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Geographical Information Science: A Perspective of 1998

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I. THE ORIGIN OF GEOGRAPHICAL INFORMATION SCIENCE

Geographical Information Science, as the name implies, is the science dealing with geographical information. It emphasises more on the scientific aspects of geographical information rather than its technological implementation, which has been the focus of geographical information systems. The term "geographical information science" is much newer than "geographical information systems". The latter was first introduced by Tomlinson (1967) 30 year ago while the former seems first appeared in an article by Goodchild (1990) for less than 10 years. Therefore, it is really a problem to determine where should be the starting point in an attempt to provide a perspective of geographical information science.

There must be different views regarding the history of geographical information science. Some may consider it as a more recent development while the geographical information systems as a technology becomes matured and research is emphasised on its scientific components. This is evidenced by the change of name for the then only academic journal in the field from *International Journal of Geographical Information systems* to *International Journal of Geographical Information Science*. It is also evidenced by the proper name of this journal when it was established in 1995. However, some researchers consider the relationship otherwise. For example, Openshaw (1987) considered geographical information system as the "20th century technology being used for 19th century purposes". It means that the scientific foundation of many applications by geographical information systems was already laid even in the 19th century. Indeed, principles of some operations such as overlay have existed for a long time. In this sense, geographical information science could be as old as other scientific disciplines, since geographical information covers an enormous range "including the distribution of natural resources, the incidence of pollutants, descriptions of infrastructure, pattern of land use and the health, wealth, employment, housing and voting habits of people" (DoE, 1987).

It is also arguable that the start of an information science could be considered in an era when computer was used as information processor. Then late 1950s or early 1960s might be regarded as the reasonable period as the early days of geographical information science. Indeed, during this period, research articles began to appear in the literature on various aspects of geographical information such as automated cartography (Tobler 1959, Sawyer 1960), digital terrain modelling (Miller and Laflamme, 1958) and geographical analysis (Coppock, 1962).

II. EARLY DAYS OF GEOGRAPHICAL INFORMATION SCIENCE

The term geographical information covers a wide range and variety and any discipline dealing with such information may claim its contribution to the origin of geographical information science. However, it seems a consensus that the following two disciplines made most significant contribution, namely, automated cartography and quantitative analysis of geo-referenced data (geographical analysis).

In the area of automated cartography, some most significant establishments were initiated by the Experimental Cartography Unit (ECU) (see Rhind, 1988a), the Harvard Laboratory for Computer Graphics and Spatial Analysis (see Chrisman, 1988) and the University of Edinburgh (see Coppock, 1988). The Harvard Lab was founded in 1966 and a number of software packages for thematic mapping were developed. Among these, the most famous one was SYMAP which had over 500 sites installed world-wide. The Lad published research results in its journal called *Harvard Library of Computer Graphics*. In the 1960s and early 1970s, a number of statistical mapping packages were developed at the University of Edinburgh. A well-known one of these was GIMMS which was installed in over 200 sites in 12 countries. Unlike Harvard Lab and Edinburgh University, ECU, which

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was established in 1967, is more practically oriented to produce digital maps. It made contributions to many aspects of automated cartography such as automated contouring, geographical database, data compression, automated digitalization, coordinate transformation etc.

In the area of automated cartography, the most influential is perhaps the Auto-Carto conference series. It was started in 1964 and has since been held for every other year. It served as a venue for the presentation of new ideas and concepts, although after Auto Carto 10 (in 1991), the conference has become less and less important than before. One reason for such a declination might be the high demand on the quality of submitted papers that need to be fully refereed since Auto Carto 10. This was evidenced by the fact that there were only 60 papers submitted to Auto Carto 10 instead of hundreds, which had been the usual number. Another reason could be the existence of numerous other conferences that claimed a large share of research publications from the community.

In quantitative analysis of geo-referenced data (spatial analysis) in the late 1950s and early 1960s, Tomlinson (1988) specially mentioned the seminal work by Harold McCarty at the University of Iowa and William Garrison at the University of Washington in the USA. In a similar period, much work was also done by Coppock (1988) at the University of Edinburgh.

III. 1998 IN THE HISTORICAL CONTEXT OF GEOGRAPHICAL INFORMATION SCIENCE

1998 was a special year in the history of geographical information science. It was a year of special anniversaries for several important events and it was also a year with full of new important developments.

1998 experienced a number of new developments which are worthy of mentioning. The International Society of Photogrammetry and Remote Sensing (ISPRS) Commission IV held its first symposium in Stuttgart (Germany) since it became a commission on GIS and mapping in 1996. It marked the active involvement of ISPRS in geographical information science. Another noticeable event was the 8th International Symposium on Spatial Data Handling (SDH) held at Somon Fraser University (Canada). The attendance was much lower than expected. Whether it will follow the track of Auto-Carto series could be a good question since the SDH series had also started to review full paper since its 7th symposium held at the University of Edinburgh in 1996.

