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CARTOGRAPHY AT THE THRESHOLD OF THE NEW MILLENNIUM

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Abstract: This paper deals with the origins and cognitive background of cartography, with the cartographic legacy of the Second millenium, with changes during the last half century and with the advantages of collaboration in science. Also it deals with basic mapping and the development of spatial data infrastructres. Today map production is characterized.

Keywords: Cartography, spatial thinking, visualization of spatial data, traditional and computer map creation.

Introduction

Many observers outside the profession of Geomatics, still regard Cartography as the production of paper-based maps to present spatial information. Thus, in this modern era of computers, GIS, multimedia and the Internet, its viable future can be open to question. This negative view may seem hard to deny, as the tradition – the human art and craft of creating maps – has changed so much over the last forty years. Although not declaring a direct challenge, the title of this paper anticipates some analysis of these changes and the offer of a reasonable explanation of the subject today and its future directions. The simplest response might be to ignore the obvious implication that the character of cartography will be quite different in the future, and merely present a structured catalogue of how new technology has always influenced map making. Most new maps will soon be derived from some type of GIS, most likely via the Internet, and therefore, 'cartography', as the direct and overall creation of maps by human author-designers, will surely fade? Is the word 'visualisation', through computing, the new son of traditional cartography, and thus its saviour?

This paper takes a broader approach. Beginning with a brief review of how *cartography* has evolved, it then attempts to look beyond mechanistic analysis and towards more fundamental issues of human ability and invention. This includes how we operate in our spatial environment, and deal with related problems. These operations are primarily mental but, probably, have always involved the creation of, and interaction with external physical aids, such as real maps, ephemeral or permanent. Against this background we can then observe the significance influence of 'new' technologies, and the dramatic changes in recent years of both the provision of spatial data and the cartographic product itself. The conclusion is that so-called 'external' aids (primarily maps) have been increasing in accuracy, complexity and sophistication throughout the history of cartography. Although the planimetric map is the most common representative of this genre it has not been alone. Other techniques, such as oblique views, block diagrams, cross-sections and transects have been devised to help deal with special problems (e.g. related to military planning and the understanding of geological structures) thus widening the diversity of traditional cartography-related tools. So instead of assessing cartography at the close of the millennium as just a new batch of advanced techniques, it can be identified as the latest stage in the evolution and utilisation of the human facility of 'mapping' which is characterised by active perceptual-cognitive dialogue between the reader/investi- gator and a spatial thinking-aid such as a map. Printed paper maps and their predeces sors may have been, primarily, archival databases, presenting what was known, but they have also been available as

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sources for research and exploration for centuries. Modern spatial visualisation tools, however, offer awesome new extensions to the power, versatility and effectiveness of human 'spatial-thinking'. At the threshold of the new age, therefore, we see the cartographic devices changing. However new technological products need not replace all of the old (has the jumbo jet replaced the bicycle?). Variety and flexibility of method will increase, offering greater choice of product and level of technical sophistication to meet the appropriate task.

A retrospective view

Origins and cognitive background

The first maps were probably drawn to depict familiar local environments. Examples such as ephemeral sand-drawings or more permanent rock engravings reflect the most fundamental of human characteristics and processing abilities, spatial awareness and spatial thinking. As explained by Piaget, the ability grows from early childhood and its nature and effectiveness depend on both formal education and first-hand environmental experience. The general process of mapping has been described by Cosgrove (1999) as "... not restricted to the mathematical; it may equally be spiritual, political or moral... it includes the remembered, the imagined, the contemplated... Acts of mapping are creative... moments in coming to knowledge of the world, and the (physical) map is both the spatial embodiment of knowledge of the world and a stimulus to further cognitive engagements". Mental visualisation has proved to be one of the most powerful aspects of spatial thinking, exemplified by its sophisticated use by many famous scientists. However, as there are clear limitations to the detail and precision of any data which can be held and manipulated in the mind at one time, an external display is an essential component of the human exploratory and analytical engine. The impulse to create a map, therefore, is the most natural of human expressions and certainly more fundamental than communication by written language.

