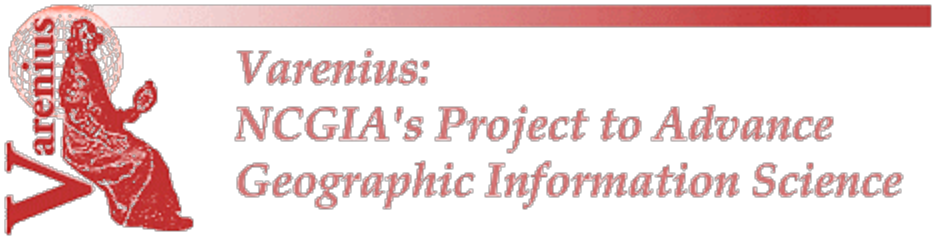

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Introduction

In the late 1980's, when the US National Center for Geographic Information and Analysis (NCGIA) was established, the National Science Foundation and others in the GIS research community identified "geographic information and analysis" as the critical areas for research. The NCGIA's original mandate was to reduce impediments to the widespread use of the technology. Now, almost 10 years later, rapid growth in the use of GISystems across a wide spectrum of application areas demonstrates the success of these and related research efforts. As a result, NCGIA has now chosen to realign its research, education and outreach agendas focusing on more fundamental issues in geographic information science while at the same time maintaining the original three site consortium (with sites at University of California Santa Barbara (UCSB), State University of New York at Buffalo and University of Maine). This paper provides a preliminary announcement of NCGIA's new mission which will carry us forward into the 21st century.

The objective of NCGIA's new research plan, entitled Project Varenius, is to advance geographic information science through basic research, education, and outreach. The research is motivated by scientific, technical, and societal concerns. First, the research serves science and scientists in two ways, focusing on areas in which our knowledge of formalizable geographic concepts is currently incomplete, and contributing to the development and refinement of tools and methods that scientists can use to study geographically distributed phenomena. Second, the research provides basic understanding of geographic concepts, which is required for the production of new technologies. Third, the research examines the impacts that these technologies have on individuals, organizations, and society, and that other digital technologies have in the context provided by geographic space.

Varenius and the *Geographia Generalis*

NCGIA's new project is named for the 17th century scientist, Bernhard Varen (latinized as Varenius) who wrote the first introductory textbook in general geography, *Geographia Generalis*, published first by Elsevier Press in 1650. To Varenius, geography was a field of

mixed (or applied) mathematics which considered the quantitative states of the earth including its shape, size and motion and the distribution and characteristics of land, water, mountains, woods, deserts and the atmosphere. In a review of Varenius' work, Warnz concluded "Clearly, general laws and that which could be demonstrated from them or described with reference to them were of paramount concern to Varenius" [1]. Geography, geometry and graphics make up an important element of this textbook, published in a number of annotated and revised versions, including some edited by Sir Isaac Newton. This work was very much a part of the debate between the Cartesian and the Newtonian scientific systems and thus provides a philosophical foundation for research to advance the science of geographic information.

Research into Geographic Information Science

Central to our new research plan are *geographic concepts* and the notion of a *geographic information science*. While geographic information systems are ubiquitous and expertise in the technology is in great demand, we foresee that in the long term the development of GISystems must rest on a strong scientific basis, as provided through the multi-disciplinary field of geographic information science.

Geographic Information Science Defined

Geographic information science is the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information and, more broadly, the digital age. It re-examines some of the most fundamental themes in traditional spatially-oriented fields such as geography, cartography, and geodesy, while incorporating more recent developments in cognitive and information science, and is beginning to embrace more specialized research themes in such established disciplines as computer science, statistics, mathematics, and psychology. Traditionally, questions in geographic information science have been addressed by researchers working within existing disciplines, and much progress has been achieved. However, the work has been spread across many research fields, and often has been conducted within very different research traditions. No systematic conceptual framework has emerged from these relatively isolated efforts. Commonalties among the questions and their solutions may be missed in fragmented research environments. We believe that by addressing these related questions within the framework provided by the emerging field of geographic information science, we can help to reduce institutional impediments to progress in these research areas, and encourage the exploration of issues in ways that go beyond the solution of immediate problems**.**

Strategic Areas for Geographic Information Science Research

The field of geographic information science is too broad to be studied in its entirety. Therefore, we have identified areas which we consider to provide the highest potential to advance geographic information science within the near future. These strategic areas of our research highlight the role of geographic information science in the era of information technology.

