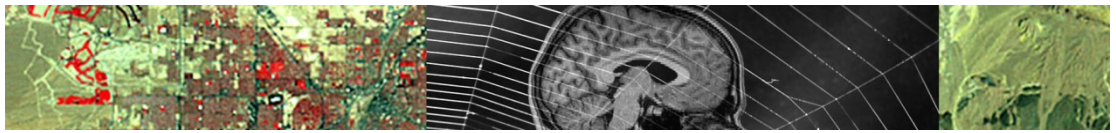
spatial@ucsb
perspectives for teaching and research

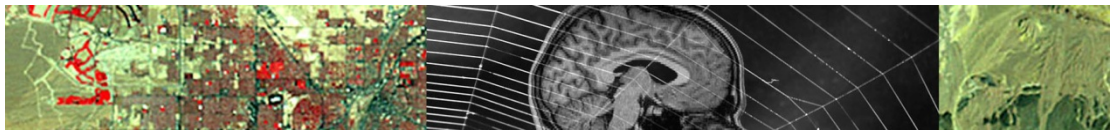
Twenty Years of Progress: GIScience in 2010

Michael F. Goodchild
University of California
Santa Barbara



Outline

- The beginnings: GIScience in 1990
- Major accomplishments
  - research
  - institutional
- The future

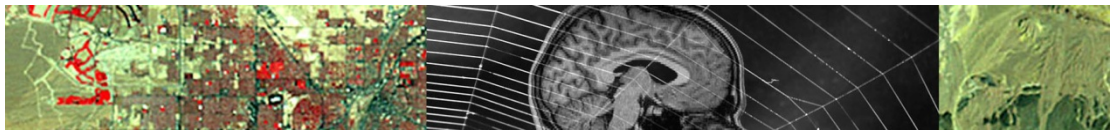


SDH 4, Zürich 1990

- Spatial information science

"What, after all, is spatial data handling? It may describe what we do, but it gives no sense of why we do it. It suggests that spatial data is (*sic*) somehow difficult to handle, but will that always be so? It suggests a level of detachment from the data themselves, as if the USGS were to send out tapes labeled with the generic warning "handle with difficulty"…We are concerned with much more than the mere handling and processing of data. We are more than the UPS of GIS."

(*Proceedings* p.3)

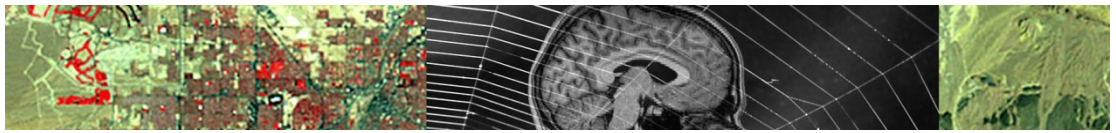


GIScience

- Second European GIS Conference 1991
  - fleshes out the research agenda
  - reference to “geographic” information science

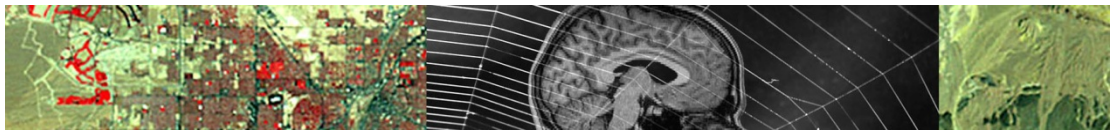
“Rapid progress was made on algorithms and data structures in the 1970s and 1980s, but many of the hard problems of data modeling, error modeling, integration of spatial analysis, and institutional and managerial issues remain. Some of these may be unsolvable – for example, there may simply be no generalities to be discovered (about) the process of adoption of GIS by government agencies, however easy it may be to pose the research question.”

(*Proceedings* pp. 342-350)



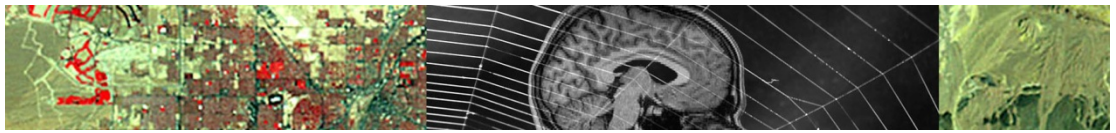
G or S?

