International Symposium on Geographic Information Science

On the occasion of the 20th anniversary of the funding of NCGIA

Santa Barbara, CA

December 10-12, 2008

Marking the beginning of National Science Foundation funding in 1988 for the **National Center for Geographic Information and Analysis** (NCGIA) at its three sites, representatives from the University of California, Santa Barbara, the University at Buffalo, and the University of Maine met in December 2008 to celebrate he twentieth anniversary of NCGIA. In honor of this occasion, a symposium was held at which retrospective and prospective analyses of the work of NCGIA were reviewed. Full presentations and related memorabilia are available at http://ncgia.ucsb.edu/projects/isgis/. Summaries of some of the presentations are provided (shown by * in listings) but the detailed discussions of plenary sessions and breakout groups are not available.

Retrospective presentations on the background, programs, and results of NCGIA

- **Mike Worboys**, University of Maine
- **Ronald Abler**, International Geographical Union
- **Stephen Hirtle***, University of Pittsburgh
- **André Skupin***, San Diego State University

Comments from invited panelists and discussants

- **Andrew Frank**, Technical University of Vienna
- **Max Egenhofer***, University of Maine
- **David Mark***, University at Buffalo

Retrospective: panel on the ten most significant discoveries and innovations of GIScience

- **Sara Fabrikant***, University of Zürich
- **May Yuan***, University of Oklahoma
- **Marc Armstrong***, University of Iowa
- **Kate Beard***, University of Maine

Prospective: panel on the future of GIScience

- **Dan Montello**, UC, Santa Barbara

- **Luc Anselin***, Arizona State University
- **Will Craig***, University of Minnesota
- **Werner Kuhn***, University of Muenster

The mechanisms of GIScience research: Panel on the role of collaboratories, international networks, and organizations

- **Greg Smith**, University College London
- **Christian Freksa***, University Bremen
- **Greg Smith**, NGA
- **Mike Batty***, University College London

Reports from small-group discussions / Commentaries on the symposium

- **Reg Golledge**, UC, Santa Barbara
- **Steve Hirtle**, University of Pittsburgh
- **Nancy Obermeyer**, University of Pittsburgh
- **Val Noronha**, UC, Santa Barbara
- **Waldo Tobler**, UC, Santa Barbara
- **Jerry Dobson**, Oak Ridge National Laboratory

Signing the funding agreement for NCGIA,1988 / Advisory Board

Participants: International Symposium on Geographic Information Science, Dec 2008

Abler, Ronald F.
International Geographical Union

Anselin, Luc
Arizona State University

Armstrong, Marc
University of Iowa

Bader, Josh University of California, Santa Barbara

Batty, Mike
University College London

Beard, Kate.
University of Maine

Berg, Dick. National Geospatial-Intelligence Agency

Couclelis, Helen
University of California, Santa Barbara

Craig, Will.
University of Minnesota

Dangermond, Jack
ESRI

Dobson, Jerome
Oak Ridge National Laboratory

Dorsey, Stuart
University of Redlands

Egenhofer, Max
University of Maine

Fabrikant, Sara
University of Zurich

Frank, Andrew
Technical University of Vienna

Freksa, Christian
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Giudice, Nicholas A.
University of Maine

Glennon, Alan
University of California, Santa Barbara

Golledge, Reg
University of California, Santa Barbara

Goodchild, Mike
University of California, Santa Barbara

Sucharita Gopal
Boston University

Gould, Michael
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Grossner, Karl
University of California, Santa Barbara

Hardy, Darren
University of California, Santa Barbara

Hirtle, Stephen
University of Pittsburgh

Hurt, Indy. University of California, Santa Barbara

Janelle, Don
University of California, Santa Barbara

Knigge, LaDona
California State, Chico

Kuhn, Werner
University of Muenster

Lee, Kun. University of Seoul, Seoul Korea

Li, Linna. University of California, Santa Barbara

Longley, Paul
University College London

Mark, David M
University at Buffalo

Montello, Dan, University of California, Santa Barbara

Noronha, Val. University of California, Santa Barbara

Obermeyer,
Indiana State

Pultar, Edward. University of California, Santa Barbara

Raubal, Martin
University of California, Santa Barbara

Rice, Matt
George Mason University

Rosati, John J.
THR Associates

Royal, Nate. University of California, Santa Barbara

Skupin, André
San Diego State University

Slater, Paul. University of California, Santa Barbara

Smith, Greg
NGA/InnoVision

Smith, Greg
University College London

Tobler, Waldo University of California, Santa Barbara

Tong, Xiaohua. Tongji University. Shanghai, China

Worboys, Mike
University of Maine

Yuan, May
University of Oklahoma

Zubrow, Ezra B.
University at Buffalo

NCGIA: A Cognitive Retrospective

Stephen C. Hirtle, University of Pittsburgh

Retrospective on the background, programs, and results of NCGIA

- Workshops, conferences, research initiatives, edited volumes, ...
- Engaged a wider community from Day 1
- Looked towards what is working and what needs to be added
- COSIT series supported strongly by NCGIA
- GIScience created to complement existing conferences

Pushed foundational issues in the field

Technical Report 94-9: Time in Geographic Space: Report on the Specialist Meeting of Research Initiative 10 (edited by Max J. Egenhofer, U. Maine, and Reginald G. Golledge, UCSB) describes the Specialist Meeting of the NCGIA Research Initiative on "**Spatio-Temporal Reasoning in GIS**" which addresses space and time as it relates to objects and people in geographic space

Pushed the field to consider alternative frameworks

- **NCGIA and Varenius Workshops**
  - Multiple Modalities & Multiple Frames of Reference for Spatial Knowledge, Santa Barbara, California, February 18-20, 1999
  - Cognitive Models of Dynamic Geographic Phenomena & Representations, Pittsburgh, Pennsylvania, October 29-31, 1998
  - Scale & Detail in the Cognition of Geographic Information, Santa Barbara, California, May 14-16, 1998
  - Mark, D. M., Freksa, C., Hirtle, S. C., Lloyd, R., & Tversky, B. (1999). Cognitive models of geographical space. *International Journal of Geographical Information Science*, 13, 747-774.

