THE EVOLUTION OF CARTOGRAPHIC VISUALIZATION IN THE DIGITAL ERA

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Abstract
The development of the digital production techniques were rapidly improved around 1980-1990 due to the requirements of desktop publishing. Both hardware and software components were essential in the development of the technology, but the first milestone of this process was the release of personal computers.
In the cartographic visualization, the GIS technologies were invented in the 1970s. However, for a very long time the development focused on the input part and on the analysis. The need for real map production features (to produce paper maps which conform to cartographic traditions) in GIS software environment was raised after most of the paper maps were converted into digital ones. On the other hand, the non-GIS based map production could easily use the development of the DTP technologies about ten years earlier. The DTP features supported all those necessary visualization features that were widely used in traditional cartography.

INTRODUCTION

To create maps and other cartographic products using digital methods we should have knowledge not only on cartography, but the knowledge of several computer programs (including operation system, file management, printing) and their relevance for our work. The technology of "analogue" cartographic production (including map printing) was developed in the 20th century. The production of colour maps became widely used when the offset printing replaced the other printing techniques (like lithography) after the beginning of the 20th century. The colour printing technology was continuously improved, although theoretically it remained the same until the digital methods were invented. This new technology very soon influenced the visualization of printed maps especially in the beginning, when the digital technology had some weaknesses.

EARLY COMPUTER MAPS

Computers became important devices since the 1960s, when more and more researchers had access to information technology on different levels. Computers at that time were very expensive devices: only large companies or state authorities (including research and higher education institutions) could access them.

One of the main weaknesses concerning the cartographic visualization was the lack of good computer (graphic) screens. The very early screens were alphanumeric; they could show only characters, and graphics were not possible at all.

GIS was initiated in 1960s, when the governmental level statistics in United States claimed a tool for analysing and visualizing the statistical data. US Census is one of the best known examples of the early use of information technology methods in statistics.

William Garrison was a recognized geographer at the University of Washington, when he came up with an idea to make use of statistics and computers to study and better understand and represent statistical problems. Waldo Tobler, a student of William Garrison invented a model called Map In – Map Out (MIMO) in 1959, which would apply computers to cartography. This model was the basis for GIS and contained all the basic features of GIS software (like geocoding, data acquisition, data analysis) available and in use today.

The Canada Geographic Information System was developed in the 1960s. Roger Tomlinson worked at an aerial survey company in Ottawa, focusing on producing large-scale photogrammetric and geophysical maps. The co-operation between IBM offices and Tomlinson brought the geographic knowledge to the table as IBM brought computer programming and data management. This was the first idea to convert the national land management to an IT driven environment.

The most famous institute of the early GIS was the Harvard Laboratories, which was founded in 1964 by Howard Fisher in Harvard University. The close relationship to the best known information technology institutes (MIT, Yale) inspired the research, but in the first years architecture, urban development and resource management were more important than the geography based research. Their famous application was the SYMAP (Synagraphic Mapping System) in 1965, which was a set of different modules for analysis and manipulation of data for production of

choropleth or isoline maps. Fisher called this application as a mathematical cartography, but the term automated cartography was much better accepted in the International Cartographic Conferences.

