# Three Years of Activity at The National Center for Geographic Information and Analysis in the United States of America[1]

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## Abstract

The National Center for Geographic Information and Analysis (NCGIA) was founded in Fall 1989 by the National Science Foundation (NSF) as a distributed center with its headquarter at the University of California in Santa Barbara and participation from State University of New York at Buffalo and the University of Maine. This paper describes the goals NSF set forth for the NCGIA and explains how the team has addressed them over the past 3 years; specifically it lists the research topics the center concentrates on and mentions some first results. It concludes that there is a need for a similar European center and international cooperation.

## 1. Introduction

In August 1989, the National Science Foundation (NSF) announced a plan for funding of a National Center for Geographic Information and Analysis (NCGIA). The new center was asked to conduct basic research on geographic information and analysis. Specifically, research efforts addressing the following five areas were requested

- new modes and methods of spatial analysis
- a general theory of spatial relationships
- artificial intelligence and expert systems in GIS
- visualization and
- social, economic and institutional issues.

The award is made to a consortium of three universities: University of California at Santa Barbara (UCSB), State University of New York at Buffalo (SUNY Buffalo) and the University of Maine (UMaine). Each of these universities has considerable experience in GIS

[1]Funding from NSF for the NCGIA under grant SES 88-10917 is gratefully acknowledged.

Frank, Andrew U. "Three Years of Activity at the National Center for Geographic Information and Analysis in the United States of America." Paper presented at the FIG Symposium, Umwelt und Landinformation, Innsbruck, Österreich 1991.

research. The Department of Geography at UCSB has one of the world leading groups in remote sensing research. The Geography Department at SUNY Buffalo has integrated GIS work with geography and has an outstanding reputation for advanced GIS education. The Surveying Engineering Department at UMaine has concentrated on the information management and processing aspects and contributes an engineering perspective to the Center.

The Center was originally lead by the co-directors Dr. David Simonett and Dr. Michael Goodchild, both at the University of California at Santa Barbara. After Dr. Simonett's untimely death, Dr. Goodchild and Dr. John Estes became co-directors. Research at each site is coordinated by the associate directors: Dr. Terrence Smith, UCSB; Dr. Michael Batty, SUNY Buffalo; and Dr. Andrew Frank, UMaine.

## 2. Major concepts

The research is organized into 'research initiatives'. These typically bring together researchers from different disciplines that can contribute to the solution of a problem that is encountered in different forms. It avoids the limitations of the traditional disciplines and enforces that new points of view are recognized. It also helps to concentrate the resources on a few selected problems at a time and avoids the equal spread of limited Center resources over a large number of problems without achieving significant results.

A research initiative is usually preceded by a 'Specialist Meeting' to refine the research agenda. Specialist meetings are of one to two weeks duration at which perspectives on a specific topic are presented by specialists drawn from Center personnel, researchers from outside the Center, and other representatives of government and industry. These meetings promote cross-disciplinary exchanges, work out the agenda for the Research Initiative, and assign responsibilities to Working Groups.

The Center is designed as a distributed center, that works as a single center but is spatially distributed. Strong ties exist between the researchers that work on the same topic, but from different sites. Most Center activities are distributed and lead by researchers from different sites. This distribution of the Center is made feasible by the extensive use of modern communication media, primarily electronic mail (BITNET, NSFnet). The Center relies on two annual meetings of its principals to discuss major issues. The distribution allows for the Center to include a greater variety of aspects in its research than any single-site center could, and the spread across the United States, from the west coast to the north east corner makes it easier to cooperate with researchers throughout the U.S.A.