FOUNDATIONAL ISSUES

- The research over the past twenty years has highlighted the importance of cognitive maps in geographic communication, acquisition and use of geographic information, wayfinding, planning, and urban design.
- From constructing user-centered in-car navigation systems that impose a minimum of attentional demands on a driver to constructing urban parks that encourage public use, research on cognitive mapping can suggest appropriate parameters to consider in the design process.

Knowledge Acquisition

- Knowledge acquisition is a messy business. The classical view of [**Landmark Recognition -> Route Knowledge -> Survey Knowledge**] does not hold under careful scrutiny.

- It clear that the acquisition sequence is not strictly linear (Allen, 1999).
- Accurate metric knowledge was either gained in the first session or never learned, calling into question the learning parameters in the original conceptualization (Ishikawa & Montello, 2006).

Hierarchical Structuring

- While automated navigation systems often provide directions using street nodes (turn left at Main St; Go 3.4 km), humans often talk in terms of neighborhoods and landmarks (when you get to downtown, turn left at the Starbucks).
- Neighborhoods form one of the basic organizing principles of cognitive maps, nested in a semi-lattice (Hirtle, 1995), which leads to hierarchical clustering like effects on judgments of distance and orientation.
- There is a symbiotic relationship between landmarks and neighborhoods provides two distinct ways of structuring space into regions, which in turn influences the perception of that space.

Schematization of Geographic Knowledge

- The London Underground map designed in 1931 by Harry Beck is seen as ideal communicator as it extracts useful information, organizes that information in a colorful and pleasing display, keeping relative directional information intact (e.g., northern stations are at the top of the map), as well as the critical linear ordering of stations along a specific route.
- Beck's map replaced a more geographically accurate, but less useful, rendition of the same information.
- In fact, it is becoming clear that photographs, virtual reality, immersive environments and other photo-realistic settings by themselves may have limited used for navigation aids (Darken & Peterson, 2001; Freksa, 1999).

ALTERNATE FRAMEWORKS

- While traditional approaches have been useful to understanding the nature of cognitive mapping, they are limited in their ability to account for the interactions of multiple criteria. A number of researchers have explored several alternative frameworks for the development of cognitive maps. Three of these approaches are reviewed below.

Naïve Geography

- Naïve Geography is an approach based on the work in artificial intelligence in the 1970's on Naïve Physics to model common-sense knowledge of objects and motions in the world (Hayes, 1979).
- Egenhofer and Mark (1995) introduced the concept of Naïve Geography to capture everyday reasoning about geographical space.
- Naïve Geography include a number of interesting principles from assuming a space is two-dimensional, even though it is not to asserting that boundaries are sometimes entities and some not.
- For example, if a boundary is always taken as a mathematical object of having length but no width then the common notion of leaving one's country before entering another country would be impossible.
- Reasoning about boundaries in such situations, including the legal standing, would follow the principles of Naïve Geography and not the underlying mathematical principles.
- Geographical Information Systems that ignore the principles of Naïve Geography might prove difficult to use. These limitations are particularly worth noting for community-based or public participation GIS systems

Naïve Geography Example?

- David Mark: "How big is the pie"?
- Answer: "The size of a triangle ... (pause) ... only a little larger."

Geocognostics

- At the Naïve Geography Meeting, Geoff Edwards (1997) developed a framework called geocognostics.
    - In this approach, he argues for the need to combine two representational structures, one for views, which is the typical focus of cognitive maps, and another for trajectories, or one's path through the space.
    - The approach of using trajectories through space was also the focus of work by Hutchins (1995) in explaining the representations of Polynesian sailors who could not depend on traditional landmarks in their navigation tasks.
    - Geocognostics gets its name from the combination of geometrical and cognitive principles that are needed to account for a rich set of empirical findings.

Synergetic Inter-Representation Network

- Juval Portugali at GIScience and COSIT has argued for the value of considering the links between internal representation and the external environment, which necessarily influence each other.
- Using the mechanics of self-organizing system, he introduces the notion of a Synergetic Inter-Representation Network (SIRN).
- SIRN provides a new underlying theory that can account for acquisition and storage of spatial information.

CONCLUSIONS 1/3

- NCGIA has been at the forefront of applied and theoretical research on cognitive mapping.
- Cognitive mapping is proven to be rich source of both empirical findings and theoretical research. In addition, it is argued that cognitive mapping is important for many areas of geoinformatics.
- The acceptance of public GIS projects, the ability to provide useful feedback to planners, the use of navigation systems, and the modeling of emergency management evacuation plans depend in part on understanding how humans process spatial information.