Due to the very limited visualization functionality of computer screens, the main output devices were computer printers. In the 1960s and 1970s, there was not too much focus on output devices in informatics. At that time, line printers and matrix printers were nearly the only opportunities to make output from digitally stored data. These devices were produced to print text (characters) based on simulating the well-known "output device", the typewriter using impact printing. However, these devices were driven by the computer at a much larger speed than any human could do. What was much more important in the cartographic point of view is the print size. In the industrial and scientific environment, where financial resources were available, such kind of large format line matrix printers and (later) dot matrix printers were used. This large output size (wider than the 80 columns of an A4 sheet) became available in the 1970s. The SYMAP technology was used only in research institutes, where line printers were available. This printing technology has never been used together with personal computers, although the technology was long time used in business environment. Finally, the large speed laser printing replaced the old technology. Dot matrix printers were developed around 1970. The very first printers used 5*7 dot matrix to form the characters; later the 9*9 dot matrix became standard. In the 1970s and 1980s, dot matrix impact printers were generally considered the best combination of expense and versatility, and until the 1990s, they were by far the most common form of printers used with personal computers. Line printer maps were not comparable to professional cartographic products made by traditional map production techniques, but due to the complexity and time consuming of the map production process even the low quality digital maps were useful. The automatic production of statistical maps showed also the potential of the GIS, but it was evident that such maps would not replace the professional looking maps, created by traditional map production techniques (Figure 1.)
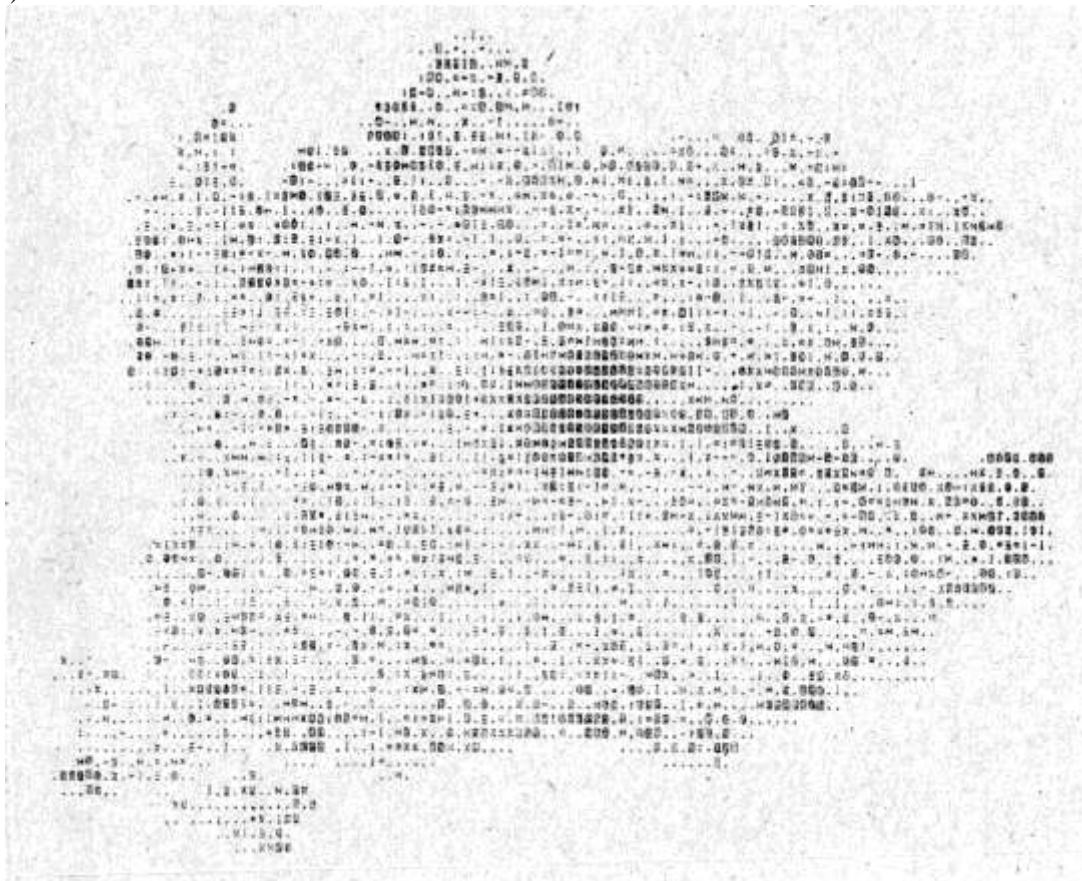

Figure 1. Experimental choropleth map of a Hungarian county, created by the COMAPO software on ICT 1905 mainframe computer (1972)

The very first special output device used in cartography was the pen plotter. Compared to nowadays printers, pen plotters were very slow and cumbersome to use. Users constantly had to worry about a pen running out of ink. If one pen ran dry at the end of a plot, the entire plot had to be re-done, which was very time consuming. Plotters could only draw lines; they could not reproduce raster or photographic images (areas could be filled only with hatching). Despite these limitations, the high resolution and colour capability made the pen plotter the colour hardcopy output device of choice until the late 1980s, especially in technical drawings and CAD graphics, which consisted of simple lines like cadastral maps. Only the inkjet technology has made pen plotters obsolete.

