A Classification of Geographical Information Systems Literature and Applications

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A CLASSIFICATION OF GEOGRAPHICAL INFORMATION SYSTEMS LITERATURE AND APPLICATIONS

INTRODUCTION

The past few years have seen a rapid growth of interest in Geographical Information Systems (GIS), although their origins go back at least twenty years. These origins are diverse and include computer-assisted cartography, computer aided design (CAD), remote sensing (RS), computer graphics, and spatial statistics. It is only recently that hardware and software developments have brought a comprehensive range of data generation and capture methods, data manipulation and analytical methods, and data presentation and display techniques into single, readily applied systems. The specific application of these processes to spatially referenced information has given rise to the GIS concept. As such these systems have found very broad application within human and physical geography, within urban and regional planning and many related areas including environmental and resource management, public utilities and retailing. Arguably, GIS have potential relevance to all analytical and policy (or management) processes that use spatially referenced data.

As the field has developed rapidly so too has its literature. Yet in their nature, the new forms of geographical information cut across many traditional subject divisions. Remotely sensed data, for example, may have relevance to human and physical analyses. Equally, information derived as a by-product of an administrative process, say land-use planning, serve analytical or policy advice processes. For those wishing to study the development of GIS, both the rapid growth of theoretical and applied literature and its organising concepts pose a considerable challenge. The same problem of diversity and lack of classification in the subject literature faces those wishing to apply the new technology to policy-making and management tasks with the added complication of making choices about hardware and software systems.

The lack of organisation in GIS literature stems partly from a rapid growth of interest and partly from the diversity of the contributing fields and technologies. The recent growth in such systems is due largely to two factors. The rust is an explosion in the amount of spatially referenced data that is now collected and which can be made available to users. The second has been developments in computer hardware and software technologies which are continually offering more computational power at lower cost. It is also important to note the contributions of associated fields. For example, satellite remote sensing is a technology which has grown up alongside GIS, yet in the early stages there was surprisingly little interaction between the two disciplines. As remote sensing has matured, however, so the volume of data available and the sophistication of image processing techniques has inevitably led to a degree of convergence with GIS and there is now a significant number of software systems that support both image processing and raster GIS capabilities. Such systems allow relatively free exchange of data between modules. Increasingly, agencies utilizing GIS see the potential of remote sensing as a powerful source of data for environmental monitoring and management. In contrast, computer-assisted cartography (CAC), may be seen as having an impact on the data structures and display technology involved in GIS, as the need for high quality map production has pushed forward innovations in digitizing, storage and plotting. The emphasis of CAC, however, has been very much on producing finished maps and less on spatial data manipulation.

Computer-assisted design (CAD) and database management systems (DBMS) have also had an influence on GIS development, particularly in regard to spatial data structuring and manipulation, and the integration of topographic with related, descriptive textual and numeric data. Developments in computer-aided design have set standards for interactive graphics and spatial data editing. Developments in database management software, notably the evolution of relational database management systems, have had an important influence on the shape of modern GIS, introducing greater sophistication in data modelling and improving efficiency in data management and retrieval. CAD and DBMS have tended to be mainly, though not exclusively, concerned with vector-based systems.

Given these diverse contributions to development, it is not surprising that the sources of information on which GIS users need to rely has lacked coherence, and it is only recently that the field has achieved some degree of organisation and identity. This has been greatly helped by international conferences; the arrival of an international journal dedicated to GIS; and by an acceleration of government supported research initiatives by research councils in the UK and the USA (e.g. ESRC's Regional Research Laboratories, and the National Science Foundation's National Center for Geographic Information and Analysis).

The very broad abilities of GIS to store, manipulate and display geographically referenced data sets, ranging from remote sensing (satellite and aerial photography) imagery to thematic maps of socio-economic data, has led directly to new forms of 'information geography'. But in addition to coding, storing and retrieving land related data, GIS can be used as an analytical tool in assessing, transforming and manipulating data and has thus provided a mechanism to study temporal and spatial trends in environmental processes and to evaluate potential future scenarios. Increasingly, GIS are being used in both private and public sectors in the management (monitoring) and modelling of land resources, both directly (e.g. mapping) and also to provide inputs to policy decision making processes. The ability to simulate the effects on management plans of alternative conditions and constraints has led to a recent increase in the use of GIS in areas such as urban and regional development planning and agricultural development. Such applications often involve inputs from a wide range of differing fields, such as legal (e.g. protected conservation areas), physical (e.g. soil, hydrology), human (e.g. settlement areas, population) and economic (e.g. industrial site location)

disciplines. A major consequence of the integration of data from several fields in such interdisciplinary analysis has been a breakdown in the traditional, dichotomous divisions between human and physical geography. This trend can be readily observed in many of the 'application-based' studies in journals covering a broad spectrum of geographical theory.