- A play on the acronym
  - systems, science, services, studies
- Would discoveries about geographic space apply to all spaces?
- (1992) Geographical information science. *International Journal of Geographical Information Systems* 6(1): 31–45.



The agenda in 1990

- "The content of GIScience" (*IJGIS* 1992)
  - Data collection and measurement
  - Data capture
  - Spatial statistics
  - Data modeling and theories of spatial data
  - Data structures, algorithms and processes
  - Display
  - Analytical tools
  - Institutional, managerial, and ethical issues



Other lists

- NCGIA research agenda (*IJGIS* 1989)
- UCGIS research agendas (from 1997)
- Tests of inclusio
  - problem is n
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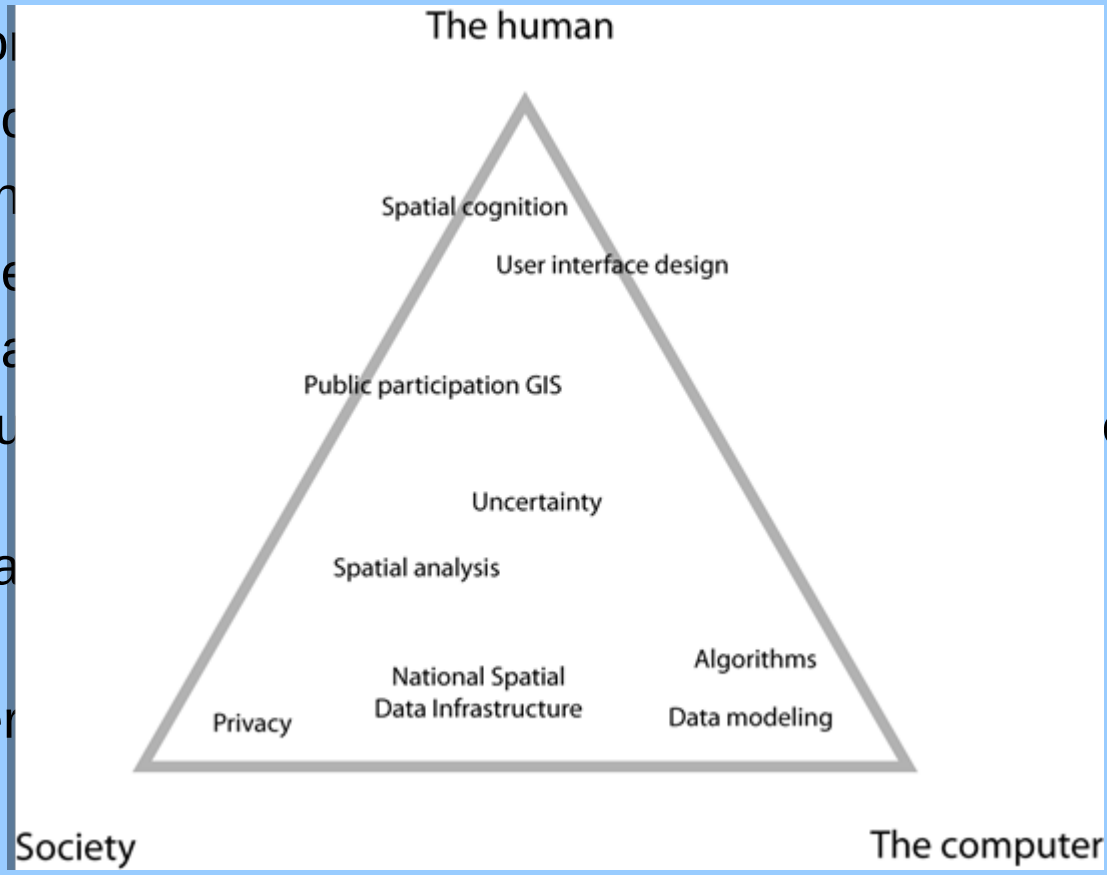
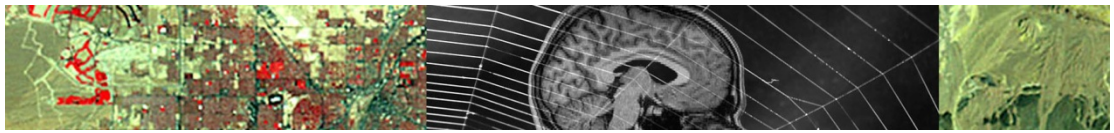
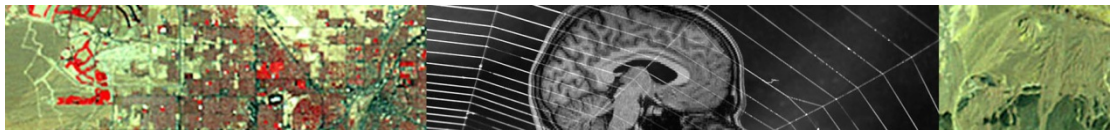
  - society