The cartographic legacy of the Second millennium

Of course the theme of the paper is not meant to challenge common approaches to the history of cartography, nor the ways in which maps have evolved and been classified. Once the value of maps had been established, for data presentation, investigation and discovery (a stage possibly achieved in some cultures well before the beginning of the First millennium, AD) as well as the only acceptable form of pre-digital spatial database, numerous categories (notably the topographic map) and applications emerged. National maps became expressions of the power of the state, atlases reflected the pride and character of countries and regions and, especially in the west, many of these became viable commercial products. There have now been over five hundred years of map printing, and the map has become a real icon of our age and culture. With the need to conceive, compile, design and produce maps of increasing variety during recent centuries, professionalism developed not only in those responsible for surveying and collecting spatial data, but also amongst map designers and craftsmen. Naturally, much of the knowledge, skill and expertise of cartography was acquired by the practitioners themselves. Unlike professions such as Law and Medicine, the formalisation of cartographic education and training at a more general level was slow to emerge and quite recent in age. This also applies to courses, mainly within Geography, on the reading and interpretation of maps.

The underlying theme of this account is the constant human need to solve spatial problems, no matter how trivial, and that the visible external map was invented and has evolved to help support this activity. Of course most people can survive on their personal cognitive maps alone... most of the time, only meeting difficulties when tackling more complex problems such as planning a road journey or navigating difficult mountain terrain. Such tasks have led to the design and development of specialist maps. However even these cannot be too sharply customised and are often criticised by individual users for being out-of-date, at the wrong scale, having insufficient detail for the intended task, or having sheet edges which cut through the area of interest. While inconvenient, such flaws are generally accepted as inevitable. In more serious scientific research, however, these difficulties are unacceptable. Instead individual maps are created to meet the tightest

standards of data accuracy and, where necessary, specialist devices, such as block diagrams, or even film-type animations have been created manually.

Changes during the last half century

When conventional maps were created manually and had to satisfy the needs of both database and presentational tool, the result was generally an unhappy compromise. Also, as the thought-processes of the searching mind move rapidly through a problem, manually-created static aids to spatial thinking were just too slow and difficult to produce. The arrival of computer-based digital solutions in the 1960s were to change all that. There were two responses to the availability of the new technology. First of all, those people who were still conventional map makers, more concerned with map-making alone, substituted computer tools for their old drawing instruments with most dramatic effects. Speed of compilation and design was transformed and alternative creations could be offered with great rapidity. However those more concerned with researching complex spatial problems involving decision support (e.g. derived from the comparison of numerous map coverages) saw their best opportunities emerging from the structuring and manipulation of the data themselves, the preferred output not always being in map form. The result was Geographical Information Systems (GIS), the power of which derived from complete, accurate and timely databases, and tools to manipulate their content.

The advantages of collaboration in science

Parallel with more recent developments in Geospatial studies, impressive innovations were also taking place, in the late 1980s, in general science and engineering. Although graphics and physical models had been used to support research into complex problems (such as molecular structures) and very large datasets (such as the atmosphere), the new power of computing to create visualisations was harnessed. The new movement of Visualisation in Scientific Computing (ViSC) recognised the power of human vision for exploring large datasets to gain understanding and insight. These computer-generated images were not just static, but dynamically linked to their core datasets through interfaces which also allowed the user to interact dynamically by exploring the visualised data, virtually, in three dimensions. Important meetings took place between scientists and cartographers in the UK in 1990/91 and this led to high-level collaboration beginning in the mid-1990s in the USA between the ICA Commission on Visualisation and the Association of Computing Machinery (ACM) Special Interest Group on Graphics (SIGGRAPH). As a result cartographers have benefited from new computing facilities while other scientists have tapped into the historical wealth of cartographic techniques. This collaborative effort has been a real catalyst in the development of new forms of spatial thinking tools, involving the latest techniques of multimedia and virtual reality. During the quantitative revolution in Geography, mathematics and statistics were believed to provide the best answers to problems. With ViSC, and its geospatial equivalent, Gvis (Geographic Visualisation), we come back to the combined power of the eye and brain for exploration and analysis.