The preceeding comments point to the main influences which we feel are relevant to an understanding of GIS. For readers seeking a more comprehensive introduction, the Report of the Committee of Enquiry into the Handling of Geographic Information, Chaired by Lord Chorley (DOE 1987), and the Report of the NERC Working Group on Geographical Information (NERC 1988) are recommended.

Our experience suggests that most readers entering the field of GIS will do so through one of two routes. Either there will be an initial interest in some aspect of the theory or technology, such as spatial modelling, geographical data structures or computer graphics, or an interest in some substantive area of GIS application such as land or resource management, urban and regional planning, transportation or housing. Accordingly, we have classified the entries in this bibliography under two main themes; theory and methodology on the one hand, and application 'areas' or 'topics' on the other. The richness of much GIS material and the wide range of potential applications means that judgements have been necessary as to the primary theme and these have not always been straightforward. We hope that no author will feel misrepresented and comments from users of the catalogue would be welcome, both in terms of suggestions on organization and contributions.

For the methodological and theoretical references we have chosen a schema which relates to the broadly defined stages identifiable in any data-processing system. This provides an organising framework which is to some degree independent of the state of current GIS technology and applications. It is therefore likely to have enduring utility and to be meaningful to a wide range of interests. A data processing system must support three types of task: data generation or capture, data structuring or organisation and data manipulation (including output). Data generation (section 1.2) refers to the creation of digital data from non-digital sources. On the one hand it includes the encoding of existing hard-copy information, as in map digitisation or keying-in of manual records, and on the other hand the direct encoding of observations through analogue sensors such as RS satellites. One of the central features of modem GIS is their ability to organise data into meaningful structures, refered to as database models. Database modelling serves a number of ends, most important of which are the gains in storage and access efficiency achieved by a good design. The particular nature of geographic data has led to much experimentation with alternative data modelling strategies. This complexity arises from the distinction between topographic and attribute data; the large size of a typical topographic database; and the need fully to represent geographic objects in terms of their individual characteristics and their topological and taxonomic relationships. This is reflected by the number of references in the data organisation section (1.3).

Data stored in an information system is normally there to be manipulated in some way (not just archived) and the broadest function of such a system can be thought of as converting data into more meaningful information. Information may be created by a simple combination of data items in response to a user's query or by more complex manipulations. Manipulation includes, for example, the processes of transformation, aggregation and modelling. It also includes graphical display since a computerised map display is a complex information product created from lower level information. The references in section 1.4 document algorithm developments for such operations as polygon overlay, fractal enhancement, contouring, raster image smoothing and geographical search.

In each of sections 1.2 to 1.4 a further classification is made on the basis of the distinction between vector, raster and non-locational data. These are considered to be primary themes of interest at each data processing stage, each with a distinguishable body of literature. Under the data organisation heading, data quality and standards and data transfer are important issues which cut across the three-fold structure classification and therefore appear as separate sub-headings. Similarly data conversion forms a distinct section within the manipulation literature.

Three other sections complete the methodology and theory classification. References concerned with general GIS issues are listed together in section 1.1 and include historical reviews; comparative systems evaluations; overviews of general concepts and implementation issues; and GIS related texts. Section 1.5, on software, documents references concerned with specific systems, ranging from turn-key suites to experimental prototypes. Eight categories of software are distinguished. There is surprisingly little written specifically about GIS related hardware issues and these references form a final section (1.6) in part one.

Part Two is a necessarily more pragmatic attempt at classification. GIS applications, we suggest, fall primarily under three headings relating to different perspectives of geographic space and its use. Natural environmental applications (section 2.1) handle data relating to land cover, agricuture, forestry, hydrology, soils, environmental hazards and terrain. Applications focusing on the built environment (section 2.2), on the other hand, use land use, cadastral, utilities and transportation data. The third type of application is concerned with the human environment (section 2.3) and includes systems which manage geodemographic, employment and health information. In addition, a number of studies take a wider view of systems application, adopting a policy-making perspective and incorporating data from multiple sources. These are covered in section 2.4. Remote sensing references are included under a separate heading (section 2.5) and represent a selection from the large literature on this subject. The final two headings cover references to applications with particular functional perspectives: teaching GIS (section 2.6), and map libraries and catalogues (section 2.7).