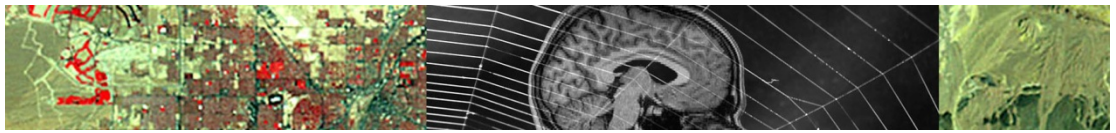
Definitions of GIScience

- David Mark in *Foundations of Geographic Information Science*, Taylor and Francis, 2003
  - "the development and use of theories, methods, and data for understanding geographic processes, relationships and patterns" (UCGIS, 2002)
  - "the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems" (Mark, 2000)



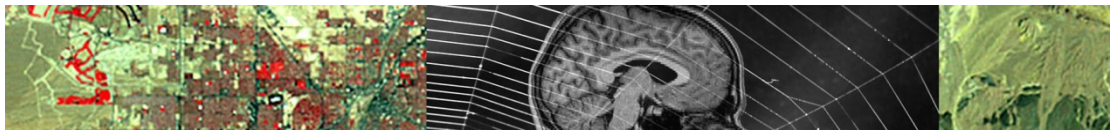
Major accomplishments in research

- International Symposium on Geographic Information Science
  - 20th anniversary of the funding of NCGIA
  - Santa Barbara, Dec 11-12, 2008
  - 49 participants
  - http://ncgia.ucsb.edu/projects/isgis/
- Ten most significant discoveries?
  - can GIScience be empirical?



Kate Beard, University of Maine

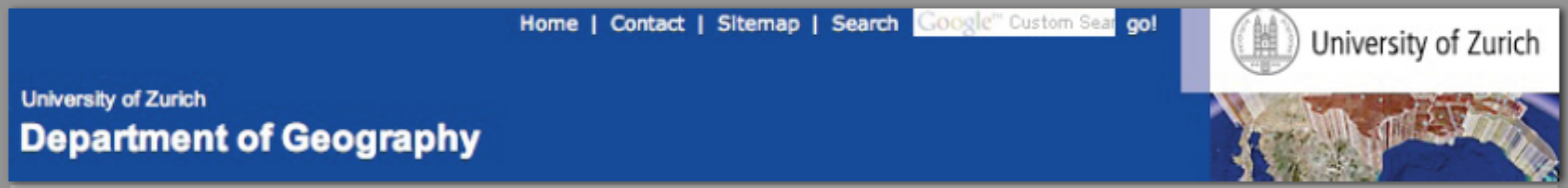
- Specification of spatial data types: object and object-relational databases
- Specification of spatial relations
- Conditional simulation
- Local spatial statistics: local autocorrelation, GWR
- User interface
- Geographic brushing
- Standardization: common formats, specifications
- Dorling cartograms
- Generalization as constrained optimization
- Google Earth



Marc Armstrong, University of Iowa

- GIScience is transformational
  - from map to machine
  - biggest discovery is GIScience itself
- Abstraction/theory
- Transformation
- Topological concepts
- Hierarchical data structures
- Ontologies
- Geocoding
- Overlay and other manipulations
- Local spatial analysis

ACCORDING TO THE UZH GISCIENCE CENTER...