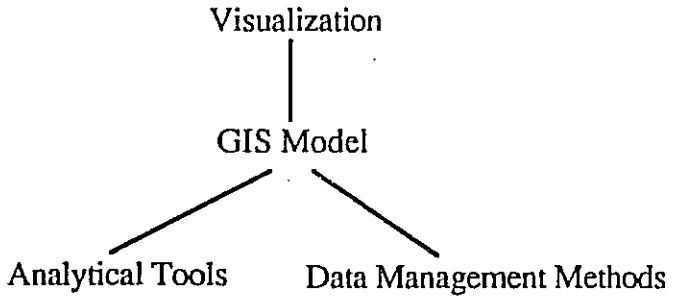
The Center is organized as a '**geographic information and analysis research**' Center that explores the theoretical issues associated with the use of spatial information. It studies the base issues of collecting, managing and understanding spatial information. It is not designed as a Center for '**geographic data and tools**' where one would collect and manage geographic data, and make the data available to researchers and maintain an array of tools for processing

and analyzing these data, (e.g the commercial GIS systems), and maintain staff experienced with using these tools. Such a Center could be very helpful, but it is not how the winning team understood the intent of NSF.

## 3. Scientific directions

The Center researchers agree on a few basic assumption of what a GIS is and what the major direction of research should be.

Some of us have found a diagram useful to illustrate the important aspects of the research to be conducted, in spite of the limitations of any such diagram:




### 3.1 GIS as a Model of (certain aspects) of Reality

A GIS is a model of reality, exactly those parts of reality that geographers, researchers in various social and natural sciences, regional planners, surveyors and similar professionals deal with. Historically, the use of formal models of their subjects has been an effective way for other sciences to advance (especially physics), but geography has only partially benefitted from such a concept.

The lack of a unifying view of GIS as a model of reality, hinders the application of different tools as they are designed to deal with specific aspects. The central concern is what methods are used to represent the available knowledge about reality (the available data). This is the common problem of knowledge representation in artificial intelligence which needs to be addressed for the specific situation of geography. The knowledge representation must be designed so that it supports the analytical and visualization methods and can be implemented on a current (or future) computer system.

### 3.2 Types of Data in a GIS

The data in a GIS describe the quality of some attribute at a specific location. Some attributes appear to be continuous, and others 'naturally' discrete. Data

for some phenomena may be collected for some sampling points, while in other cases uniform values are delineated. Analytical work with a GIS most often implies conversions from the 'natural' scale of the phenomena to the one the tool at hand uses. The questions users ask are often not related to the properties for which values were collected, but are for other properties, for which values must be deduced from those collected.

### 3.3 Errors and Other Imprecisions

Neither the observation and recording of values for attributes nor the determination of locations can be carried out without error. Determining a value with more precision is generally more expensive and cumbersome. Depending on the purpose, attribute values are often collected not on their natural scale (e.g. ratio) but on a simpler one (e.g. ordinal).

The lack of a theoretical understanding of error measurement and propagation of errors through the derivation of data based on collected values, is a major limiting factor in the use of GIS. It affects GIS in two ways: 1) we cannot assert what level of precision is necessary in the data originally collected (and thus not determine the economical effort); and 2) we cannot assess the quality of results derived in a GIS (and thus not prevent the distribution and use of meaningless or misleading information). The fear of liability for problems associated with the information produced will hinder its availability.

### 3.4 Multiple Representation ( or generalization hierarchy)

Geography deals with spatial phenomena existing on a broad range of scales. For instance, scales may vary from single house/tree/small stream on a topographic map sheet, to a world scale of large cities, ecosystems and major rivers.
Typically we deal with representations for the same phenomena on different scales (or better, different levels of aggregation) inside a GIS or during an exchange of data between GIS.

Moving from a detailed representation to a more general one has two advantages (to humans as well as to computers): (1) it reduces the amount of data to be stored; and (2) processing becomes faster. Understanding the connections between multiple levels or resolution of detail for the same phenomena (including the errors associated with it) will allow the use of heuristics to solve problems for which no straightforward (brute-force) approaches are known.

### 3.5 Spatial Theory

The data in a GIS are related to space. In many instances the analysis to be

performed on them includes spatial properties. Current systems do not incorporate comprehensive methods, but instead have a specialized subset of spatial operations. There are very close links between the models used to represent spatial data and the operations applicable. Today's systems include each of several different models available and are restricted to a subset of spatial relations and operations.

