# The GIScience Research Agenda: Inventory and Prospect

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# Outline

- Early beginnings, some key early events
- Consensus-building
- Varenius
- Moonshots and grand challenges
- The laws of GIScience

# 1985

- GIS well established
  - a nascent software industry
  - texts
    - Burrough, *Principles of GIS*
    - MacDougall, *Computer Programming for Spatial Problems*
  - a scattering of courses
    - UWO circa 1976
  - various things could be achieved by computer processing of spatial data
    - measurement
    - production and editing
    - map-making

# …but some big questions

- What to teach?
  - training in software?
  - education in principles?
    - what were those principles?
- What to research?
  - algorithms and data structures to do it "faster, better, cheaper"

# CAG 1985 Trois Rivieres

- Session on teaching GIS
  - Poiker, Maher, Goodchild, …
  - "GIS in Undergraduate Geography: A Contemporary Dilemma"
    - what are the foundations for an education in GIS?
    - what are the basic principles?
    - *The Operational Geographer* 8: 34-38

# The analogy to statistics

- A branch of mathematics dating from well before the advent of computers or calculators
  - theory, numerical analysis predated computation
- Where is the equivalent theoretical framework for GIS?
  - computation predated the development of theory
- GIS is to *x* as the statistical packages are to statistics
  - what is *x*?
- "A spatial analytic perspective on GIS", *IJGIS* 1: 327-334, 1988

# The NCGIA research agenda

- Discussions initiated by Ron Abler, 1986-1987
- The 1987 solicitation
  1. Spatial analysis and spatial statistics
  2. Languages of spatial relations
  3. Visualization
  4. Artificial intelligence and expert systems
  5. Social and institutional issues

# The winning bid

- A consortium of UC Santa Barbara, SUNY Buffalo, University of Maine
- David Simonett as PI
  - a background in remote sensing
  - is remote sensing a set of techniques, or are there basic principles?

# SDH, Zurich, August 1990

- Goodchild keynote
  - why "spatial data handling"?
  - are we the UPS of GIS?
- "Spatial information science"
  - NCGIA as a multidisciplinary enterprise
  - what disciplines can contribute to a basic science of geographic information?
    - spatial statistics
    - spatial databases
    - computational geometry
    - spatial cognition
  - "Geographic information science", *IJGIS* 6(1): 31-45 (1992)

# Consensus-building: UCGIS

- An organization to represent the growing GIScience community
  - building the political base
- Opening UCGIS Assembly, Columbus, June 1996
- What is the research agenda of GIScience?
  - white papers, discussion, vote by institutional members

# The UCGIS research agenda (1996, revised 1998)

- Cognition
- Extensions to representation
- Acquisition and integration
- Distributed and mobile computing
- Interoperability
- Scale
- Uncertainty
- Spatial analysis
- Future of the spatial information infrastructure
- GIS and society

# Conflicting motivations

- A taxonomy of the field
- A set of priorities
  - given societal needs and funding opportunities
- Two lists
  - long-term
  - short-term

# Long-term UCGIS research challenges, 2002

- Spatial ontologies
- Geographic representation
- Spatial data acquisition and integration
- Scale
- Spatial cognition
- Visualization
- Space and space/time analysis and modeling
- Uncertainty in geographic information
- GIS and society
- Geographic information engineering