- Pia Bereuter
- Dirk Burghardt
- Arzu Çöltekin
- Stefano De Sabbata
- Somayeh Dodge
- Sara Fabrikant
- Martin Lacayo
- Anna-Katharina Lautenschütz
- Patrick Lüscher
- Ross Purves
- Tumasch Reichenbacher
- Ralph Straumann
- Martin Tomko
- Ramya Venkateswaran
- Rob Weibel
- Jan Wilkening

WHAT COUNTS AS A DISCOVERY ?

- GIScience as an inherently interdisciplinary endeavor
  - disciplines operating with various scientific paradigms
- GIScience as an enabler for discovering the world?

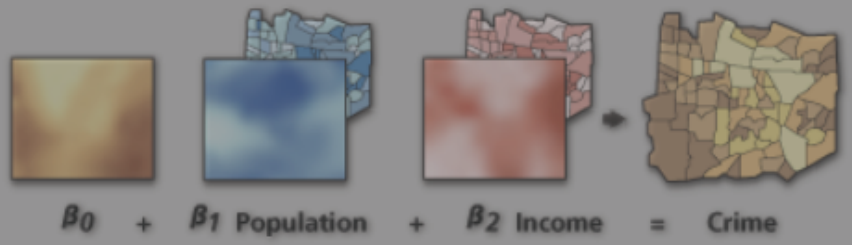
rephrased questions:

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
  - geographic information retrieval/spatial search
- geography awareness for the masses
  - globe viewer effect, neogeography, VGI, LBS, etc.
- geographic visualization
- agent-based, spatio-temporal simulations/CA



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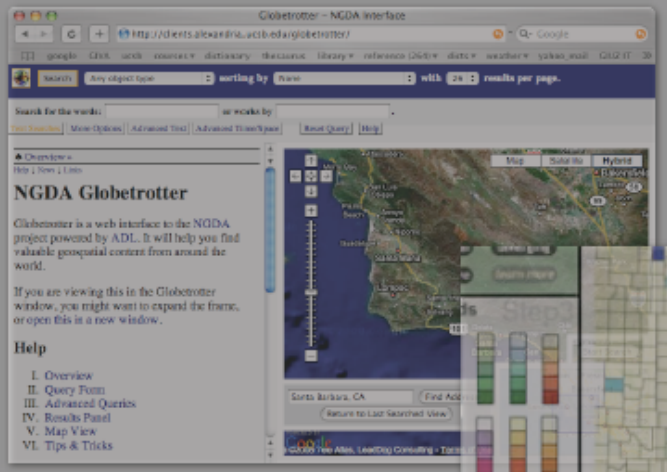

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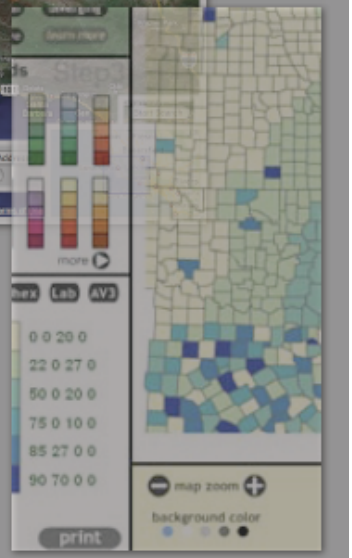

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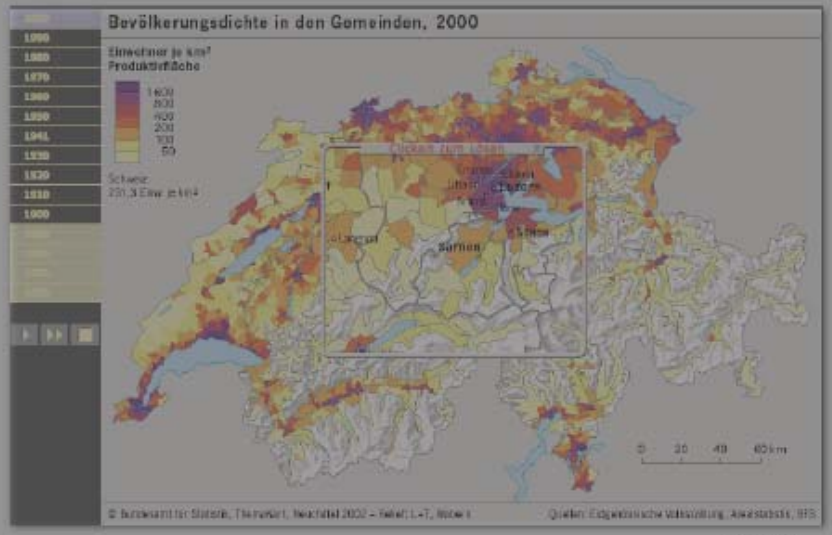
IMPROVED UNDERSTANDING IN...

