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REVIEW OF THE LATEST TECHNOLOGY IN CARTOGRAPHIC DATA ACQUISITION, MANIPULATION, STORAGE AND PRESENTATION, WITH SPECIAL EMPHASIS ON POTENTIAL APPLICATIONS IN DEVELOPING COUNTRIES: AUTOMATED MAPPING PROJECTS: DEVELOPMENT AND APPLICATION OF DIGITAL CARTOGRAPHIC DATABASES, INCLUDING DIGITAL TERRAIN MODELLING

Maps and mapping: the ICA vision of the future

Paper submitted by the Secretariat**

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Introduction

Maps pre-date scientific measurement but cartography has continued to adapt to changes in concept and technology. Following a restatement of the unique character and vital importance to spatial science of maps and (their designers), this paper reviews how technological changes are challenging cartographic theorists in the fields of both production and use. Current trends and future possibilities are noted and the inevitability of a longer-term convergence between the component spatial sciences is foreseen. The increasing institutionalisation of commonly employed technologies such as Global Positioning System (GPS) and Geographic Information System (GIS), and a greater focus by the whole spatial science community on seeking solutions to world-wide problems should encourage the growth of teamwork rather than isolated scientific activity to confront these challenges.

Background

There should be no need to justify the vital part played by cartography within the geospatial sciences. But in this increasingly complex and technology-led world such obvious and fundamental truths can easily be taken so much for granted to render them invisible ! Also cartography is changing and not everyone seems fully aware that maps are no longer merely the end points of a data manipulation/assembly process - manual or digital.

The International Cartographic Association (ICA) is founded on one of the most natural human creative processes, that of mapping, and traditionally the creation of 2D graphic images of mapped information. Maps and mapping have pervaded history and prehistory, the Arts and the Sciences, and cartographers have been regarded as the compilers and ultimate creators of those unique, versatile and valued graphic images. A classic well-designed topographic map, for instance, offers (within the sheet lines) a most sophisticated graphic summary of a region. Symbols and names may be densely packed but are still intelligible, and the design allows for both wide and more focused views. The content has been generalised to be true to scale and thus the map has overall integrity. Such an image offers scope for all types of reading, from rapid overall scanning down to selective focus on the smallest regions or symbols. This makes effective use of both foveal and peripheral vision and over the centuries we have become very sophisticated in the way we read and otherwise use such paper documents. Maps of this type have played (and continue to play) a significant role in the transformation and expansion of our knowledge and understanding of the world. Cartographers, with their craft, may have partly controlled the subject in the past. As with other experts their knowledge and skills are largely intuitive. People accept that good maps are produced by expert cartographers (hopefully with quality data). However, over the past half-century in particular, scientific enquiry has tried to look beyond the craft and the artefact into the more fundamental processes of spatial modelling, map creation and use. The study of map use strategies naturally embrace psychology, including human information processing, and today there is a greater appreciation of the relationships between the nature of a task and the requirements of the circumstance and the user. Together

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these can inform and support the way maps are employed, be it in a data manipulation and management tool such as GIS, or in a graphic software package offering more sophisticated product design.