# Short-term UCGIS research priorities, 2002

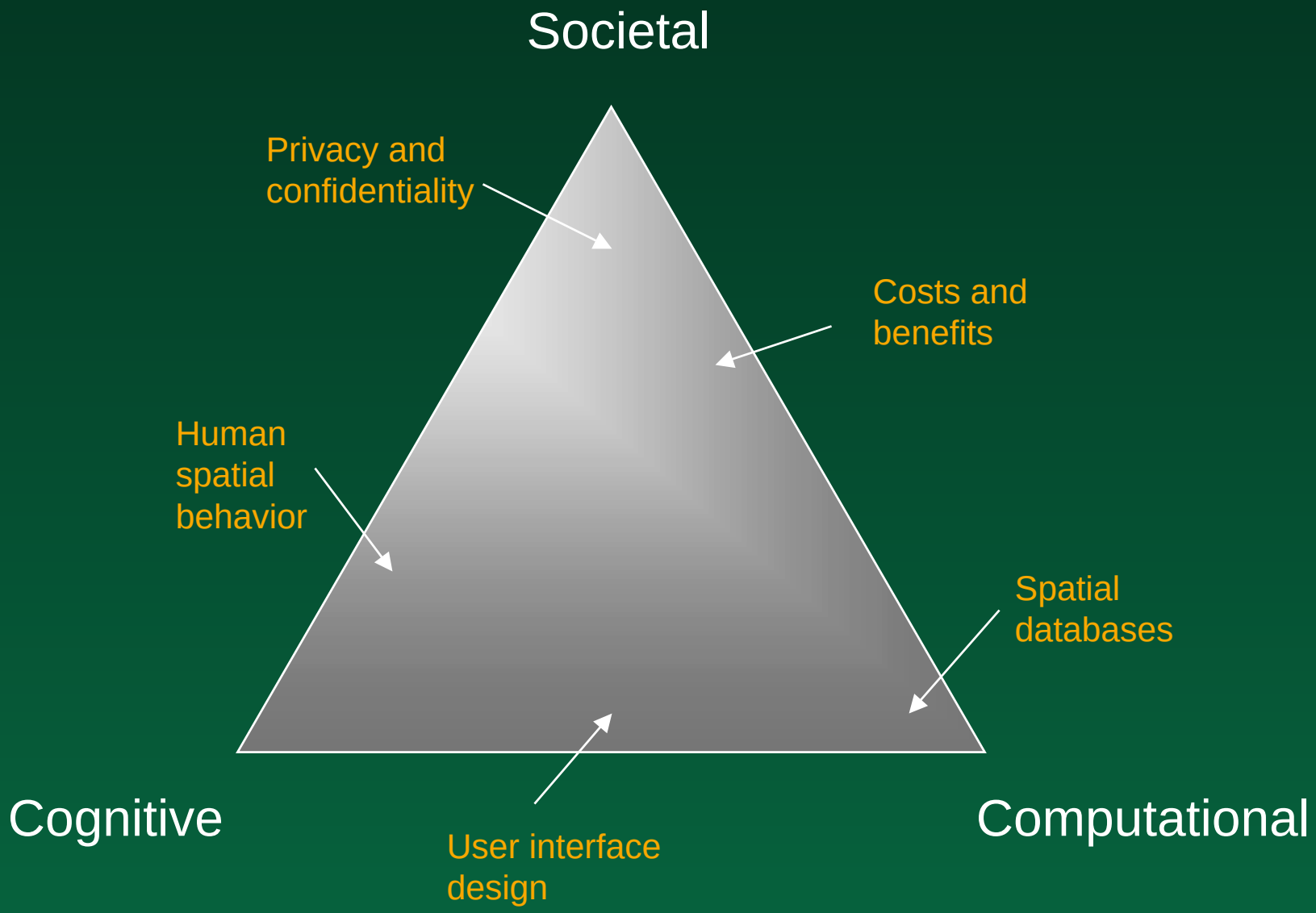
- GIS and decision making
- Location-based services
- Social implications of LBS
- Identification of spatial clusters
- Geospatial semantic web
- Incorporating remotely sensed data and information in GIS
- Geographic information resource management
- Emergency data acquisition and analysis
- Gradation and indeterminate boundaries
- Geographic information security
- Geospatial data fusion
- Institutional aspects of spatial data infrastructures
- Geographic information partnering
- Geocomputation
- Global representation and modeling
- Spatialization
- Pervasive computing
- Geographic data mining and knowledge discovery
- Dynamic modeling

# Other agendas

- Socially focused
  - Rhind 1988
- Computationally focused
  - NSF Digital Government Initiative
    - National Center for Supercomputer Applications, OGC
  - National Research Council Computer Science and Telecommunications Board
    - "IT Roadmap for a Geospatial Future", 2003

# Varenius: a top-down perspective

- NCGIA funded by NSF as an 8-year project, 1988-1996
- Varenius: NCGIA's Project to Advance GIScience
  - 1996-1999
- A three-vertex research agenda
  - the cognitive vertex
    - human-centric
  - the computational vertex
    - computer science
  - the societal vertex
    - social science


Societal
Privacy and confidentiality
Costs and benefits
Human spatial behavior
Spatial databases
Cognitive
User interface design
Computational

# Moonshots and grand challenges

- Is there a single phrase that can motivate GIScience, capture popular imagination?
  - "putting a man on the moon in this decade"
  - "mapping the human genome"
  - "completing the web of life"
- Are there grand challenges at the core of GIScience?
  - research problems that are unusually difficult
  - that if solved will convey extraordinary benefits
- Is there a Hubble Telescope of GIScience?
  - a massive investment that will benefit the field as a whole?