CONCLUSIONS 2/3

- In part, cognitive mapping provides the framework for developing user-centered GISs.
- A navigation system working only in longitude and latitude would be accurate but worthless as an in-car navigation system.
    - While this example may seem obvious, the reality is that multiple coordinate systems are already in use and emergency call operators are faced with translating from caller's natural language information to a GIS to a rescue vehicle's code, resulting in a large number of possible confusions or miscommunications (Goodchild, 2000).
- **The NCGIA has**
    - Fostered leading research through engagement with wider research communities
    - Consistently brought multiple voices to the table to address issues of concern
    - Manage to examine both theoretically interesting problems and motivated real-world applications, often within the same meeting or research endeavor

CONCLUSIONS 3/3

Questions or comments welcomed.

NCGIA @ 20

André Skupin
San Diego State University

1. There be dragons!
2. I link, therefore I am!
3. Nothin' but a **G Thing!**

NCGIA @ 20 born in '88

So you are:

- a beautiful creature, colorful and flamboyant
- an extroverted bundle of energy, gifted and utterly irrepressible
- everything on a grand scale—big ideas, ornate gestures, extreme ambitions
- fearless in the face of challenges, because of its confidence, and therefore almost inevitably successful
- making it to the top

Oh, but you may also suffer from:

- too much enthusiasm can leave you tired and unfulfilled
- though willing to aid when necessary, pride often impedes from accepting the same kind of help from others
- generosity attracts friends, but solitary at heart
- self-sufficiency means there are few close bonds with others

NCGIA @ 20Born in '88

In short, one could expect that baby to grow up to be:

- Innovative
- Enterprising
- Flexible
- Self-assured
- Brave
- Passionate
- Conceited
- Tactless
- Scrutinizing
- Unanticipated
- Quick-tempered

Then again, this might get tempered by one of the five elements:

- **Metal, Water, Wood, Fire, Earth**

- Which one will it be?

NCGIA @ 20 born in '88
EARTH it is, naturally!

- great manager because being **practical, level-headed** and demonstrating **a knack for organizing**
- still has the **need to dictate and be admired**, but is **affable, congenial and supportive**
- compared to other dragons, this one is **less likely to breathe fire at the least irritation**
- will work diligently to **complete its life goals**
- earth element adds a greater portion of **self-control**, so that it is deserving of the respect it desires
- takes its life and **romantic** (!?) responsibilities quite seriously

It's a G Thing!
National Center for **Geographic** Information and Analysis
NOT
National Center for **Geospatial** Information and Analysis

It's a *revisionist* G Thing!

Open Geospatial Consortium (OGC). In describing its own history, the organization makes the following statement (http://www.opengeospatial.org/ogc/historylong; accessed July 29, 2009)

The company was incorporated as "OGIS Ltd." on August 25, 1994. An Oct 22, 1994 Board resolution changed the name to "Open Geospatial Consortium, Inc."

No, it did not!
It was called the Open **GIS** Consortium from 1994 until at least 2003
(http://www archive org)

It s a *different* G Thing!

'Geographic' is the right word for graphic presentation—maps—of features and phenomena on or near the Earth's surface. 'Geospatial,' (or 'spatial') also refers to data about Earth features and phenomena, but the data are not necessarily graphically presented. Many geoprocessing applications do not involve a human-readable map on display.

(http://www.opengeospatial.org/ogc/faq/; accessed July 30, 2008)

"It's a *new* **G Thing!**"

Uh, wait, first let me redefine your G in suitably narrow terms and call that the old G. That makes it easier for me to claim mine as new:

"Neogeography means 'new geography' and consists of a set of techniques and tools that fall outside the realm of traditional GIS."
[Turner A (2006) *Introduction to Neogeography* O'Reilly]

Since I can't have your GIS,
I'll just take over your G! Hah!

Search Phrase and	**Google Hits**
"geographic information system"	1,810,000
"geographical information system"	1,130,000
"geospatial information system"	45,900
"geographic"	113,000,000
"geographical"	46,900,000
"geospatial"	4,980,000

There's nothing like that for B, C, or A Things

"biological"	102,000,000
"biospatial"	1,820
"chemical"	246,000,000
"chemospatial"	0
"astrospatial"	22
"sociospatial"	26,200
"anthrospatial	6
"infospatial"	52
"econospatial"	0

Does it even matter?
(a) avoid **redundancy**
(b) leverage **geographic concepts**
(c) highlight the power of **abstraction**
(d) highlight the power of **transformation**
(e) **scale** matters
(f) **people** matter
(g) **space** matters

Another G Gem

"Geospatial information education is only one of many technology areas that are suffering from the lack of education standards. In the United States two groups have stepped up to try to fill this void—the **National Center for Geospatial Information and Analysis** (NCGIA) and the DoD-sponsored Community Geospatial Information Training Committee (CGITC) and Community Imagery Training Committee (CITC). In 1996 NCGIA proposed a core curriculum for **Geospatial Information Science** (GIScience). The primary purpose of this core curriculum was to provide the academic community with a generic design of courses that act as the foundation of a comprehensive GIScience program."

http://www.ncgia.ucsb.edu/other/ucgis/summit/nima_full.pdf

So ...

Geospatial see **Geographic**

as in

National Center for Geographic Information and Analysis

Or

There be Dragons!!!