In developing this classification we wish to make no more than a contribution to the systematisation of the field. We expect our headings to be ephemeral but have found the

material listed here of value and believe that others in this fast developing field may find it equally so. What is listed is in some ways a sample, for some of the headings already have extensive literatures. In principle we have selected items which we feel make some contribution to the understanding of GIS. This includes background texts in fields such as computer graphics and spatial modelling; references covering GIS issues in related technical or application fields, for example GIS and remote sensing; and references to specifically GIS work. References to related fields *per se,* for example, RS or cartography, are not included. Also we make no particular qualitative judgments by implication in our selection or exclusion of material.

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Abbreviations used in the bibliography

General:-

Mem.	Memorial
Photo.	Photogrammetry
Proc.	Proceedings
S ymp.	Symposium

Organisations:

AAG	American Association of Geographers
ACSM	American Congress on Surveying and Mapping
AFT	American Farmland Trust
AM/FM	Automated Mapping/Facilities Management
ASPRS	American Society for Photogrammetry and Remote Sensing
AURISA	Australian Urban and Regional Information Systems Association
BCS	British Computer Society
BGS	British Geological Survey
BURISA	British Urban and Regional Information Systems Association
CERMA	Centre for Environmental Resource Management Applications
CORINE	Co-ordinated Information on the European Environment
CRSC	Centre for Remote Sensing, University of Utah
EARSeL	European Association of Remote Sensing Laboratories
ERIM	Environmental Research Institute of Michigan
ESRI	Environmental Systems Research Institute
ESA	European Space Agency
ESRC	Economic and Social Research Council, Swindon
HMSO	Her Majesty's Stationary Office
ICA	International Cartographic Association

IEEE	Institute of Electrical and Electronics Engineers
IGARSS	International GeoScience and Remote Sensing Symposium
IGU	International Geographic Union
ISPRS	International Society for Photogrammetry and Remote Sensing
ISSS	International Soil Science Society
ITC	International Training Centre
ITE	Institute of Terrestrial Ecology
LAMSAC	Local Authorities Management Services and Computer Committee
LARS	Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette
NASA	National Aeronautical Space Administration
NCGIA	National Center For Geographic Information and Analysis (USA)
NERC	Natural Environment Research Council, Swindon
NRSC	National Remote Sensing Centre
NSF	National Science Foundation (USA)
NUTIS	NERC Unit for Thematic Information Systems, Reading
OPCS	Office of Population Censuses and Surveys
RICS	Royal Institute of Chartered Surveyors
RRL	Regional Research Laboratories (UK)
RSS	Remote Sensing Society
SAUS	School of Advanced Urban Studies, Univeristy of Bristol
SORSA	Spatially Oriented Referencing Systems Association
SUNY	State University of New York
URISA	Urban and Regional Information Systems Association
USGS	United States Geological Survey

Journals of relevance to Geographical Information Systems, Remote Sensing and Database Management Systems:-

GIS **World, Mapping Awareness, Photogrammetric Record, Earth Orientated Applications of Space Technology, Image and Vision Computing, International Journal of Remote Sensing, Cartographic Journal, Remote Sensing Monographs, Computing Vision Graphics and Image Processing, Cartographica, American Cartographer, Computer Journal, Computers & Geosciences, IEEE Transactions on Geoscience and Remote Sensing, International Archives of Photogrammetry and Remote Sensing, Computer Graphics World, Geo-Processing, Remote Sensing of Environment, International Journal on Policy Analysis and Information Systems, Photogrammetric Engineering and Remote Sensing, International Journal of Geographical Information Systems, Geo-Abstracts, Geographical Magazine, Transactions Institute of British Geographers, Area, Geographical Journal, Progress in Physical Geography, Progress in Human Geography, The Planner.**

Symposia/International Conferences:

GIS Session in Annual AAG Conferences, NERC GIS Workshops (e.g. Keyword' - June 1988, Swindon - Dec. 1988), National Mapping Awareness Conference, ACSM/ASPRS Conventions, Auto Carto Series, International Symposia on Remote Sensing of the Environment, Annual Conference of the Remote Sensing Society, Proceedings of Machine Processing of Remotely Sensed Data, Wm. T. Pecora Memorial Symposia, ASPRS GIS Workshops, Regional Research Laboratory Workshops, CORINE Working Papers, ACSM/ASPRS Annual Convention Papers, GIS-Annual Intenational Conference (e.g. San Francisco - 1987), AAG/GIS Conference (e.g. Washington - Nov. 1987).

Part One: GIS Methods and Theory.

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