- 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)
  - TFL
  - "what is a mountain", naïve geography, etc.
  - scale
  - vagueness
  - fields/objects
  - cartographic design principles



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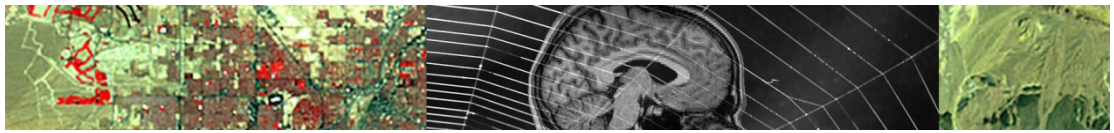
INCREASED AWARENESS OF...

- representation (image, diagram, database, unstructured text)
- taxonomies, ontologies
- semantics, social networks
- time-space integration / dynamics (moving objects, etc.)


It was 20 years ago …
NCGIA
BEATLES



Classics from IJGIS ed. Fisher (2007)

- 19 prominent articles based on citation
  - all basic research, one per researcher
  - even distribution over 20 years

Openshaw, Charlton, Wymer, Craft: A Mark I Geographical Analysis Machine for the Automated Analysis of Point Data Sets (1987)

Brassel and Weibel: A Review and Conceptual Framework of Automated Map Generalization (1988)

Heuvelink, Burrough, Stein: Propagation of Errors in Spatial Modelling with GIS (1989)

Skidmore: A Comparison of Techniques for Calculating Gradient and Aspect from a Gridded Digital Elevation Model (1989)

Worboys, Hearnshaw, Maguire: Object-Oriented Data Modelling for Spatial Databases (1990)

Egenhofer and Franzosa: Point-Set Topological Spatial Relations (1991)

Miller: Modelling Accessibility Using Space-Time Prism Concepts within Geographical Information Systems (1991)

Goodchild: Geographical Information Science (1992)

Fisher: Algorithm and Implementation Uncertainty in Viewshed Analysis (1993)

Raper and Livingstone: Development of a Geomorphological Spatial Model Using Object-Oriented Design (1995)

Jankowski: Integrating Geographical Information Systems and Multiple Criteria Decision-Making Methods (1995)

Fotheringham, Charlton, Brunsdon: The Geography of Parameter Space: An Investigation of Spatial Non-Stationarity (1996)

Frank: Qualitative Spatial Reasoning: Cardinal Directions as an Example (1996)

Kiiveri: Assessing, Representing, and Transmitting Positional Uncertainty in Maps (1997)