In drum technology, the papers were fixed and a pen was moved in a single axis track, and the paper itself moved on a cylindrical drum to add the other axis or dimension. Where the paper was fixed on a flat surface and the pens were moved to draw the image was called a flatbed plotter. This type of plotters regularly can use several different colour pens to draw with.

CalComp was incorporated in 1958. This was one of the first companies in the United States to market peripheral products designed specifically to work with computers. CalComp's appearance coincided with the first wave of acceptance of computers by such mainstream businesses as banks and insurance companies. In 1959, the company developed the world's first drum plotter, but few expected the instrument to grow into CalComp's strongest product line.

Figure 2. HP7475A plotter

The HP 7470 model was a small low-cost desktop pen plotter created by Hewlett Packard in the 1980s. It used a revolutionary "grit wheel" design, which moved the paper held in place by a wheel with embedded grit and a pinch roller. The HP 7470 had originally only two pens, one on either side. It was much less expensive than the previous flatbed design, which was very heavy but had four pens. The HP 7475 used a rotating carousel with six pens. This design was also scaled up for very large pen plotters (Figure 2.)

When the personal computers became affordable, having larger storage capacity, and GIS software were used more frequently, cadastral maps were the first map types in state cartography to process digitally. Cadastral maps were ideal concerning the digital processing: they used only straight lines, practically no map symbols, no (or very few) areas to fill, and they used only limited colours. Another advantage of cadastral maps was that these maps were not regularly copied. Normally, there was only one hand drawn copy which was updated.

THE DESKTOP PUBLISHING

Although the development of GIS was vital for the conversion of cartography to digital, one aspect of this process (the output side) is regularly neglected or not mentioned at all. The opportunity of the automation of the whole map production process became possible with the development of desktop publishing (DTP) in the personal computer era. The main aim of the DTP is to manage different text (rich formatted text, tables) and graphic information (illustrations, equations, photos) of a page in a computer environment as it is usually necessary when producing books, magazines or any other publication (especially where we have lot of different typefaces in various sizes). Such computer programmes were available for about a decade before the personal computers were released, but these systems were so costly that only very large international publishing companies were able to afford them (mostly in North America, Japan and Western Europe).

DTP was the individual alternative of the traditional, professional publishing and printing industry. DTP replaced the first part of the very expensive infrastructure of the printing industry making it a really personal activity: having a personal computer and a suitable DTP software, one was able to design any product on the screen. The most important development of DTP was the invention of the technical part of the process: laser printers were used for proofing and image setters (laser plotters) for the production of printing films. Image setters were very expensive, but when the technology became available around 1985, it was easily available as an affordable service (like the photocopy machines). The most significant advantage of DTP was the integration of the typographic and graphic knowledge of publishing in software which gave the user enough freedom in the design.
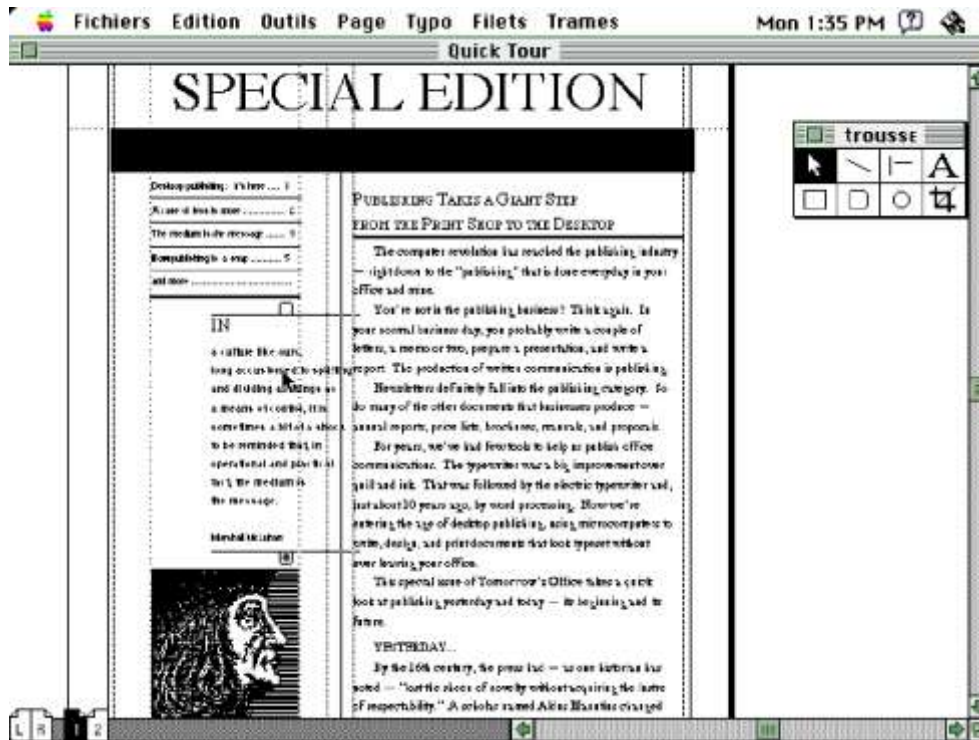
Figure 3. Aldus Pagemaker 1.0 screenshot (Mac version), source: http://www.makingpages.org/pagemaker/history/