# A 1998 moonshot: Digital Earth

- A virtual environment that would present all that is known about the Earth to its users
  - centered on a user-defined location
  - spatial resolution from 10km to 1m
  - past, present, and future
  - dynamic simulation of processes
  - 3D visualization
- UCGIS congressional breakfast
  - achieve by 2005

# DE today

- Evolving efforts
  - NASA's Virtual Earth
  - the USGS's Geospatial One-Stop
  - ISDE III in Brno in September
- Technical feasibility
  - broadband, enhanced PC graphics
  - Geofusion, ArcGlobe
  - www.earthviewer.com
- Research issues
  - rendering abstract variables
  - integrating dynamic simulation

# Some grand challenges

- Report to NSF: "GIScience: Critical Issues in an Emerging Cross-Disciplinary Research Domain"
  - D.M. Mark, editor, *URISA Journal* 12(1): 45-54 (2000)

# Challenges 1

- Representation
  - infinite complexity in the real world
  - spatio-temporal continuity
  - an infinity of themes
  - must be useful, efficient
- The digital computer
  - finite capacity
  - binary alphabet
- *To find ways to express the infinite complexity of the geographical world in the binary alphabet and limited capacity of a digital computer*
  - and dynamism

# Challenges 2

- Uncertainty
  - no representation can be complete
  - what the data indicate about the world
  - what the user believes the data indicate about the world
- Scientific measurement model
  - the database as one sample from an error distribution
  - not decomposable because of very strong spatial dependencies
- *To find ways of summarizing, modeling, and visualizing the differences between a digital representation and real phenomena*

# Challenges 3

- Cognition
  - cognitive concepts of geographic space
  - instantiated in geographic information
  - Piaget etc.
- GIS technology
  - learned in Upper Division or Graduate School
  - binary representations, computational concepts
  - the Spatially Aware Professional
- *To achieve smooth transition between cognitive and computational representations and manipulations of geographic information*

# Challenges 4

- Simulation
  - *The Fractal Geometry of Nature* (Mandelbrot)
  - the Blair election, Hollywood location scouts
  - terrain, forests, urban landscapes
  - the Turing test of geographic models
  - artist's rendering of scenarios
  - generic data for testing
  - incredibly difficult
- *To create simulations of geographic phenomena in a digital computer that are indistinguishable from their real counterparts*

# The laws of GIScience

- The success of a discipline that studies real phenomena is expressed in the principles it discovers
  - its empirical laws
- GIScience studies the real world and its digital representation
- Are there statements that are *generally* true about *all* geographic information?
- Such statements can guide the construction of geographic information technologies
  - the choice of data models, indexing schemes, algorithms, etc.

# Some candidate laws

- Tobler's First Law of Geography
  - positive spatial dependence
- A law of spatial heterogeneity
  - the Earth's surface is non-stationary
- A fractal law
  - additional detail is revealed at a predictable rate
- An uncertainty law
  - any representation must be incomplete

# Elements of a GIScience future

- Ways of organizing the discipline's content
  - what are the component parts of GIScience?
- What can GIScience do for society?
  - what will get funded?
- A moonshot
  - a long-distance target that can motivate the discipline
- Grand challenges
  - persistent themes and hard problems
- The search for empirical laws
  - what can we say about geographic information?

# Beyond GIScience

- What can we say about other spaces?
  - can GIS be used to analyze their content?
  - what can we learn from people who study other spaces?
  - do the laws of GIScience apply to other spaces?

# GIScience and information science

- GIScience as the study of a particular class of information
- Information that is decomposable into atoms of the form <**x**,**z**>
  - where **x** is a location in space(-time)
  - and **z** is a set of general properties associated with that location
- This class is particularly well-defined
  - and therefore fundamental progress in the parent discipline can be expected from the study of GIScience

# GIScience and geography

- GIScience suggests an emphasis on form
  - GIScience is to geographic science as form is to process
    - but form is caused by process
    - and information about process is often more valuable than information about form
    - and geocomputation and GIScience are strongly related
  - unlike GI, process knowledge is abstracted from space and time
    - but so are the structures and algorithms of GIScience
  - perhaps GIScience is to geography as digital is to analog
    - it's too soon to tell