## 4. Research Initiatives

Initiative 1: Accuracy of Spatial Databases - Leader: Michael Goodchild (UCSB)
Objectives:

1) Assess statistical models of spatial data
2) Construct and evaluate techniques for interpolation and estimation to overcome problems of variable reporting zones and missing values
3) Develop indices of data uncertainty and confidence for GIS products
4) Conduct studies of the effects of aggregation on spatial modeling.

Initiative 2: Languages of Spatial Relations - Co-Leaders: Andrew Frank (UMaine) and David Mark (SUNY Buffalo)
Objectives:

1) Identify formal cognitive/semantic models of spatial concepts and relations in natural languages
2) Develop reliable methods for determining reference frames for spatial language
3) Construct formal mathematical/logical models of spatial concepts and relations based on topology and geometry
4) Integrate the two kinds of formal models into a general theory of spatial relations.

Initiative 3: Multiple Representations - Leader: Barbara Buttenfield (SUNY Buffalo)
Objectives:

1) Critically examine the relations of the geometry of geographic features to the scale of representation (self-similarity vs. scale dependence etc)
2) Develop models for digital description of cartographic features (object-oriented vs. spatially addressed models; hierarchical models; conversion between models)
3) Study problems associated with scale-changing, and propose solutions and algorithms based on pattern recognition and feature identification, inference across levels of resolution, and automation of feature simplification and selection
4) Characterize the effects of multiple representation on error propagation
5) Determine database organizations capable of dealing with multiple representations of the same objects

Initiative 4: Use and Value of Geographic Information in Decision Making - Co-Leaders: Harlan Onsrud (UMaine), Hugh Calkins (SUNY Buffalo)
Objectives:

1) Identify problems of dealing with uncertainty and risk associated with decision making
2) Develop and test models of the decision-making process regarding land use, focusing on the role of information
3) Identify primary and subsequent users of spatial information and determine the value of such information
4) Evaluate the direct and indirect benefits of GIS/GIS

Initiative 5: Architecture of Very Large GIS Databases - Leader: Terence Smith (UCSB)
Objectives:
1) Assess the requirements for very large databases
2) Determine characteristic data types for remotely sensed data
3) Identify functional components for very large GIS databases and related GIS products
4) Develop methods to group components to achieve high performance
5) Build prototypes and test components

Initiative 6: Spatial Decision Support Systems - Co-Leaders: Michael Goodchild (UCSB) and Paul Densham (SUNY Buffalo)
Objectives:
1) Design GIS data structures to support decision systems
2) Develop methods for effectively structuring spatial search algorithms within a GIS framework
3) Classify spatial search problems and identify gaps in current models
4) Produce and test prototypical user interfaces

Initiave 7: Visualization of Data Quality - Leaders: Kate Beard and Barbara Goodchild

Initiative 12: Integration of GIS and remote sensing - Leader: Jack Estes

Initiative 13: User interfaces for GIS - Leaders: David Mark and Andrew Frank

Future initiatives: Six more initiatives are planned for the following years. They include:

Initiative 8: Expert System for Cartographic Design
Initiative 9 Institutions Sharing Spatial Information
Initiative 10: Temporal Relations in GIS
Initiative 11: Space-Time Statistical Models in GIS

## 5. Education

NSF noted a need to improve GIS education. It was observed that few universities offered such courses. It is difficult to find faculty to teach the courses and it was difficult to teach in the absence of text books and other course materials. The NCGIA has made a large effort to produce a complete set of course notes for a two to three semester course. This extensive set of

notes - written with the help of many GIS faculty from outside the Center - was tested in 1989/90 and then revised. It was published in Spring 1990 and a large number of universities around the world have bought these notes and many use them.

## 6. Development of NCGIA

The NCGIA has now operated for abut 3 years. It has followed very closely the original plan and has been generally successful. Some minor adjustments in the organizational structure became necessary to adapt to the natural fluctuation of personnel in the academic world; we consider the ease with which such changes have been possible as a proof of the soundness of the whole structure.