It was 20 years ago . . . NCGIA

Max Egenhofer

Department of Spatial Information Science and Engineering

University of Maine

Five Highlights

Highlight #1—The Research Initiative Model

- Specialist meeting + closely monitored research activities
- Specialist meetings only

Research Initiatives

- **Excellent *internal* model**—Provides focus, accountability, change
- Requires:
    - The right topic
    - SM + research
    - Willingness to collaborate
    - Persistence despite critique
    - Time

Recipe for Successful Specialist Meetings?

- The location (sequestered) and atmosphere
- Right granularity of topic
- Timeliness of topic
- Right mixture with multidisciplinary breadth
- A few controversial participants
- Fresh blood

Research Initiatives

- **Problematic *external* model**
    - result delivery in small pieces (i.e., papers)
    - lack of coherent picture
    - no unified product

Highlight #2—Board of Directors Meetings

- Momentum towards the meeting
- Living under pressure, being quick on your feet
- Interactions with Board members

- Dissemination beyond the core academic community

Highlight #3—The Las Navas Meeting

- Intellectual cradle of spatial cognition and computation
- Model for interdisciplinary interaction
- Formation of a social network

Highlight #4—Impact

- COSIT, SSD, GIScience, Spatial Uncertainty
- The countable impact: Google Scholar about ***IJGIS***
- 20 of the top 50 most frequently cited papers
- 7 of top 20, 4 of top 10, 2 of top 3

Highlight #5—Impact beyond GIS

- Most frequently discussed: geography
- Much less controversial: computer science

Impact on Database Field

- a modest topic already before Initiative 5
- Spatial Database Symposium (SSD) got the organized
- *GeoInformatica* as a now popular outlet
- Spatial now mainstream in DB
- A decline of *spatial* on the DB research agendas

Impact on AI

- The *bullet* that was not explicitly pursued
- Qualitative Spatial Reasoning as emerged theme around 9-intersection, RCC, and cardinal direction models

The Five Bullets in 1988

- New modes and methods of spatial analysis
- A general theory of spatial relationships
- Artificial intelligence and expert systems in GIS
- Visualization
- Social, economic, and institutional issues

Max's Five Bullets in 2010?

- Spatial cognition about geographic space and systems
- Spatial semantics for information systems
- A general theory of geographic space and time
- Spatial communication
- Societal issues of spatial information *and* spatial systems

Comments on the Background, Programs, and Results of NCGIA

David M. Mark, NCGIA-Buffalo

Is the Semiotic Triangle Larger than a Piece of Pie?
Concept / Symbol / Referent

The mid-1980s, GIS was still fairly primitive . . . image of Early GIS photo taken before NCGIA and color were invented

A National Center

- . . . then, in 1987, the National Science Foundation issued a **call for proposals for a "National Center for Geographic Information and Analysis"**
- One key feature of the solicitation was a bulleted list of important research topics, and a suggestion that the NCGIA should research some of these
- These "Five Bullets" played a role in shaping GIScience

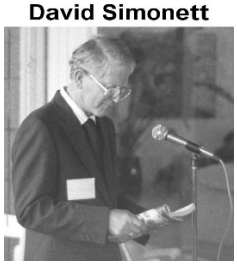
The Five Bullets:

- improved methods of spatial analysis and spatial statistics
- general theory of spatial relations and database structures
- artificial intelligence
- visualization
- social, economic, and institutional implications of the technology

Initiative 1, and the ***Accuracy of Spatial Databases*** book; "**Spatial Uncertainty**" meeting
Initiative 2, and the **COSIT** (Conference on Spatial Information Theory) series
Initiative 4, "**Use and Value of Geographic Information**"
Initiative 5, and the "**Large Spatial Databases**" conference series

A large amount of effort went into writing our proposal!

- June 1987: 3-site consortium formed
- August 1987: 5 days proposal writing in Santa Barbara
- September 1987: 3-day proposal-writing in Maine
- September 1987: 3-day proposal-writing in Buffalo
- November 1987: 3-day proposal-writing in Crystal City
- December1987, January 1988: proposal-writing in Santa Barbara
- January 1988: Submitted to NSF
- June 1988: Site visit
- August 1988: Announcement
- December 1 1988: Start date



NCGIA PROPOSAL team (in part) at work in Santa Barbara, December 1987

Innovation?: Research Initiatives and Specialist Meetings

- The ideas of "Research Initiatives" and "Specialist Meetings" were key innovations
- In Crystal City, Andrew Frank had to work a long time to convince the rest of us
- *An appropriate degree of specificity?*
  - 12 Research Initiatives were defined in our proposal
  - A process for establishing more
  - 19 Research Initiatives in total under the NCGIA grant
- Participants from multiple disciplines, multiple 'sectors'
- Thesaurus: Expert -> **Specialist**
- A "House Style"
- Adopted in Europe by the GISDATA project

Large Projects Followed

- CSISS: Center for Spatially-Integrated Social Science; etc.
- Two IGERTs in GIScience at Buffalo
  - Supported 62 Ph.D. students in GIScience, in seven disciplines
  - 18 have graduated (5 departments), 32 are still in the program (12 have left without PhD) – as of Dec 2008.
- Several IGERTs at UCSB, including "Interactive Digital Multimedia"
- IGERT at Maine, "Sensor Science, Engineering, and Informatics"
- Vespucci Initiative
- Etc.

Impacts

- The people who were involved!
- Faculty at the NCGIA sites
- Graduate students
- Specialist Meeting participants
- Others...
- It is very difficult to measure the effect of this, due to the 'contingency problem'.