New technology, from the drawing aids of the mid-twentieth century to computers and beyond, has progressively removed the yoke and obvious limitations of manual production. Now the whole mapping process has become much more dynamic, flexible, multi-dimensional and interactive. The wonders of multimedia have also added new depth and excitement to computer maps, providing opportunities for both science and the general public. Visionary cartographers in the past had, of course, already experimented with many similar or related ideas but only now can technology help remove the frustrations of their dreams. Visualisation in scientific computing (ViSC), a technology-supported facility which is raising the effectiveness of research especially into large datasets across the sciences and engineering, and which has accelerated in scope and power over the past decade, shares its roots (and much of its terminology) with cartography. The interactive scope and versatility of both ViSC and the emerging (and related) Geographic Visualisation systems (GVIS) - especially when they incorporate high quality data and innovative design - can be interpreted as natural extensions of human mental visualisation which is, in itself, one of the most powerful facilities for qualitative exploration and analysis. Just as ViSC has, within a decade, added exciting new visually intuitive routes for research in science, engineering and manufacture, so it can be observed that the scope and potential of modern cartography - for both data exploration and representation - are on a rising curve toward new status and scientific respectability. However, all these radical changes in the field of mapping may have led many users (especially new users not previously involved with maps in their business) to disengage the term 'cartography' from what is happening today. There are countries where the mapping culture has been in decline within the general population, but when the situation is transformed and the GIS vendors arrive, many truly think that 'GIS' is the new term for cartography! Cartography is one of the most important tools of science and management. Although now digital in nature, much of its power lies in its visual characteristics, and there is a danger that the 'visible' side of cartography is being taken for granted as more and more people embrace the subject as an integral part of their own fields. Indeed the new term 'Geomatics' could well be described as an abbreviation of a more clumsy but more honest term, 'Geo(visio)matics', the essential visual core having been rendered invisible! The power of cartography has always existed but restricted in the past by technology. Today, with precise data - available almost universally on the Internet, huge data manipulation possibilities (integration, analysis), virtual (screen) output as well as the world of hypermedia, this power is certainly now fully established. After decades of developing technology it is now reaching effective maturity.

But, has this new technological age of apparently limitless mapping power arrived too soon? At present workers in certain branches of our field may be striving to make accessible large quantities of high quality data which does not suffer in the process of transfer. This (and other much poorer) spatially-related data is being accessed with increasing energy and enthusiasm by a wide and growing range of users. Also most GIS users appear to be applying their systems, directly or indirectly, largely towards the production of maps (or at least map-like images) and professionals and others are being confronted with more maps than ever before. In addition, increasing numbers of people have access to so-called user-friendly map-making tools, but they lack an understanding of the principles of cartography. A word-processing package alone does not transform a user into a leading author. It merely facilitates the manipulation and storage of words. Unfortunately new data sources and visualisation systems may have arrived before we know how even the more traditional static map images are used. Research into such vital cartographic topics is essential to help theory keep pace with practice, and the ICA is providing the international framework within which such work can progress.

Mapping - for the new millennium

Although progress will vary from country to country, by the year 2000 the technology-influenced trends of the 1980s and 1990s will have spread more widely across the developed and the developing world.

Computers. Lower cost/higher power computing will help accelerate the transition from manual to digital map production - although there will continue to be a demand for topographic and thematic map series as well as customised map creation by professional cartographic practitioners.

Effects of advances in other related fields. These will continue to have an impact on various stages of the mapping process -

- Sources : GPS, GIS, image processing, large spatial databases.
- Design scope : computer graphics.
- User support : artificial intelligence/expert systems, virtual reality

Widening base of non-cartographically expert map creators. Professionals in many fields, as well as the general public, will, increasingly be offered low-cost map-related software. Like the diffusion of word-processors and database packages, these will also become more accessible through, e.g.

- GIS and mapping modules incorporated into word processors, spreadsheets and database software.
- Navigation aids of many kinds, personal and vehicle guidance.
- User-friendly interfaces incorporating enhanced intelligence advisory (help) facilities. Like Microsoft's 'wizards', these will guide users towards structured approaches to map generation and will also be available in more context-sensitive modes to aid compilation and design operations.
- Huge expansion of low-cost electronic atlases of all kinds (CD-ROM, networked).

Enhanced spatial analytical facilities for professionals. GIS with more advanced statistical packages, etc., will facilitate the creation of analytical maps. This will encourage greater application of geo-spatial thinking within real-life problem solving and as an aid to decision-making.

Growing awareness of the new data sources and mapping technologies will lead to expansion and new focus of cartographic theory. There will have to be more understanding of the cognitive aspects of information transfer as technical and philosophical problems are solved.

Widening facility for interaction by users with software and data sources. Packages may be customised to meet particular user-working-strategies and needs so that systems can appear more intuitive and offer more rapid responses to queries for data or routes to the cartographic approaches to problems.

Geographic (scientific) visualisation. This new way of defining map use in exploratory research will lead to a renaissance in cartography. Innovative processes, packages and ideas will be accompanied by developments in map use theory.