Cartography at the threshold

Although I have provided one way of assessing how cartography has evolved to its current stage in 1999, a complete description of the state of the subject in the final year of this millennium is beyond the intended scope of this paper. Not only would it have to include an inventory of mapping world-wide, topographic and thematic, but also an assessment of the current extent of computer-based production, common products (sheet maps, atlases and electronic products, on CD and on the Web) and the availability of map-ready spatial data, at local and global levels. However some of these themes are briefly reviewed below.

Basic mapping and the development of Spatial Data Infrastructures (SDI)

Topographic maps, based on some common standards, still offer the best form of description of the countries and regions of the world. Unfortunately, although good topographic coverage has been completed and is being maintained in certain areas, some countries, notably in developing regions, are still poorly served. This decade has seen the rapid promotion of the idea of spatial data infrastructures, associated with information

networks and associated metadata and transfer standards. These initiatives are still under development, but will depend, ultimately, on the nature and quality of national mapping. The value of SDI for an individual nation is obvious and the networks will develop stage by stage. However the wider initiatives of Regional and even Global SDI are, in some ways, much more urgent. The wider Global need arises with cross-border crises, such as those related to catastrophic climatic events or volcanic activity. Then mapping and other spatial information provision can be critical to the rescue efforts and rehabilitation.

Map production today

For almost two decades now increasingly friendly desk-top graphic and mapping packages have been replacing the traditional compilation and drawing environments in mapping agencies and commercial companies. These continue to replace the older methods, and practitioners, who cannot make the transition, are often lost to the profession. Fortunately a new genre of map-makers has emerged. Years of experience with these new and versatile computer systems are leading to a restricted but valuable professional group which has transferred the ethos of old cartography onto a new digital plane. The new cartographic process is much more compact and certainly does not involve the extended series of stages and activities associated with previous conventional methods. Designs can now be tested out and changed much more quickly, and the whole process of production has been vastly abbreviated. The products of these new cartographers also differ from those of their predecessors, ranging well beyond the printed map. Few maps are now produced in large stock numbers. Short runs to order, increasingly from high speed laser printers, are more common, as are maps for multimedia products or for electronic atlases on CD-ROM or the Web. Unfortunately many of these practitioners work alone (or linked by email to each other) without an environment in which ideas can be shared and apprentices trained. The demise of readily-available formal training courses will lead to the dilution and eventual loss of the essential body of knowledge required to maintain the status of the subject. Usable GIS packages have also grown in popularity but are associated with certain shortcomings. Although they can be used for analysis and even map compilation, their cartographic output facilities have been notoriously poor. It is true that the graphic qualities of such products, when used privately between collaborating workers, can afford to be lower than if designed as part of a public document. It has been observed that, as with spreadsheets and word-processing packages, an increasing number of specialist (non-cartographic) professionals are becoming competent in the use of cartographic packages and GIS. The increasing use of in-built intelligence (such as Microsoft 'wizards' or name-placement software) can support the less experienced and raise the standards of cartographic output to more acceptable levels of mediocrity. Linked to this is the need for automated map generalisation. Of all the skills that are being lost to the profession, this has been the most difficult to replace with intelligent software. Mapping from and within the Web is another dimension of map use, with provision for both general societal needs as well as for education and science. It is already possible to access web sites which not only contain databases which are constantly maintained, but also embody analytical tools such as GIS. As data transfer speed across the Internet increases, the use of such 'runtime' software in conjuction with databases will become more common and convenient to the 'visiting' user. Another database issue, still under development, is the derivation of multi-scale and, hence, multi-purpose products from existing databases. All these activities are raising the status of mapping operations within society and making them more ubiquitous. A likely and desirable outcome will be an increase in familiarity with maps and of general map literacy in the population.