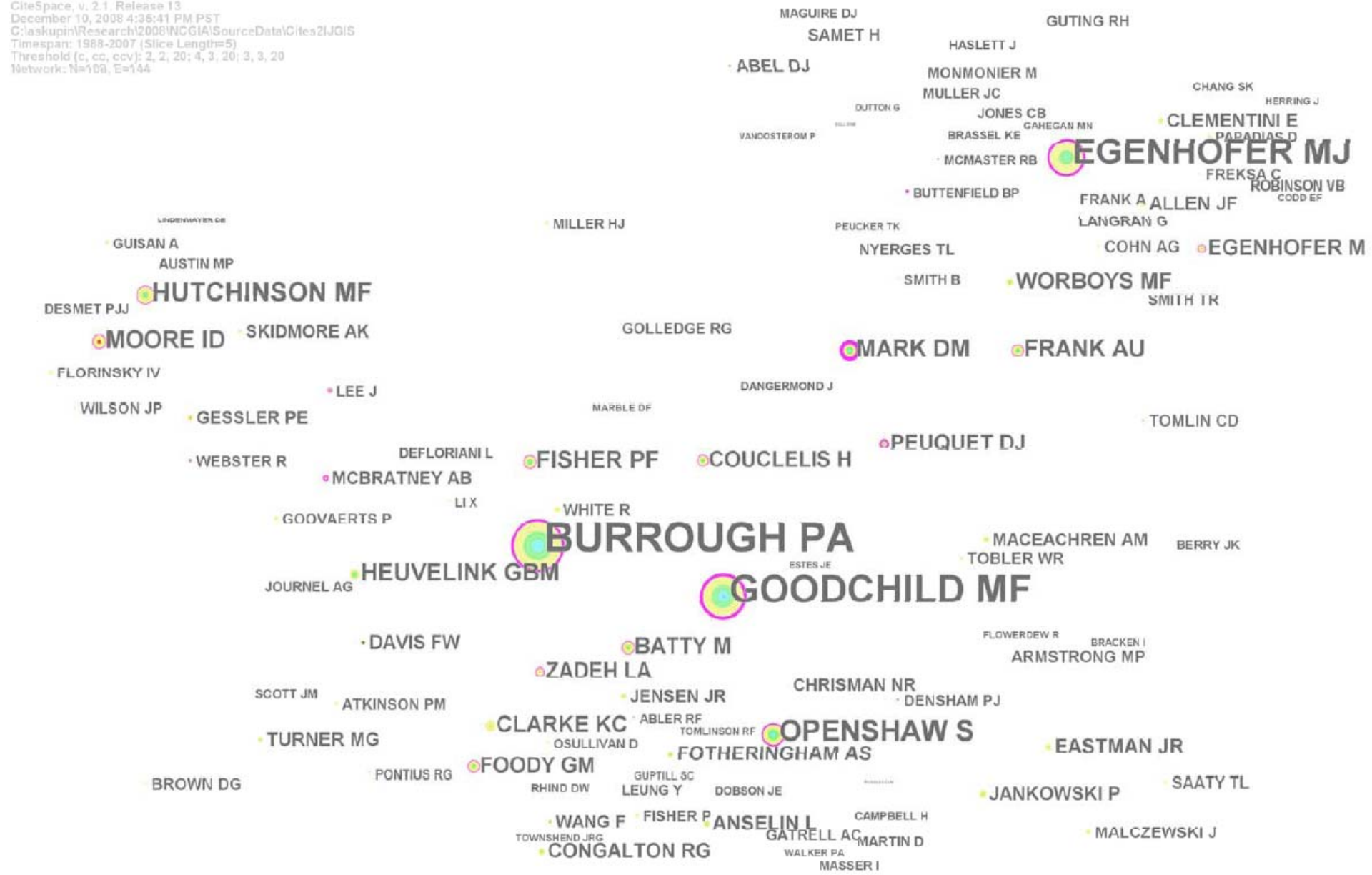
Clarke and Gaydos: Loose-Coupling a Cellular Automaton Model and GIS: Long-Term Urban Growth Prediction for San Francisco and Washington/Baltimore (1998)

Bishr: Overcoming the Semantic and Other Barriers to GIS Interoperability (1998)

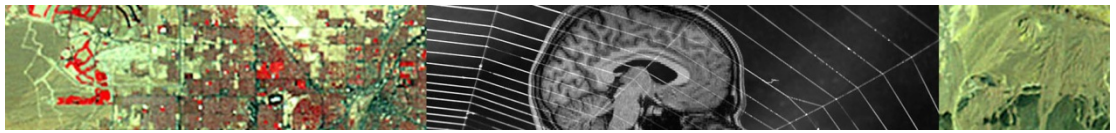
Andrienko and Andrienko: Interactive Maps for Visual Data Exploration (1999)

Smith and Mark: Geographical Categories: An Ontological Investigation (2001)

Llobera: Extending GIS-Based Visual Analysis: The Concept of Visualscapes (2003)