Mapping - 25 years on

Apart from the strengthening of today's trends mentioned above other characteristics will emerge:

- World-wide networks with related infrastructures will have been established. This will offer what might be called 'distance mapping'. Across the Internet will come real data
  - geospatial databases with true-to-scale generalisation facilities,
  - state-of-the-art electronic maps and atlases,
  - user-friendly software providing even more customisable map presentations for the cartographically naive (e.g. with hyperlinks to pictures, movies and text).
- Standards: especially data quality and transfer standards related to growth of the Internet. The costs of hardware and software have dropped dramatically; today 85% goes on data.
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- Virtual reality (virtual worlds): with increasingly detailed spatial databases and appropriate software and interactive devices, real physical space may to become increasingly 'irrelevant' and remote for some users. This will certainly introduce questions about the misuse of data or decision-making in artificial worlds.

- Working in teams: While cartography will be different in 2020 AD, the changes will be towards greater stature and identity for the subject within geospatial science and the scientific community in general. This will grow from a richer foundation of theory and practical experience in the areas of map and system design as well as in the techniques and strategies of map use. New, semi-automatic, GIS will depend much more heavily on enhanced intelligence cartographic display interfaces to satisfy regular professional users who will continue to demand high quality (if perhaps somewhat standardised) products as part of the decision-support facility. However total automation need not be (indeed cannot be) the ultimate goal for cartography. In the field of architecture and building, today, for instance, many processes and products may similarly have been standardised to reduce costs and increase speed of completion. But when it comes to special commissions for buildings, small or large, the full scope of the individual architect's imagination and creativity is required to. provide innovative solutions to unique problems. While this analogy is not perfect, similar circumstances can apply in mapping when expert cartographic designers are required to help resolve specific problems relating to data characteristics for special needs, representation-communication objectives and customer profiles. Ideally, in both situations (semi-automated and customised), and dependent on the size of the project, cartographic advisors would work in teams with other geo-information specialists, in data collection, assessment of local circumstances and data processing. Naturally these cartographers would also have some knowledge of these other fields especially where they have a bearing on data quality.

Geospatial Sciences and the Future

I. A more general kind of spatial science?

Looking towards the broader field (referred to variously as Geomatics, Geoinformatics, Geospatial Science...) we see similarities between the associated technological trends and those listed under 'mapping'. But there will also be, for example, more digital methodology, more remote sensing with higher resolution, and an increasing shift from data to knowledge. Currently there appear to be a number of separate international organisations concerned with cartography-related fields such as geodesy, surveying, photogrammetry and remote sensing. There seems to be a gradual and inevitable process of convergence. The component sciences are coming closer together and this is closely related to (if not the direct consequence of) a simultaneous merging of component technologies. If this convergence continues, along with increasing integration of technology and methodology, a more general kind of spatial science may emerge in due course.

There may be other key strategic aspects which can support the change:

- The emergence of a distinct science of spatial information, from an evolutionary background period of studies which may have seemed more technology-based. This will require a total review of spatial modelling and representation. Although it exists in other fields, a commonly-agreed theory of knowledge structure and representation has not yet emerged for geospatial science. When it has, the field will become more interdisciplinary in nature.
- Interdisciplinarity and multidisciplinarity. Tomorrow's spatially related problems cannot be solved without these two approaches being facilitated through the employment of spatial information systems.
- Inter-operability. With all their technological, organisational and even political aspects, the following will depend on increasing interoperability :
  - Spatial data infrastructures,
  - Systems and people,
  - Legal and pricing factors,
  - Maps, to achieve and maintain seamless, scaleless (i.e. with generalisation), multi-scale and multi-temporal spatial databases.
- Technology transfer. This must be achieved in various directions, such as :
  - Downscaling of high-technology for everyday use,
  - Transfer towards developing countries.
- Education
  - of spatial information system experts
  - to bridge the gap between experts and others
  - in developing countries

II. The application of geospatial science to general societal needs.

Naturally all this accumulating knowledge is already being applied but perhaps too often used as narrow examples of single techniques or technologies. There is an ever-growing need for unique and more broadly-based practical geospatial solutions to many world-wide social, environmental and economic problems, the ultimate challenge being to balance the development of natural resources against the maintenance of optimal environments. This will require rethinking the approaches to development, more globalisation, growing economic interdependence and social justice, equality and sustainable development. There is no doubt that exploration of these problems will require reliable geoinformation and the tools for its management, analysis and display as discussed in this paper and this will be enhanced by growing integration between sister organisations with common interests in spatial aspects of the environment.