At the pioneering fringe of 'Cartography-as-spatial thinking' is the new field of Geographic Visualisation (Gvis). Here seemingly magic combinations of computing skill, problem analysis and innovative thinking are helping to create powerful pioneering tools for scientific research. An example of this is an approach to the process of constructing knowledge through structured exploration of large spatiotemporal datasets. This involves use of Gvis and Knowledge Discovery in Databases (KDD) software*.

Although the future trend seems to be of increasing use of spatial thinking with the aid of maps and map-based visualisation tools, I believe that not all this activity will be di-

rectly user-driven. As explained by Rhind (1998), maps contain hugely differential methods of abstraction and, until the unlikely stage when software exists to handle this necessity, professional cartographers (perhaps a new breed!) will continue to provide a service to both professional users and the general public. While interactive GIS-like tools can be excellent for the investigation of complex datasets, there are some tasks which can be served best with a map, carefully compiled and designed by the application of human skills and graphic sensitivity.

Conclusion

This paper has tried to identify a thread of continuity through the history of cartography. Research into map design, map use and the perceptual/cognitive processes of human interaction with maps suggests that rather that focussing attention on one prototypical map type, we can think of 'cartography' as an integral part of the process of spatial thinking. Five centuries of printed static images have left their mark on our culture and, perhaps made it more difficult to move on to the innovative and very different 'cartographic' tools of the present and future. Getting 'back to basics' may help us bridge the gap and accept the new dimensions being offered by facilities such as Gvis. However I do not believe that each new technology need replace, in entirety, everything which has been used before. Just as aids to travel today extend from the bicycle to Concorde or a jet ski, so should the tools to support spatial-thinking remain as diverse as the tasks they are designed to support.

In conclusion, I believe that we have reached the threshold of the new millennium with a richly diverse cartographic palette of techniques and technologies. I am also proud to be part of the International Cartographic Association which has within its energetic commissions and working groups some of the leading international scientific forums concerned with the cartographic sub-fields referred to in this paper.

References

Cosgrove, D. (1999). Introduction: Mapping and Meaning. In *Mappings*. Reaktion Books, Guilford.

Rhind, D. (1997). *In Framework for the World Geoinformation International.* Cambridge.

* URL: http://www.geovista.psu.edu/publications/ijgis99/.

R e s u m é
Kartografia na prahu nového tisícročia

V súčasnom období počítačov, GIS-ov, multimédií a Internetu veľa odborníkov z oblastí nachádzajúcich sa mimo geoinformatiky (geomatiky) ešte stále nazerá na kartografiu ako na výrobu papierových máp, čo ohrozuje jej životaschopnosť. Tento negatívny obraz, ktorý by sa mohol zdať že popiera tradičný názor na kartografiu ako na umenie a schopnosť tvorby máp, sa ale za posledných 40 rokov značne zmenil. Hoci názov tohto príspevku nedeklaruje priamu zmenu, predpokladá určitú analýzu týchto zmien a venuje sa primeranému vysvetleniu otázky dňa a jej budúcemu smerovaniu. Jednoduchá odpoveď môže ignorovať samozrejmé dôsledky, že charakter kartografie bude v budúcnosti celkom iný a že iba zavedenie štruktúrovaného katalógu nových technológií ovplyvní tvorbu máp. Väčšina nových máp sa bude čoskoro získavať z GIS-ov, možno z Internetu a teda kartografia ako riadená a úplná tvorba máp ľudmi-autormi sa úplne vytratí? Výraz "vizualizácia" cez počítače je nové dieťa tradičnej kartografie, a teda jej záchranca?