The first DTP software on personal computers was the Aldus PageMaker (released in July 1985 for Apple-McIntosh computers and in 1986 for IBM PCs). The first black and white personal laser printers (HP Laserjet, Apple LaserWriter) were also launched at that time (1984-1985). Although these early laser printers were quite expensive for home users and had only relatively low resolution (300 dpi), due to the special invention, the Postscript language, the laser printers were essential to use as a proofing device before we started the printing process in a print shop. Other software products were also very important, like vector graphics and image manipulation software, because the DTP offered the integration of different page elements. However, the manipulation was possible only in the original software component (Figure 3.)

Postscript is a page description language (developed by Adobe, which was established in 1982); it was the first widely available product that allowed for control over a large number of fonts and graphical objects. The main advantage of Postscript is the device-independency and that Postscript is not related to any concrete operation system. Postscript devices (laser printers, image setters) have a raster image processor (RIP), which performs the instructions of the Postscript file, so the quality of the printed output depends on the resolution of the output device. RIPs were built-in in the output devices, which increased the price and prevented home users from affording a Postscript device. Postscript was treated as a professional application, and Adobe earned considerable amount of money on licensing Postscript language for printer manufacturers.

Other important feature of the Postscript language, especially concerning the desktop publishing, is the handling of typefaces as vector structures, so the characters are scalable and rotatable. Practically, users can manage all kinds of graphic manipulation. Previously, all industrial DTP systems, different operation systems used raster fonts, which gave very limited options: only few fonts could be used and only some predefined sizes were allowed to use. In a later period, more features of raster fonts were added, but the printing time of these extra elements was very long.

What DTP requested for a computer based system was also useful for map production. The technological part of map production was a very complicated process: required special and very expensive devices (reproduction cameras, precise treatment of drawing materials, screens etc.) and the potential human errors were not easy to avoid. For example, in Hungary, at that time only few state institutes had such infrastructure (Cartographia, the main and practically the only civil map publishing company, the Military Cartography Institute, the Hungarian Geological Survey and the Department of Cartography). The entire map drawing technique was based on special transparent films, which were produced in Western Europe. When the whole map production industry changed to the digital production line, the Western European companies stopped the production of these special films. This made the traditional map production process impossible in the beginning of the 1990s, unless the Hungarian cartographic institutes started to transfer their map production technique to digital.

SCREEN MAPS

Screen map images had a special role in the early digital cartography. These raster maps were regularly designed for the screen to make cartographers understand the special requirement of modern visualization.

Such kind of maps were presented even on hobby computers in the 1980s, but due to the very small screen resolution and colour palette (not larger than 320*200 pixels) these images could be used mostly for games only. (Figure 4.)