Lastly, Alternative Histories

- What if...?
- What if there had been no NCGIA award from NSF?
- What if the NCGIA grant had been awarded to a different institution or consortium?
- Of course, we will never know...

Thanks to everyone who made NCGIA happen the way it did!

Ten Things

Marc P. Armstrong
Professor and CLAS Fellow
Chair, Department of Geography
Interim Director, School of Journalism and Mass Communication
Administrative Fellow (Dean-like Object), CLAS
The University of Iowa

Charge by MFG

- To give a perspective on "the ten most significant discoveries in GIScience".
- My quick reply was that I wasn't sure there were any discoveries...

GIScience

- We do basic research, but much of what we do can be viewed as "translational" science
- In medicine the term is "from the bench to the bedside" or "from mouse to man"
- Ours might be "from map to machine" (Overlay / light tables)
- Perhaps the single biggest thing that we have discovered is "GIScience" itself... but that's kind of nebulous, so I'll turn to abstract categories to make things concrete

1. Abstraction/Theory

- **Transformational "view"** (Waldo Tobler, map "algebra")
- **Topological concepts** (initially enabled topological data model, error checking, but then Max et al. relations)
- **Hierarchical data structures** (interleaved binary addresses!)
- **Ontologies**

2. Operations

- **Geocoding** (from text to coordinates: basis for mashups and Web 2.17, aside from affine, the most common transform?)
- **Overlay and other map layer manipulations** (band sweep, etc., but basic ops have not evolved)
- **Local Spatial Analysis** / Statistics

If you're counting, I only fired nine bullets

• NCGIA supported work in 1990s that, with hindsight, was related to cyberinfrastructure (NSF term, not mine) and e-science (CSDM, etc.)
• Despite subsequent good work at UCSB and elsewhere, need stronger engagement with distributed collaboration, simulation and data intensive computing

The End

10 Most Significant Innovations in Geographic Information Science

Kate Beard
Department of Spatial Information Science and Engineering
University of Maine

Metrics for significance

The innovation:
- Was widely adopted
- Lead to increased ease of use
- Lead to scientific breakthrough or benefits
- Improved data or information understanding

1). Specification of spatial data types: Object, object-relational databases

Why?
- Provided pathway for GIS to fully participates in the database world

2). Specification of spatial relations

Why?
- Ontologically important—codified concepts and terms
- Formalizes qualitative concepts for natural language processing
- Basis for spatial query language

Statistical

3). Conditional simulation

Why?
- Creates the basis for statistical analysis of geographic distributions

4). Local spatial statistics: local autocorrelation, geographically weighted regression, local cluster detection

Why?
- Geographically meaningful, computationally important in geosensor networks

User interface

5). Common interface icons; pan zoom, identify

Why?
- Widespread adoption, recognizability, ease of Use

6). Geographic Brushing, linked views

Why?
- Spatial exploratory power, linkage of attribute space to geographic space, statically space to geographic space, space to space

7). Standardization; common formats and specification for spatial data

Why?
- ISO standard—specifies how we expect spatial data to be documented
- Supports common expectations
- Promotes much broader use and ease of use

Visualization

8). Dorling cartograms

Why?
- Simple elegant solution to area equalization

9). Generalization as a constrained optimization problem

Why?
- Constraints operate locally

10). Google Earth

Why?
- Incorporates much of GIS innovation and thinking
- Popularizes simple analysis of geographic phenomena
- Encourages exploration in an easy to use format

20 Years of NCGIA

What are the ten most significant discoveries in GIScience?

Sara Irina Fabrikant, Department of Geography, University of Zurich

Sara polled her colleagues at the University of Zurich and presented the results

What counts as a Discovery?

- GIScience as an inherently interdisciplinary endeavor
    - Disciplines operating in various scientific paradigms
- GIScience as an enabler for discovering the world

Rephrased Questions:

> *What are (if any) significant "discoveries, contributions, outcomes, products" of the GIScience research community?*
>
> *In other words, do we know something now, or can we do something now or do we have something now that we could not have known/done/gotten without the existence of GIScience?*

Success Stories / Products

- 9-intersection model
- Map algebra
- Geostatistics
    - Handling of spatial autocorrelation
- Geolibrary
    - Geograp;hic information retrieval/spatial search
- Geography awareness of the masses
    - Global view effect, neogeography, VGI, LBS, etc.
- Geographic visualization
- Agent-based, spatio-temporal simulations/CA

Improved Understanding in . . .

- Spatial reasoning/cognition
    - Core spatial concepts: location, distance, region, network, etc.
    - Navigation, orientation, etc.
- Formalization/frameworks of fundamental spatial concepts in geography/spatial sciences (based on empirical research)
    - Tobler's First Law

- "what is a mountain", naïve geography, etc.
- Scale
- Vagueness
- Fields/objects
- Cartographic design principles

Increased awareness of . . .

- Representation (image, diagram, database, unstructured text)
- Taxonomies, social networks
- Semantics, social networks
- Time-space integration / dynamics (moving objects, etc.)

Most significant contribution . . .

- Bringing together various disciplines related with / interested in Geographic Information
- Conference series: SDH, GIScience, AGILE, COSIT, etc.
- Books: NATO series, etc.
- Journals: *Spatial Cognition and Computation*, *Geoinformatica*, etc.