Cognitive Models of Geographic Space

Theories and models of human spatial cognition have included both general and particular components. There seem to be some universals of human spatial cognition, and these appear to arise from the physics of human environments, from the nature of human bodies and senses, and especially from the ways people interact with and are influenced by their environments, both physical and social. But there are also many aspects of human spatial cognition that seem to vary across individuals. Some of these variations may be correlated with factors such as culture, language, or gender, while others may be truly individual differences. Of particular interest here is that GIS-using professionals from different fields may have systematic differences in their cognitive models for geographic phenomena and processes. Work on cognitive aspects of GIS user interfaces has emphasized spatial cognition by "spatially aware professionals" who made up the bulk of the GIS user community in the early 1990s. However, as information systems come "on line" to the general public through home Internet access and other means, we will need to know a great deal more about spatial cognition in general. Current geographic information systems are difficult to use without extensive education and training that is generally unavailable to the public. Even academic researchers find it difficult to find available training opportunities, or to fit them into their already full professional schedules. Making the technology truly easy and natural to use will empower new communities of users, thus increasing the value of the software and databases being built now and in the future by government and the private sector.

Computational Implementations of Geographic Concepts

Most current methods in geographic information science were designed from the perspectives of the computer scientist and the cartographer, aiming at efficiency in capture, storage, and processing of cartographic features. The state of the art in formalizations of geographic knowledge, as reflected in most current GISs, requires that certain constraints be fulfilled before a user is allowed to perform any analysis. They include:

- positions must be recorded in absolute terms in a Cartesian coordinate space;
- geographic objects must be described by precisely defined boundaries, and
- all geographic data sets must be complete.

Our goal is to overcome some of these and other limitations, and to find formal representations that come closer to human practice, capture more complex geographic concepts, and better match cognitive processes. Computational models based in sound theory promote interoperability between systems, another component of ease of use.

Geographies of the Information Society

The third strategic area for NCGIA research is the emerging geographies of the information society where our proposed basic research will identify positive and negative impacts of technology on individuals, organizations, and society, and examine the new geographic structures of the information age. The widespread development and adoption of the geographic information technologies is occurring simultaneously, and many debates about geographic information mirror broader debates about information generally, particularly in

areas such as ownership of data and invasion of privacy. New, more efficient techniques are emerging for collecting and processing spatial data and for communicating geographic knowledge from the field to the consumer, all driven by the changing economics of information creation, dissemination, and use. The use of geographic information technologies is providing to users substantial economic, legal, and political advantages. The world of the National Spatial Data Infrastructure (NSDI), in which everyone can be a producer as well as a consumer, will be very different from the one we are used to, with its linear flow of data from producing agency to consuming public. It will require research to develop measures of fitness for use, based on metrics that take producers' descriptions of data available, and consumers' descriptions of data required, as operands. More profoundly, however, it raises fundamental questions about how information is described between one person and another, and about the processes by which semantic meaning is communicated.

NCGIA Research Initiatives

The National Center for Geographic Information and Analysis will continue to use the research initiative as a vehicle for conducting our research program. Research initiatives, which are multi-year, multi-investigator research projects, address high-priority topics. They start with specialist meetings, which include experts from within and outside the Center, to focus and prioritize a detailed research program while promoting research on the topic by the broader community. The specialist meeting is followed by a period of basic research whose outcomes are reported at workshops, seminars and in the academic literature. Other research vehicles employed by NCGIA will continue to be conferences and workshops, research partnerships with other centers and research organizations, and a visiting scholars program.

Continuing research initiatives

Three active NCGIA initiatives will continue into 1997. These are I-16 (Law, Information Policy and Spatial Databases): I-17 (Collaborative Spatial Decision-Making); and I-19 (The Social Implications of How People, Space, and Environment are Represented in GIS).

Initiative 21 (Formal Models of the Common-Sense Geographic World) was started late in 1996 but it is included as one of the major initiatives under the new research program. The goal of this research is to better understand how people conceptualize geographic space, entities and processes, and to provide a means for incorporating such naÔve geographic knowledge and reasoning into GISs.

An additional initiative already approved will begin in 1997. Initiative 20 (Interoperating GISs) will focus on the basic research needed to achieve interoperability between GISs, thus improving access to software and data. Complementary to the GIS industry's activities in Open GIS, this research initiative will investigate issues of semantic interoperability for GISs.

Proposed research activities

In the area of Cognitive Models of Geographic Space, high priority will be given to the initiation of research on scale (i.e. level of geographic detail). We believe that there is an urgent need to study scale from a cognitive perspective and that scale is a poorly understood but fundamental geographic concept that presents very substantial problems in digital geographic worlds.