Conclusion

The world is changing through the forces of nature and the actions of humankind. The responsibility of science is to promote the good and control, if not stop, changes which are bad. Although geospatial scientists need not be directly involved in solving all the world's problems, their responsibilities in the fields of collection, manipulation, analysis and display of spatially-related data is self-evident. Many geospatial science organisations have grown from a need to develop and apply appropriate technologies within one field (perhaps within specific

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environments). Some such groups have a sharper focus than others whose remits may have become extended through the evolution of their subject. However the common core is still reliable spatial data, well established, clearly standardised and referenced and easy to store, access and transfer. This data will be manipulated, analysed, changed and viewed in various ways in the process of supporting a wide variety of tasks, from simple presentation to complex problem-solving. This relates to a number of disciplines. Cartography (analogue and digital), however, is, to a greater or lesser degree, present in them all. Even after a simple tacheometric survey, a map is produced, and maps or map-like objects are created at various stages in photogrammetry, remote sensing, GIS-supported studies, etc.

This all-pervading presence of maps relates back to the opening theme, that to many map users the field and scope of cartography may be 'invisible'. The truth is that maps are not just the visible (or digital) end-points of a survey or GIS-based operation. They are also tools for spatial modelling, data exploration, analysis and representation and can be used at almost every stage of an investigation. Indeed cognitive maps are frequently used to review spatial problems even before the involvement of hard data ! Cartography and cartographers therefore not only add value to geodetic frameworks, reference systems and spatial data but they also make them eminently more accessible to the using public at every level.

As explained above, cartography is evolving, both in theory and practice, but is currently at a critical stage in its development. Never before has the potential value of maps (in all their forms) been so great : in helping structure conceptual models of reality, for the active visual exploration and analysis of problems and for the representation and sharing of knowledge and solutions. But all this is happening on a still insecure foundation of mapping theory at the data modelling and combination stage, for product design and for human usage of the facilities. The urgency to develop these fields is paramount. It is thus essential to have an international dedicated body, such as the ICA, which can promote and co-ordinate developments in both theory and technology and seek their successful application to the good of humankind.

Increased awareness of the nature and potential of new cartographic tools and geo-spatial databases will lead to an expansion and re-definition of the scope of cartography with a parallel development of cartographic theory for electronic (digital) mapping. The recent emphasis on Geographic (scientific) Visualisation (and the incorporation of multimedia) as a new way of defining map use in exploratory research is another reason to maintain a uniquely identifiable body of experts in this field. Transition from technology-based to true science (spatial information science) - from the currently mechanistic, technology-driven studies of space to a deeper understanding of the basics of models and other representations of space is an added reason to do so.

Idealistically a Geospatial Scientific team will involve, directly or indirectly, all the relevant experts (remote sensing, geodetic, cartographic, etc.). Some may be present 'in person', especially professional users (e.g. resource managers), tussling with the problem in hand, others, e.g. cartographers, may have contributed an enhanced-intelligence help module and GVIS/Mapping package to link with a GIS. This would permit the visual exploration of data and the display of intermediate and final solutions. What is not in doubt is the increasing need in the future for co-ordinated interdisciplinary activities with each branch of the science being at least aware of and having respect for the scope and unique characteristics of the others.

The ICA vision of the future of cartography therefore is to have a firm theoretical basis for knowledge representation and the modelling of reality, a fuller appreciation of map reading and map use strategies (especially in the more animated and interactive image environments of today), to become established as a subject, through the application of GVIS, as an essential tool for data exploration and analysis and and not just data representstion, but, nevertheless to retain and develop its status as the most powerful method of spatial data representation. Cartography will be applied within geospatial science as an essential component and of equal value to the facilities of sister subject fields. Only through access to a full array of geospatial science procedures will world problems be successfully addressed and resolved.