The Center has started 9 research initiatives so far. The initiatives produced edited volumes of contributions to Initiative topics 1, 2, 3, and 5, and the interrelation between the Initiatives is always felt as very strong with the results of the earlier ones effectively influencing the later ones. The major effect of the Specialist Meetings with which initiatives are usually started has been to bring researchers with different backgrounds and from different disciplines together and have them address a problem from a broader perspective. The extensive and very open discussions - later Initiatives typically have not reserved time for formal presentations - lead often to changes in the approaches the researchers take in their successive work. These meetings typically bring together about 40 researchers, of whom only about a dozen are from the NCGIA and the rest from other universities and industry. This guarantees that the Center remains open to other viewpoints. Its research is influenced early by the community at large and in turn influences the work done by others. Increasingly we observe cooperation between the sites and researchers at other universities and industry.

## 7. International aspects of NCGIA

The NCGIA is an institution primarily financed by the U.S. government through the National Science Foundation (comparable to the Deutsche Forschungsgemeinschaft or the Austrian Forschungsfoerderungsfonds). It started with strong international ties, primarily to researchers in the English-speaking world, but also to continental Europe and South America, and all specialist meetings have been attended by some researchers from outside the U.S. So far, only one major event has been held in Europe (a NATO-sponsored Advance Study Symposium on Cognitive and Linguistic Aspects of Space in Spain), but the Center intends to become increasingly international. Several upcoming events are planned to be held in Europe, including an effort to organize one of the specialist meetings that start a Center research initiative in southern Europe. Lead by the conviction that GIS research, as any true research, must transgress boundaries and should be independent of nationality, the Center is preparing to cooperate with other similar entities and to share its research agenda.

The NCGIA is an unique institution. There are a small number of somewhat similar, but usually more applied and smaller, organizations in the U.K., the Netherlands and in other

countries. They often do not have the long term stability and the mission to carry basic research, but there is widespread agreement that such basic research and the capabilities for it are crucial for the development of future GIS and their successful use to solve the pressing needs in the region.

In this context it should be pointed out, that research carried out in the Center has lead to the suspicion that there is a strong interaction between the (national) language and the cognition of space. Clear is, that current GIS are strongly influenced by anglo-saxon languages, a planning methodology typical for the U.S. and cognitive spatial concepts relevant for the North American environment. It is an interesting research question how one would have to build a GIS to be appropriate for say, southern Europe, South America or Southeast Asia, but it is a question of eminent political and economic impact.

It seems necessary that European researchers in Geographic Information Systems and Geographic Information Analysis establish cooperation based on important research themes of common interest. The NCGIA shows that a theme-oriented effort that intentionally crosses disciplinary boundaries can be effective to work on the difficult but pressing problems in the GIS arena. The methods of electronic communication (electronic mail, but also FAX and telephone) allow such cooperation effectively . We can today create international research groups without regard to geographical location and the traditional walls of the university!

## References

Abler, R.F., 1987. The NSF National Center for Geographic Information and Analysis. *International Journal of Geographical Information Systems*, Vol. 1, No. 4, pp. 303-326.

National Center for Geographic Information and Analysis, 1989. The Research Plan of the National Center for Geographic Information and Analysis. *International Journal of Geographic Information Systems*, Vol .3, No. 2, pp. 117-136.

FIG SYMPOSIUM
Innsbruck Austria
Sept 30 - Oct 1, 1991

# Environment
and
# Landinformation

# Umwelt
und
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1991
Verlag Konrad Wittwer, Stuttgart

Geodätentag '91
Innsbruck
2.—5. Okt. 1991, Kongreßhaus

INTERNATIONAL FEDERATION OF SURVEYORS
FÉDÉRATION INTERNATIONALE DES GÉOMÈTRES
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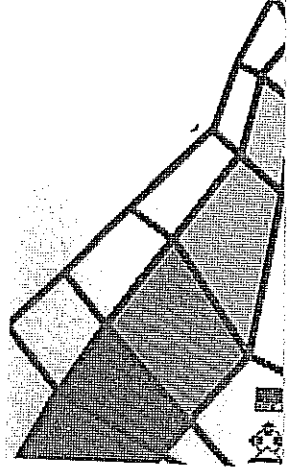
DER VERMESSUNGSINGENIEURE



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