Under Computational Implementations of Geographic Concepts, an initiative on the Ontology of Fields is proposed. Geographers and other geographic information scientists have long recognized a fundamental duality in conceptualizations and models of geographically distributed phenomena, between spatially continuous fields on the one hand, and discrete objects on the other. The proposed initiative will examine the concepts of fields, their formalization in computer implementations and the effects of this process on geographic understanding.

The third strategic area of research, Geographies of the Information Society, is perhaps the most radical new direction for the NCGIA. Rather than identifying *a priori* specific research activities, activity in this area will begin with a Specialist Meeting which will examine the range of research topics falling within this theme, identify important gaps and determine the topics most likely to yield to research organized according to the mechanisms and timetable of the Varenius Project. Participants in this meeting will come from information law, information economics, communications, geography, sociology, public policy, political science, planning and spatial data policy.

NCGIA Research Partnerships

Recently, NCGIA has been finding increasing opportunities for collaboration with similar major research projects and centers. Two such research partnerships are already in place.

The Alexandria Digital Library

In October 1994, UCSB was awarded one of six projects funded under the Digital Libraries Initiative of the National Science Foundation in cooperation with other US federal agencies. The project, known as the Alexandria Digital Library (ADL, at http://alexandria.sdc.ucsb.edu), is undertaking the necessary basic research and developing prototype technology for a digital library for spatial and spatially referenced objects, including maps, images, and atlases, but also for any object in a library collection with a defined geographic footprint. The two primary objectives of ADL are to achieve a dramatic improvement in the accessibility and ease of use of spatially referenced materials by building a digital library facility that allows information to be accessed and retrieved over the net; and to exploit the potential of geography as an indexing and access mechanism that is potentially as powerful as the traditional subject, author, and title.

The project is centered in the Map and Imagery Laboratory of the UCSB Library, and includes many faculty from the departments of Computer Science, Electrical and Computer

Engineering, and Geography. All three of the NCGIA sites are participating. The partnership between NCGIA and ADL includes collaboration in research initiatives, particularly I-16 on law and spatial information policy.

National Center for Ecological Analysis and Synthesis

The establishment of a National Center for Ecological Analysis and Synthesis in Santa Barbara (http://www.ceas.ucsb.edu/) was announced by NSF in June, 1995, as a focal point for collaboration between the nation's ecologists. The successful proposal emphasized the potential for collaboration with NCGIA, in which ecology would provide a large and well-defined domain for the development and application of geographic information and analysis; and in which NCGIA would support the use of geographic information technologies at NCEAS through mechanisms such as training programs and jointly sponsored workshops. We see NCEAS as a model for other partnerships with domain-specific research groups, reflecting the increasing interest within the GIS community in the issues raised by adoption and application in specialized domains.

Education and Outreach

The education and outreach activities of NCGIA are intended to build human resources in geographic information science and related fields, and to disseminate research results to the broader scientific and technical communities. A variety of projects fall within this category including further development of three new Core Curricula (for Remote Sensing, for Geographic Information Science and for Technical Programs). As well, NCGIA will continue to organize conferences and workshops intended to facilitate discussion of topics that fall outside its active research initiatives. One example planned for 1997 is the Third International Symposium on GIS in Higher Education to be held in Chantilly VA, Oct 30-Nov 2, 1997 (see the WWW at http://www.ncgia.ucsb.edu/conf/gishe97). We will also continue to publish our technical report series and the semi-annual newsletter but will move these to a new electronic format in addition to their current paper and electronic forms.

For more information

The NCGIA continues to use the WWW as the primary means of communication with the GIScience community. Details on all of these activities can be found at http://www.ncgia.ucsb.edu.

References

[1] W. Warntz, 1989. "Newton, the Newtonians, and the Geographia Generalis Varenii," Annals of the Association of American Geographers, vol. 79(2):165-191.

NCGIA's new project is named for the 17th century scientist, **Bernhard Varen** (latinized as Varenius) who wrote the first introductory textbook in general geography, Geographia Generalis, published first by Elsevier Press in 1650. Bernhard Varenius was born in Hannover, Germany in 1622 and died at age 28 in Amsterdam in 1650 or 1651. To Varenius, geography was a field of mixed (or applied) mathematics which considered the quantitative states of the earth including its shape, size and motion and the distribution and characteristics of land, water, mountains, woods, deserts and the atmosphere. In a review of Varenius' work, William Warnz concluded "Clearly, general laws and that which could be demonstrated from them or described with reference to them were of paramount concern to Varenius" [1]. Geography, geometry and graphics make up an important element of this textbook, published in a number of annotated and revised versions, including some edited by Sir Isaac Newton. It was a required text in Cambridge at the time of Newton. This work was very much a part of the debate between the Cartesian and the Newtonian scientific systems and thus provides a philosophical foundation for research to advance the science of geographic information.