Top ten most significant discoveries and innovations of GIScience

May Yuan, University of Oklahoma

In David Letterman style

10. Cyberinfrastructure: we started with money (DIME) and power (TIGER)
9. Two per family: field/object; raster/vector; geometry/attributes
8. Do you think space is complicated? Try space-time? Get me out of cells and make me an agent.
7. If we get closer, we will be more similar.
6. How long is Maine's coastline? It depends what's the meaning of "is" is.
5. Need higher r-square? No problems, just change scale.
4. Topology is hard, typology is harder. Not enough? Try ontology. How about semantic similarity
3. The certainty about space is uncertainty. Huh?
2. There is no positive relationship, there is no negative relationship, but there is geographically weighted relationship.
1. PPGIS, Mash-up, VGI, geography can't hide anymore.

1. **The duality of geographic space: raster and vector** are two basic frameworks to represent and analyze geographic space; The duality of geographic phenomena: fields and objects are two basic frameworks to conceptualize what constitutes geographic space
2. **Geospatial cyberinfrastructure**: census data, environmental data; combined strengths of CAD and RDBM
3. **Scale:** need a higher r-square? no problem. Just change the scale of analysis.
4**. Spatial autocorrelation**: if we get closer, we will be more similar.
5. **The certainty of spatial uncertainty**: We can never know it for sure the length of Maine's coastline. Spatial resolution

In More Detail

Infrastructure and Spatial Database

10. The seeds of cyberinfrastructure

- Digitization, data sharing, resource sharing: GBF, DIME, TIGER, census, CGIS
- automated cartography: algorithms and tools
- metadata, spatial data standards, and infrastructure: FGDC, NSDI, spatial linguistics, ontology, digital gazetteers

9. Spatial data:

- Combine strengths of CAD and RDBM
- Spatial data structures, spatial ordering schemes
- Formalizing topological relationships in databases

Representation and Visualization

8. Duality of space

- spatial conceptualization: fields and objects
- spatial representation: rasters and vectors
- spatial constructs: geometry and attributes

7. Complexity and dimensionality

- space, time, space-time, change, events, processes,
- dynamics (and narratives)
- geovisualization
- spatialization and visual analytics

Geographic Measurements and Analysis

6. Scale rules

- certainty of spatial uncertainty
- fractal dimension: how long is Maine's coastline?
- need a higher r-square? Change the scale of an analysis

5. From global to local:

- spatial autocorrelation
- spatial neighborhood
- LISA (local indicators of spatial association)
- GWR (geographically weighted regression)

GIS Modeling

4. Divide and conquer

- geographic themes, variables, and data layers
- spatial overlays
- map algebra
- dasymetric mapping

3. From aggregate to disaggregate

- computationalize time geography
- cellular automata
- agent-based modeling

Information Services

2. Location-based service and web service

- interactive on-line maps
- customized routing and navigation
- web GIS applications

1. Democratize geography

- ubiquitous spatial thinking and reasoning
- mash-up local knowledge and global perspectives
- PPGIS (public participation GIS)

Some Thoughts on the Future of GIScience

Luc Anselin
GeoDa Center
School of Geographical Sciences and School of Planning
Arizona State University

Introduction

- geospatial technology
- mainstreaming of spatial thinking
- example: spatial econometrics

Geospatial Technology

- ubiquitous GIS
- new computing paradigms
- geoinformatics

Spatial Thinking

- disappearance of disciplinary bounds
- mainstream sciences adopt spatial perspective
- daily practice adopts spatial perspective
  - drives demand for theory
  - how to deal with massive geospatial (space and space-time) information: methodological and computational needs
  - education and training
  - new modes: collaboratories, cyberinfrastructure

Spatial Econometrics

- from the fringe to the mainstream
- spatial aspects in applied work
- who are the drivers
- challenges: theory, methods, computation

Institutional Research

Will Craig

University of Minnesota

URISA's Research Agenda and the NCGIA

Craig, W.J. 1989. *URISA Journal*, 1(1), 7-16.

Social Concerns

- System Adoption
- Social and Legal Concerns
- Management Issues
- Economic Factors

Technology Concerns

- Database Development
- User Interface and
- Empowerment
- Software Critique

John S. Mayo, "Evolution of Information Technologies" in *Information Technology and Social Transformation*, National Academy of Engineering, National Academy Press, 1985.

> Depicting the Social Gate and the Technology Gate in the Pull of Society and the Push of Technology, Source: AT&T Bell Labs

NSGIC's Advocacy Agenda

- Imagery for the Nation (IFTN)
- Parcel Mapping
- Partnership Funding
- Transportation for the Nation (TFTN)
- Technology for the 21st Century
    - Broadband access
    - E-Government Reauthorization

University of Minnesota, geospatial.umn.edu

- 88 faculty and staff
- 29 units in 9 colleges / institutes
- 25 research centers

- 7 student labs expressly for GIS/geospatial use
- 40+ courses directly related to geospatial research
- 50+ courses indirectly related to geospatial topics
- 3 PhD programs
- 2 MS/MGIS programs
- 1 graduate minor
- 1 undergraduate minor

+ Facilities Management new “Enterprise System”

Craig’s Research Agenda

- Implement NRC reports
- 1:24,000 / 1:2400 gap
- GIS in an IT world
- Cost/benefit methodology
- Library of models
- University GIS centers

GIScience
or
GIEngineering+Sciences?

