stances, roots in wartime mapping and analysis, and the specific trajectories of institutions. Any of the most current developments has a particular pathway that will reach back centuries. It is important to consider, for example, how the 17th-Century Scientific Revolution laid the groundwork for current Big Data analytical developments. In this larger view, the particular details about priority (which GIS was "first") do not matter as much as does the inherent bias in modern administration for statistics and data collection.

Meanwhile, the societal impacts of GIS in all its diversity are all around us. Unlike the single-purpose justifications for efforts like the Canada GIS, the promise of a multipurpose spatial data infrastructure has been realized. Instead of a centralized national mapping agency, we see a much more complicated scene, including major corporations vying for consumer attention and citizen-driven data developments covering the globe at a rapid pace. The old national mapping institutions have been challenged by crowd-sourced collectives like OpenStreetMap or just rendered less relevant by corporate spending. Sensors on everything (particularly including every mobile phone) tipped the tables from data-poor to data-rich. GIS has always been at the cutting edge of what is "big data" in any particular era. The goalposts keep shifting.

There are substantial issues of personal privacy that become more apparent as various datastreams become better integrated and more processing power is made available. Critics pointed out these issues long ago, and some research has tried to provide solutions to retain some level of protection of personal data. So far, the commercial pressures to sell the attention of consumers have overwhelmed the pressure of privacy advocates. Yet, the concerns of Harley and some critics have focused on the universal view of integrated data in the holdings of a centralized surveillant state. Other critics, such as Denis Wood also noticed how partial a view each map provides. His original analysis of the topographic map showed the concentration on "permanent" geological timescales, and the absence of transitory people in the scene. The current information resource seems to respond to Wood's critique, though probably for other reasons. Much of the current situation involves filtering and throwing data away; multiple competing commercial actors; the ability to distort and manipulate what is taken as reality. It may be as crucial to consider which items are forgotten, as well as which are retained.

The commercial sector, for decades dominated by what seemed like big companies that originated in the 1980s, has been overrun by truly huge companies like Google (Alphabet) and Apple. The claims that maps and GIS were important to the economy no longer need footnotes and supporting documents. Individuals can call up sophisticated route planning information based on real-time traffic on a handheld device with impressive storage and networking capabilities. In the announcement of the first iPhone (2007), Steve Jobs performed a GIS query: nearest pizza delivery service. While it may sound mundane, this query requires a full database of service providers, spatially referenced to the same framework as the handheld device. The past 10 years have seen more restructuring of the mapping world than during many centuries previous. Our cartography is no longer one-size fits all, produced by central organizations with decades to cover the country. Competing companies run LIDAR scanners and multiple cameras down every street, with a frequent repeat cycle to capture changes. People expect to have various forms of route information (maps, street views, and verbal accounts of turns), delivered in real-time. A common feature is that the map is now centered on the viewer. Sheets of paper have gone the way of buggy whips, something for historical curiosity. The current arrangement of services provided online are far beyond the promise of a continent wide inventory of natural resources as envisioned in the 1960s for Canada, but the path from the early vision to the current capability can be traced. It was not a simple path of inevitable progression. Many projects were false starts and blind alleys.

See Also: Critical Geographic Information System.

Further Reading

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