Figure 4. Radarsoft Maps World, a Commodore screenshot (1985)

These early maps were mostly made by computer specialists instead of cartographers; cartographers could have been asked to contribute as experts, but the special requirements of screen maps were very unusual for the traditional cartographers at that time. The task required some time for cartographers to be familiar with the digital environment and the very special limitations.

The screen resolution of the home and personal computers improved relatively slowly in the 1990s, because the manufacturers were rather focusing on hardware elements like processors, hard disks, and memory chips.

In the early PC era, there were very strict limitations:

- Hard disks were very small, they were not able to store too many images (the first hard drives with more than 1 GByte were launched in 1992).
- The screen resolution was limited; this was partly physical limitation, but was also due to the poor performance of early graphic adapters. The first colour graphic adapter for PC's was the CGA (Color Graphics Adapter), which was released together with the first PC in 1981. The resolution was 320*200 pixels with 4 colours. The next standard was the EGA (Enhanced Graphics Adapter) in 1984, and later the VGA (Video Graphic Array) in 1987 (640*4801 pixel resolution with 16 colours).
- Colour depth was also a critical factor in the beginnings. Even in the early 1990s, colour palette with 256 colours was the most common, which was much less than perfect for the photographs and very good quality images.
- Screen maps were regularly generated in computer software from a vector database, but they could also be scanned. Scanners were unusual peripherals at that time. They became more affordable when a fast and cheap interface between the PC itself and a scanner was developed: this was the Universal Serial Bus (USB) released in 1996.

The real screen map is optimized for the computer screen. The most sensitive map feature is the text: this should be clearly legible on the screen. Due to the limited screen resolution, maps should be well generalised. The very first interactive global map service was the Xerox Parc Map Viewer in 1993; the program allowed the user's computer to create on-demand maps from a geographic database. Each interaction with Map Viewer would request a new map from the server that was zoomed in on a specific point. Individual maps were generated in a raster graphic file and presented as a web (HTML) page.

Map Viewer: world 0.00N 0.00E (1.0X)
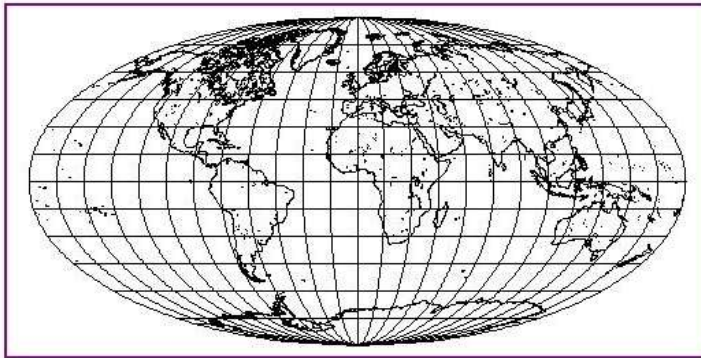
Select a point on the map to zoom in (by 2), or select an option below. Please read About the Map Viewer, FAQ and Details.

Options:

- Zoom In: (2), (5), (10), (25); Zoom Out: (1/2), (1/5), (1/10), (1/25)
- Features: Default, All; +borders, +rivers
- Display: color; Projection: elliptical, rectangular, sinusoidal; Narrow, Square
- Change Database to USA only (more detail)
- Hide Map Image, No Zoom on Select, Reset All Options

Figure 4. Xerox Parc Map Viewer

The first CD-ROM atlases were also produced at that time (an American company, DeLorme produced the first consumer CD-ROM street atlas called Street Atlas USA in 1991, and the first world atlases were also produced at that time). CD-ROM was a very important storage device. The 640 Mbyte capacity was comparable to or much higher than the storage capacity of the hard drives. This large storage space encouraged the software developers to add contents like audio, photo and video to develop the multimedia product. Even the manufacturers used raster maps or vector maps in their CD atlases, but the required storage place was not too large. Such products were also sold on floppy disks (especially because CD-ROM was not yet widely used), and most users would buy only the floppy disk version. Hungary produced the first vector based world atlas in 1994 in cooperation with various institutes (private firm, map publishing company, national institute). The whole map database was smaller than 10 MB, so the rest of CD-ROM was filled with photographs. The product was not very successful; the Hungarian market was not prepared for CD-ROM products.