Tento príspevok podáva širší prístup. Po krátkej úvahe o tom, ako sa má kartografia vyvíjať, usiluje sa uvidieť za mechanistickou analýzou fundamentálnejšie problémy ľudskej schopnosti a invencie. Zaoberá sa problémom nášho pôsobenia v novom prostredí a s tým súvisiacimi problémami. Tieto operácie sú predovšetkým mentálne, ale pravdepodobne vždy obsahujú tvorbu a interakciu s vonkajšími fyzikálnymi prostriedkami, akými sú reálne (nestále a stále) mapy. Oproti tomuto pozadiu môžeme pozorovať dôležitý vplyv "nových" technológií a dramatické zmeny v posledných rokoch tak čo do zabezpečovania priestorových dát, ako aj čo do vlastného kartografického produktu. Záver je, že tzv. "externá" pomoc (primárne mapy) mali stúpajúcu presnosť, kompexnosť a kultivovanosť počas celého vývoja kartografie. Hoci je pôdorysná mapa vo všeobecnosti najviac reprezentatívna, nie je to jediný spôsob. Sú aj iné techniky, napr. blokdiagramy, profily a rezy, ktoré sú určené na špeciálne ciele (napr. pre vojenské zámery, alebo na pochopenie geologických štruktúr), ktoré rozširujú rozmanitosť tradičných kartografických prístupov. Na prahu nového veku vidíme teda zmenu motta

kartografie. Avšak nové technologické produkty nepotrebujú vymeniť všetko staré (vari bol bicykel nahradený jumbo jetom?). Variabilita a flexibilita metód bude vzrastať tým, že ponúknu väčší výber produktov a úrovne technickej vynaliezavosti na plnenie potrebných úloh.

Prvé mapy boli pravdepodobne kreslené a zobrazovali malé známe prostredie. Kresby v piesku, alebo rytiny v skale odrážali charakteristiky, ktoré boli pre ľudí dôležité, ale tiež aj spracovateľskú zručnosť, priestorové vedomie a myslenie. Mentálna vizualizácia sa stala jedným z účinných aspektov priestorového myslenia, čo ilustrujú príklady jeho komplikovaného využitia mnohými slávnymi učencami. Impulz tvoriť mapu je teda väčšmi prirodzený ľudskému vyjadrovaniu a rozhodne podstatnejší ako komunikácia písaným jazykom.

Hodnota máp bola kedysi v zobrazení dát, v bádaní, objavovaní, ako aj v akceptovateľnej forme predigitálnej priestorovej databázy, v početnosti zobrazovaných kategórií a v aplikačných možnostiach. Štátne mapy sa stali výrazom štátnej moci, atlasy odrážali pýchu a charakter krajín a regiónov, obzvlášť na Západe, kde sa mnohé z nich stali životaschopným komerčným produktom. S potrebou koncipovania, zostavovania, kreslenia a produkcie máp so stále vyššou rôznorodosťou počas tohto storočia, profesionalizmus sa rozvíjal nielen v zodpovednosti za namerané a nazhromaždené dáta, ale tiež medzi mapovými kresličmi a remeselníkmi. Prirodzene, že veľa kartografických vedomostí, zručnosti a schopností sa získalo samotnými praktikmi. Na rozdiel od takých profesií, ako právnické a lekárske, formalizácia kartografického vzdelávania a výchovy bola vo všeobecnosti ťažkopádna. To sa týka aj geografie, najmä čítania a inerpretácie máp.

Hoci bežné mapy boli tvorené ručne a mali uspokojiť potreby tak databáz, ako aj vyjadrovacieho média, výsledkom bol zvyčajne nešťastný kompromis. Nastup počítačov v 60. rokoch všetko zmenil. Tradiční spracovatelia máp začali používať počítačové nástroje ako kresliace pomôcky na dosiahnutie výrazného efektu. Zmenila sa aj rýchlosť zostavovania a kreslenia a dostavila sa možnosť tvorby alternatívnych máp z tej istej databázy, resp z toho istého GIS-u.