Werner Kuhn
Institute for Geoinformatics (ifgi)
University of Münster

Can there be a GIScience ?
Yes, if the following add up to a scientific core (which is not occupied by others, such as geography):

1. **The G in Information Science**, e.g., spatial data structures, spatial reasoning, geo-visualization?, economics of spatial information, legal and institu4onal aspects
2. **The I in Geo-Sciences**, e.g., geo-statistics, spatial analysis, geo-ontology, terrain analysis, simulation of spatial processes

1 Does information science have (or need) a spatial part?
This is the what's special about spatial question
Pro

- TFL and (very few) other laws
- Scale
- Field / Object
- Experientialism
- ...

Contra

- neo-geography: who cares
- OGC and W3C: spatial is normal
- Google: simplicity is key

2 Do geosciences pose common information handling challenges ?

Part of this is the research using GIS (RuGIS) aspect
Pro

- many GIScience questions arise from applications
- GIScience research results need to be evaluated in applications
- it helps a GIScientist to understand a geo-domain

Contra

- RuGIS is and should be different from GIScience
- GIScience has to pursue its own subject

Assessing the case

1. shaky case for G in IS
2. strong, but marginalized, case for I in GS
3. does this together warrant a GIScience ?

  - or does it miss an emergent property?
  - 20 years may be too early to tell
4. reducing my personal aspirations to GI engineering

- building useful representations of space
- but: playing important roles in other sciences (geography, computer science, cognitive sciences, ...)
- science is not about innovation, but understanding

Challenges

1. define GI engineering research paradigm(s) in addition to hypothesis-experiment
2. find ways to contribute (respectably) to the other sciences
3. should Vespucci be called an "initiative for the advancement of the sciences through GI"?
4. technological and social: ubiquitous computing, sensors, VGI, location tracking, SOA and cloud, Google, vendor monopoly, open source

Thanks especially to Andrew, David, Mike and many others at NCGIA, for creating a very stimulating intellectual environment

International Networking
Christian Freksa

Universität Bremen

Three Research Areas

- Reasoning
- Action
- Interaction

Reasoning

- Modeling human and external cognition
- Spatial assistance for experts and lay people
- Human navigation in complex environments
- Qualitative spatio-temporal reasoning
- Spatial action planning

Action

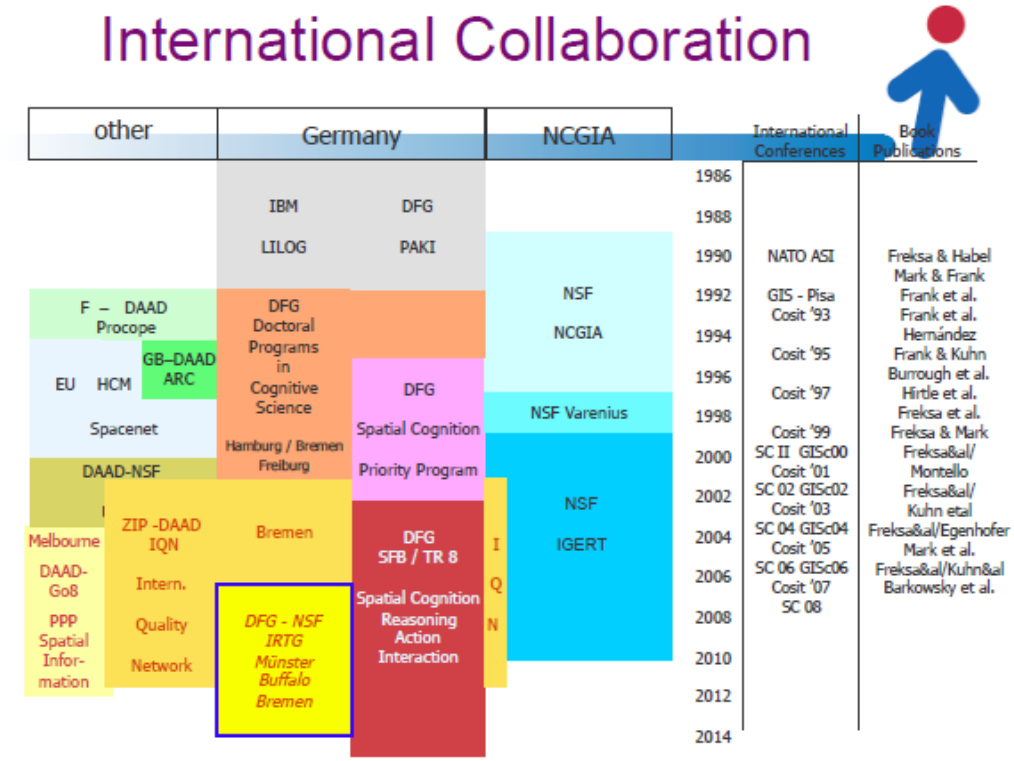
- Navigation in autonomous artificial systems
- Exploration, map learning, and route planning
- Coordinated multi-agent interaction
- Perception-based navigation in humans and robots
- 3D visualization for complex real-time tasks