The screen maps and CD-ROM products lost their importance around 2000, when the development started to focus on the Internet. MapQuest introduced its online mapping site based on a large database in 1996, which included most streets in North America.

The actual era started by Google in 2005, when the company effectively added a map-based search engine through Google Maps, and the stand-alone Google Earth became a de-facto standard of on-line map services.

The visualization issue of screen maps became important only when the screen resolution and the colour depth was good enough to be comparable to traditional paper maps. When this happened, the users continued insisting on having a printing function in the software product no matter whether it was a special stand-alone product or an Internet service. It is still a challenging problem to manage a professional on-line service or a commercial map product also including a perfect printing function.

EARLY DIGITAL MAPS IN HUNGARY

The conversion process of the Hungarian cartography into a digital era was affected by various factors. Although the limited access of Eastern and Central European countries to the high technology of computer products made it difficult or sometimes impossible to follow the developments, the Hungarian cartographers tried to do their best. The first research on automated map production was carried out around 1972: thematic maps were created by computer printing (dot-matrix print) and plotters (Figure 1). At that time, only the state offices had a chance to access IT devices; the government established a special company on servicing governmental needs in 1974. It was a wise decision to concentrate the limited financial resources (the Hungarian currency was not convertible and Hungary had no many experts in this field).

The conversion of state topographic maps into digital form started in 1987, when the 1 : 200 000 scale military topographic maps were digitized in AutoCAD environment. At that time all topographic maps were classified (including the civil ones), so the digital version (which did not include the contour lines) was not for sale, and was only

used in military environment. Even if it had been available for sale, there were very few PC's in the country and they were mostly used by state institutes and authorities. The classification of state topographic maps was discontinued when the political system changed around 1990. The digital version of the 1 : 100 000 scale civil topographic maps (EOTR – Hungarian Unified Map System) was much more influential, because it was digitized by the first and most famous Hungarian GIS company (Geometria Ltd.). This product was named OTAB (National GIS Database) and was especially available for sale; the content of that database was similar, contour lines were also omitted. This product was widely used by the foreign and multinational companies, which started their activities in Hungary at that time.

This was the time when the first paper maps were published by using totally digital methods. Small map publishing enterprises were formed by the former Cartographia employees, who had all cartographic knowledge and market connections. Naturally, it took some years until these cartographers became familiar with the digital techniques. In the first years, few paper maps (small city maps) were also made by IT experts, who had no previous cartographic experience. City maps and road maps were the most common map types produced by the early digital cartographers.

The first fully digital version was the DTA-50 (Digital Cartographic Database), which was the digital version of the 1 : 50 000 scale military topographic maps. The digitizing process was completed in 1996. The process was speeded up by the risk of the Balkan wars; the US Defence Mapping Agency and NATO provided financial support to the digitizing process.

Hungarian cartography has turned to digital including not only the map producing, but also the development of GIS companies.

CONCLUSIONS

The last two decades of the 20th century were a very challenging era in cartography not only in Hungary, but all over the world. The technological development, the new digital techniques considerably changed cartography, gave much more emphasis on the geographic information systems. This was the time when the technological development partly overshadowed the visualization part of cartography; most companies were focusing on converting the existing paper maps into digital form and the importance of visualization was re-discovered when the GIS software became capable to manage enhanced visualization and map production features.

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Biography

Prof László Zentai is the head of the Department of Cartography and Geoinformatics, Eötvös Loránd University, Budapest. He created the first Hungarian digital map in 1990. His papers deal with computer cartography, topographic maps, education in cartography, webcartography.
He served as Vice-Dean of the Faculty of Informatics between 2003 and 2007 and Vice-Rector of Eötvös Loránd University between 2008 and 2011. He starts to work as Vice-Dean of the Faculty again in the second half of 2012.
He has been working for the International Cartographic Association since the 1990s. He was Chairman of the Commission on Education and Training between 2003 and 2007 and Vice-Chairman between 2007 and 2011. He has been the Secretary-General of the International Cartographic Association since 2011.