1998 is the anniversary of a number of important events. The *International Journal of Geographical Information Systems* was renamed as *International Journal of Geographical Information Science* - marking an emphasis on the theoretical aspects of geographical information. *GeoInformatica*, an international journal on advances of computer science for geographical information systems, was launched, which marked the active involvement of computer sciences in Geographical Information Science. An international workshop on dynamic and multidimensional GIS was held at the Hong Kong Polytechnic University. This was the first of a new series of conference in geographical information science to be organised by ISPRS (International Society for Photogrammetry and Remote Sensing) jointly with International Geographer Union (IGU).

1998 was the 10th anniversary of a few important events as follows: (a) the establishment of National Geographical Information and Analysis (NCGIA) in the USA and thus the commencement of the NCGIA initiatives (Abler, 1987; Morrison, 1991), (b) the establishment of Regional Research Laboratories (RRLs), which is UK's equivalent to US's NCGIA, and thus the commencement of RRL initiatives, (c) the establishment of Association of Geographical Information (AGI) in Britain; and (d) first research agenda in this area published by a high-profile researcher (Rhind, 1988b).

IV. GEOGRAPHICAL INFORMATION SCIENCE IN THE NEAR FUTURE

Looking at the near future beyond 1998, a number of important developments are already visible.

In 1999, some relevant magazines will have their names changed to show their broadening scopes. The *GIS world*, *GIS Europe* and *GIS Asia Pacific* will be renamed to *GeoWorld*, *GeoEurope* and *GeoAsia-Pacific*, respectively.

In the very near future, one-metre resolution satellite images will become commercially available. It means that very detailed spatial information is extractable from these images and one could have such data with a temporal frequency of 2-3 days. This type of images will be the major data source for a number of applications and there will be urgent demands and challenges on the technology for information extraction from, and management of such images.

In the near future, as Openshaw (1998) pointed out, distributed spatial analysis on Internet would be feasible with the development of Java and heterogeneous GIS. One could send spatial analysis tasks to a particular web site and receive the results back later.

As the Vice-President of the USA, Al Gore (1998), pointed out in his famous article – *The Digital Earth* – there is a serious problem with current information display and there is an urgent need on multi-scale representation and 3-D visualisation of terrain. Some of these problems will certainly be tackled in the near future.

It has been considered by Wright and Goodchild (1997) that marine would be the candidate to 'captivate the public and to serve the pragmatic interests as vital as the military' while creating vast opportunity for jobs and investments in the near future. This requires the dynamic and multidimensional data model, which is clearly one of the major focuses of the current research force in geographical information science.

V. THIS SPECIAL ISSUE IN THE CONTEXT OF GEOGRAPHICAL INFORMATION SCIENCE

Indeed, 1998 could be a year to remember in the context of geographical information science. It is not only due to the many facts outlined in the previous section but also possibly due to the publication of this issue.

In this issue, *Openshaw* reviews the trends on spatial analysis and offers some future perspectives on this topic. *Openshaw* concludes that distributed spatial analysis on Internet would be feasible in the near future and the spatial analysis and geographical data mining flood gates are about to open. He further claims that the Internet provides an obvious channel for meeting many of these needs.

Health data are an important type of spatial data. Spatial analysis of health data using geographic information systems has attracted much attention from geographic and public health communities. In 1998, two conferences were held: one in San Diego on "GIS in Public Health" and the other in Baltimore on "Health Geographics." *Spear et al.* report a unique application of remote sensing and GIS to the control of schistosomiasis.

To achieve Internet-based spatial analysis, some robust software architectural models are required. In this issue, *Zhang, Li and Lin* present a model for "GIS Virtual Machine", which is a software framework allowing different functional components to inter-operate through the Internet to provide spatial analysis service.

As has been discussed in the previous section, dynamic and multidimensional data models will become one of the major research focuses. As a result, an article on hybrid 3-D data structure written by *Wang and Gruen* is presented. It was designed for cyber city and takes consideration of the geometrical, topological, textural and thematic information of 3-D objects.

To facilitate 3-D visualisation of the terrain and/or to build 3-D models terrain objects, digital terrain models (DTM) or digital elevation models (DEM) is the essential basis. With the availability of high-resolution satellite images, high-quality DTM (fine resolution and high accuracy of data points) are obtainable using automated matching techniques. This kind of DTM, however, does not always provide an advantage and intelligent compression may be applied to filter out some less important points. This will undoubtedly cause a loss of accuracy. *Li, Lam and Li* report some experimental test on such a loss.

Indeed, DTM has become a type of spatial data in a national geospatial data infrastructure. It is not only the basis for 3-D visualisation and 3-D modelling but also the basis from which carious types of information can be extracted for different applications. The flow distribution estimation in hydrological modelling is one of such information to be extracted from DTM. *Pilesjö and Zhou* present a new technique for estimation of flow distribution over a DTM based on the analysis of topographic form a surface facet that dictates the flow distribution.