Interaction

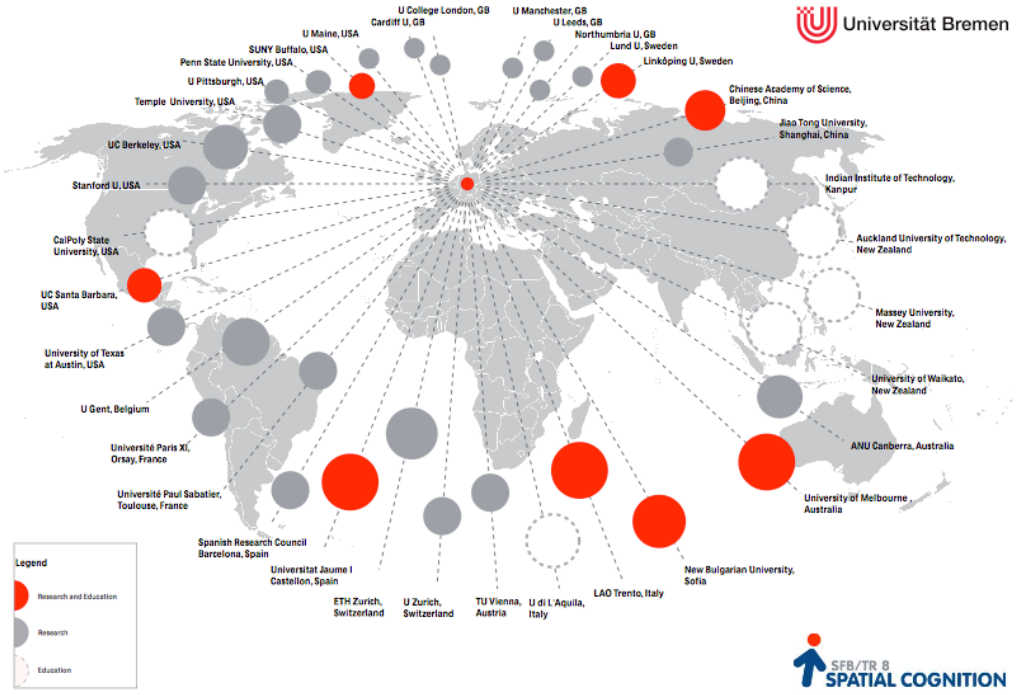
- Intelligent communication in language and maps
- Integration of spatial and linguistic capabilities
- Ontology-based models for natural language interaction
- Adaptive wayfinding assistance systems
- 'Cognitively adequate' human-robot interaction

The Universitat Bremen and the Albert-Ludwigs Universitat Freiburg research collaboration on spatial cognition

- + 50 researchers in 15 projects
- Start: January 2003
- Duration
  - 4+4 years funded
  - 12 years planned
- DFG-Funding
  - 6.6 M€ (2003-2006)
  - 10.5 M€ (2007-2010)
- Coordination
  - Christian Freksa (coordinator, Bremen)
  - Bernhard Nebel (deputy coord., Freiburg)



IQN—International Quality Network on Spatial Cognition



Mechanisms for Research: Centres, Networks, Collaboratories

Mike Batty

University College London

It was twenty years ago today . . .

. . . . . ***Sgt. Pepper taught the band to play . . . . .***

51 and a bit years ago, not quite today,

Mike (Batty) was in the same class at the Quarry Bank High School for Boys as John.

John Horton Conway was in the same class at the Liverpool Institute High School for Boys as Paul.

Various of us in NCGIA starting with Waldo Tobler began to work on cellular models of spatial systems inspired by John Conway's ***Game of Life***

Mike Worboys also wrote his thesis on one of Conway's finite groups. It is a small world after all.

Key "cells to cities" into Google Scholar and it is Keith Clarke's work that gets the most hits – more NCGIA

It's All About Networks

Networks are about linking people to places to ideas to outputs and to each other etc.

Five Questions

- How Do We Build Research, in GI Science, in Universities, in Teams? As Networks?
- What Should We Research in this Broad Domain?
- Where Should We Do This Research?
- How Long Should a 'Good Idea' Last?
- How Should We Judge Success?

How Do We Build Research, in GI Science, in Universities, in Teams?

1. Different Types of Centre: The RRLs, NCGIA, CASA
2. Top Down versus Bottom Up
3. Institutional Context
4. Networks: National and International

What Should We Research in this Broad Domain?

1. The Institutional Structure: how organised, how corporate?

2. The Expertise
3. My Own Context at UCL: where we focus on cities and the built environment because of the critical mass there in terms of departments – architecture/planning, geography, archaeology, geomatics and transport
4. What We Should Not Research

Where Should You Do This Research?

1. Location, Location, Location
2. Networks: The Success of the NCGIA Three Centre Model combined with the Initiative Structure
3. But this relates to institutional structure and the funding agencies. You could not do this in many places, for example in the UK where research grants have to employ new full time people, not just post-docs and where faculty do not get paid from them as such

How Long Should a Good Idea Last?

1. If I look at the centres that I know in the UK, few have lasted longer than 30 years
2. NCGIA has morphed rather cleverly and this perhaps is the trick
3. How Long Will NCGIA Last? The Next Big Thing, or the Next, Next Big Thing.
4. Centres need renewal from within and without and the fashions change

How Should We Judge Success?

1. Longevity
2. Outputs
3. PhDs
4. But it is impossible to figure out real success because there are no counterfactuals and ideas are contingent on the times and places we live in, that's pretty relativistic and I know doesn't appeal to many.

And to finish

It's wonderful to be here,
It's certainly a thrill.
You're such a lovely audience,
We'd like to take you home with us,
We'd love to take you home.
I don't really want to stop the show,
. . . . . .