Pôsobivé inovácie sa v 80. rokoch odzrkadlili aj všeobecne vo vede a technike. Hoci grafické a fyzkálne modely sa používali na podporu výskumov, počítače sa zapojili aj do ich vizualizácie, pričom ponúkli nové možnosti. Počítačmi generované obrazy už neboli len statické, ale pomocou ďalších rozmerov získali virtuálnosť (priestorovosť a dynamiku). Dôležité boli stretnutia medzi vedcami a kartografmi. Vo Veľkej Británii viedli k vyšej úrovni spolupráce začiatkom a uprostred 90. rokov, v USA sa rozvinula spolupráca medzi Komisiou vizualizácie ICA a Asociáciou počítačových prístrojov (ACM) a Špeciálnou grafickou skupinou (SIGGRAPH). Táto solupráca bola katalyzátorom v rozvoji nových foriem priestorového myslenia.

Topografické mapy ešte stále ponúkajú najlepšiu formu opisu krajín a regiónov sveta. Hoci je svet dosť dobre pokrytý topografickými mapami, predsa sa nájdu krajiny, obzvlášť rozvojové, kde je mapovanie na nízkej úrovni. V poslednom desaťročí sa však zrýchlil postup zabezpečovania priestorových dátových infraštruktúr (SDI). Táto snaha je ešte len v počiatkoch, ale rozvíja sa v podobe národného mapovania ako regionálna, ba dokonca globálna inciatíva. Globálne potreby vyplynuli najmä z pohraničných konfliktov a rôznych katastrofických udalostí.

V kartografických organizáciách boli v posledných dvoch desaťročiach tradičné mapovacie postupy a zariadenia nahradené počítačovými prístrojmi a technológiami. Strácajú sa mnohé mapovacie a kartografické profesie. Objavili sa však nové kartografické postupy, umožňujúce transfer starých kartografických spôsobov do digitálnej oblasti. Nové kartografické postupy sú oveľa kompaktnejšie a komplexnejšie, zlučujúce niekoľko bývalých postupov. Kresba máp je testovaná a menená oveľa rýchlejšie a proces výroby máp je oveľa menej komplikovaný. Početnosť druhov máp sa zvyšuje. Vznikli úplne nové druhy elektronických máp, atlasov na CD-ROM-och, alebo na Web-stránkach. Mapy sa ľahšie demonštrujú a ľahšie sa uskutočňuje výučba tvorby máp. Očakáva sa nárast popularity GIS-ov, hoci je sprevádzaný mnohými nedostatkami. Hoci sa Gis-y využívajú na analýzu a zostavovanie máp, ich mapové výstupy sú notoricky chabé. Tento trend napreduje vďaka tomu, že o mapových výstupoch z GIS-ov rozhodujú nekartografickí odborníci. Ale je to aj obraz nízkej úrovne programového vybavenia mnohých používaných softvérov. Podčiarkuje to aj potreba automatizovanej generalizácie. Stratili sa mnohé profesie, ale nenahradili ich žiadne inteligentné softvéry. Webovské mapovanie je iná dimenzia využitia máp na vzdelávacie a vedecké účely. Je už možný taký výber webovských stránok, ktoré nielen obsahujú databázu (permanentne aktualizovanú), ale tiež obsahujúcu analytické nástroje, ako napr. GIS. Je žiadúce, aby sa to odzrkadlilo na zvyšovaní mapovej gramotnosti obyvateľstva. Ako vysvetľuje D. Rhind (1997), mapy vládnu obrovským množstvom rozmanitých metód abstrakcie, ktoré slúžia tak profesionálom, ako aj širšej verejnosti.

Verím, že zastihneme prah nového tisícročia s rozmanitou paletou kartografických techník a technológií. Som tiež hrdý na to, že Medzinárodná kartografická asociácia sa svojimi činnými komisiami a pracovnými skupinami, ako aj organizovaním medzinárodných vedeckých podujatí sústreďuje na problémy spomenuté v tomto príspevku.