In any geographical modelling, e.g. the estimation of flow distribution, error is always a concern. With errors, some uncertainty in final results will be created. The best strategy is to avoid error if possible. However, sometimes, errors are inevitable thus one has to manage them. For such management, an understanding about the nature of errors is essential. *Meng, Shi and Liu* present an experimental result on the distribution of the errors in the cartographic lines that were manually digitised from analogue maps.

Social-economic data are a major type of spatial data in geographic analysis. Foe such data, TIGER files have been widely employed. *Pang and Zhu* demonstrate the use of such data to study the spatial structure of rental cost in an urban area.

In a broadened scope, geographical information science should also include Global Positioning System (GPS) and Remote Sensing (RS). In this issue, an article on GPS in navigational applications authored by *Chao and Ding* is included. This article is about the integration of GPS with GIS for navigational applications.

In remote sensing, land-cover & land -use classification and their change detection are the fundamental topics. Although they have been studied for over half a century, rooms are still left for improvement. *Pu and Gong* introduce a new approach based on gray systems theory to predict land cover change from historical aerial photographs.

VI. EPILOGUE

In this editorial, we feel very inconvenient to write down the full names of "geographical information science" and "geographical information systems" in most cases in order not to mix them up. Since "GIS" has been booked to refer to "geographical information systems", it might be a good idea to adopt another word for "geographical information science".

Looking at the development and the context of geographical information science, it may be regarded as a discipline which integrates theories, techniques and methodologies in spatial information processing. From this point of view, the term *Geoinformatics* might be more appropriate. This word consists of "geo-" and "informatics". The latter comes from German "Informatik" which refers to a discipline that studies the coding, transmission, process, retrieval and utilisation of information. Therefore, it is quite natural to refer "Geoinformtics" to geographical information science. Indeed, "Geoinformtics" has already been adopted in the Netherlands, although in Germany this term is not adopted because of the strong objection from the "informatik" community.

At last, we wish that everyone, either researcher or practitioner, could find this issue informative, useful and worthy of reading.

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Some Trends and Future Perspectives for Spatial Analysis in GIS

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Abstract
This paper reviews the development of GIS and spatial analysis techniques and provides perspectives on spatial analysis in GIS.

I. BACKGROUND

GIS is now a global big business that continues to experience rapid growth. Probably over a million workers now use GIS on a daily basis and well over quarter of a million systems have probably been distributed; indeed ESRI claim that over 100,000 copies of Arc/View have been sold. At the same time new GIS data continues to be created at a rapid rate; e.g. as digital mapping expands to cover the globe and the new generations of space borne ex-spy satellite commercial technologies create vast new remote sensing databases. Additionally, the computerisation of all the world's administrative systems, of retailing, of financial services, of travel, etc are all nearly complete. The IT State is here and nearly all these data bases are capable of being geographically referenced and an increasing number are becoming, or are already, geographic information in the broadest sense. Inexorably, continuously and at an ever increasing speed, this data collection, integration, cross-referencing, and storing process is rapidly expanding to cover more and more aspects of modern life. Within 1 to 10 years (depending on which country is being considered) there will be complete GIS coverage with sub 1 metre accuracy of most physical objects shown on maps or visible on the Earth's surface (e.g. houses, roads, trees, etc) and a large amount of human activity related things (e.g. addresses, movements, spatial patterns of behaviour etc). Commercial business (and governments) in every country are expanding their data warehouses and dart marts, as they realise that their future viability depends on them storing and then using more of the data they are almost "forced" to gather (because of IT) in order to optimise their future profits, competitiveness, or just to improve efficiency. A major driving force is the need to be seen to making good use of the available technology to avoid being negligent and open to legal challenge. For example, in the UK the Crime and Disorder Act (1998) placed a statutory obligation on all Local Authorities to perform crime pattern analysis at a time when virtually none was being performed. This will force a rapid integration of Local Authority corporate GIS systems (if there is one and most probably do not at a District level) with Police databases.

Nearly all of the new data bases being captured and created by developments in IT, probably about 85%, are, or have the prospect of becoming, geographic information. The world really is a GIS world! It is a pity, therefore, that there are some key technologies missing from the currently available GIS tool-kits that may well have a major impact on what GISs are, or could be, used for in the immediate future.

The purpose of creating immensely detailed, comprehensive, accurate and multi-level high resolution GIS databases is to allow users to do useful things with it. You do not create GIS databases merely because you like doing it! Nor do you develop such data bases so that you can ring fence them with copyright and ownership barriers to wider use and access. Nor do you imagine that the principal analysis tool is mapping! Yet it is at this stage that the GIS world's collective imagination seems to desert many of its users. Of course you can analyse point referenced data distributions by drawing maps. You can plan investments in retail networks using potential surfaces and a spreadsheet but there are far more powerful methods around than these. Some think that the answer is a statistical package. This may, sometimes, occasionally be helpful beyond a most basic data description function, but do not rely on it to do anything particularly useful. Imagine a situation in which there is a few hundred observations and a few variables. This presents no problem. You

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