Reference [1] W. Warntz, 1989. "Newton, the Newtonians, and the Geographia Generalis Varenii," Annals of the Association of American Geographers, vol. 79(2):165-191.

Vermeer's "The Geographer"- Varenius is rumored to be the model for this painting, but evidence points to Anthony Van Leeuwenhoek (father of microbiology) another contemporary, as the model.

The following is extracted and translated from the 1712 Newton and Jurin edition of Bernhard Varenius' ***Geographia Generalis***.

A COMPLETE

SYSTEM

OF

GENERAL GEOGRAPHY:

EXPLAINING

The Nature and Properties of the EARTH

VIZ.

It's [sic.] Figure, Magnitude, Motions, Situation, Contents, and Divifion, into Land and Water, Mountains, Woods, Defarts, Lakes, Rivers, &c.

With particular Accounts of the different Appearances of the Heavens in different Countries; the Seafons of the Year over all the Globe; the Tides of the Sea; Bays, Capes, Iflands, Rocks, Sand-Banks, and Shelves.

The State of the Atmosphere; the Nature of Exhalations; Storms, Tornados, &c.

The Origin of Springs, Mineral Water, Burning Mountains, Mines, &c. The Ufes and Making of Maps, Globes, and Sea Charts.

The Foundations of Dialling [?]; the Art of *Meafuring Heights* and *Diftances*; the Art of Ship-Building, *Navigation*, and the Ways of *Finding the* LONGITUDE at Sea.

Originally Written in LATIN

By *BERNHARD VARENIUS*, M.D.

Since Improved and Illuftrated.

By Sir ISAAC NEWTON and DR. JURIN;

And now Tranflated into *Englifh*; with additional *Notes*, *Copper-Plates*, an *Alphabetical Index*, and other Improvements.

Particularly ufeful to Students in the *Univerfities*; Travellers, Sailors, and all thofe who defire to be acquainted with *Mixed Mathematics*, *Geography*, *Aftronomy*, and *Navigation*.

By Mr. *DUGDALE*.

The Whole Revifed and Corrected by *PETER SHAW*, M.D.

The Fourth Edition, with large Additions.

In TWO VOLUMES.

LONDON,

Printed for L. Hawes, W. Clarke, and R. Collins, at the *Red-Lion* in *Pater-Nofter-Row*.

M.DCC.LXV

The Translator's Preface

The Original of this Work was re-printed at Cambridge in the Year of 1672, for the Ufe of the Students in that Universfity; and an Advertifement was given of it, the Beginning of the Year following, in the Philosophical Tranfactions.

THE Dutch Edition being then out of Print, was carefully corrected, in many, Places enlarged and improved, and the neceffary Tables and Schemes fupplied by the Illuftrious Sir ISAAC NEWTON, at that Time Lucafian Profeffor of Mathematics in that Univerfity.

THE Reafon why this great Man took fo much Care in Correcting and Publifhing our Author, was, becaufe he thought him neceffary to be read by his Audience, the Young Gentlemen of Cambridge, while he was delivering Lectures upon the fame Subject from the Lucafian Chair. And tho' many Hundreds were then printed at Cambridge and from that Edition often reprinted abroad; yet by being frequently read in both Univerfities, all the Impreffions were in Time fold off; fo that their Scarcity among the Bookfellers was obferved by the Reverend Dr. Bentley to be a great Detriment to the Young Gentlemen of Cambridge in perfecting their Studies.

WHEREUPON this worthy Encouraged and Advancer of all Sorts of Literature, importuned the Learned Dr Jurin (as being the fitteft Perfon) to take particular Care of a new Impreffion; and, for the Benefit of the younger Students, to fupply the Defects of Varenius with an Appendix, containing the later Difcoveries and Improvements.

TO Him therefore is owing that correct Edition of Varenius, wish an excellent Appendix, printed in the Year 1712, and Dedicated to Dr Bentley; which is the Edition from whence the following Tranflation was made.

The Principles of Geography.

From Section 1 Preliminaries, Chapter 1 Of the Definition, Division, Method &c. of Geography, pp. 5-6

The Principles from which Arguments are drawn for proving Propofitions in Geography are of three forts: 1. Geometrical, Arithmetrical, and Trigonometrical Propofitions. 2. Afstronomical Precepts and Theorems (tho' it may feem ftrange we fhould have Recourfe to the Celeftial Bodies, which are diftant from us fo many Millions of Miles, for underftanding the Nature of the Earth we inhabit). 3. Experience; becaufe the greateft Part of Geography, and chiefly the Special, is founded only upon the Experience and Obfervartions of thofe who have defcribed the feveral Countries.