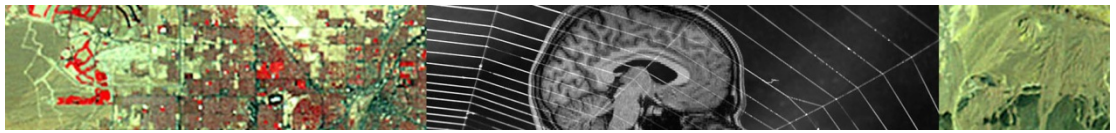


Andre Skupin, San Diego State University



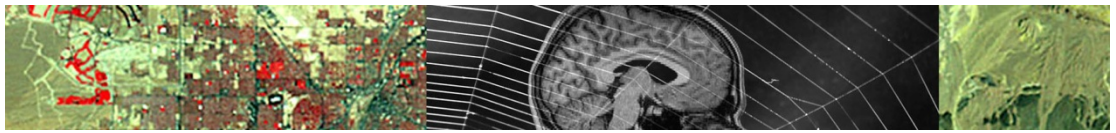
My own (highly subjective) list

- Theories of representation
  - discrete objects and continuous fields
  - object fields, metamaps
  - unification
- Models of uncertainty
  - error propagation
  - downscaling
- Principles of spatial cognition
- Theories of the geographic world
  - spatial dependence, spatial heterogeneity



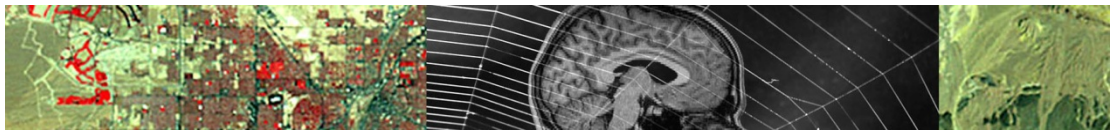
Institutional accomplishments

- Journals and articles
  - *IJGIS*, *CaGIS*, *J GISciences*…
- Conferences and societies
- Books and curricula
- 4 members of the US National Academy of Sciences
- 4 members of the Royal Society



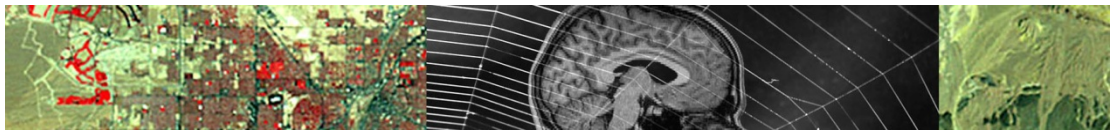
What of the future?

- Max Egenhofer's list for 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



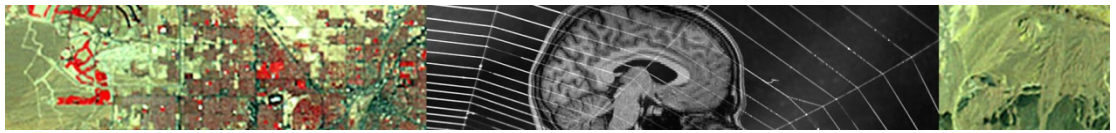
Future prospects

- Knowing where everything is (at all times)
  - every mobile phone
  - every vehicle
  - every farm animal
  - every item in a store
  - every construction beam
  - every asset for emergency response
  - every victim of a disaster



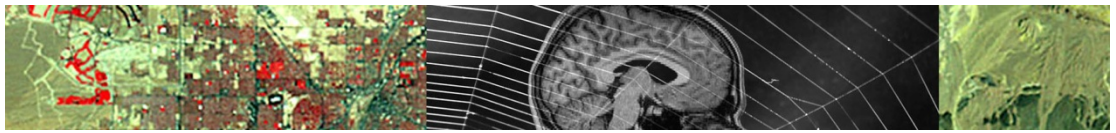
The role of the citizen

- Placenames, streets, social characteristics
- Early notification of change
- Early reports of damage from a disaster
- Both producer and consumer of geographic information
- The local expert



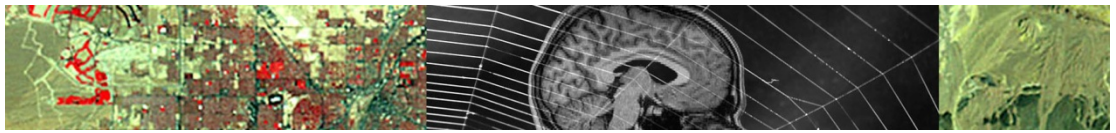
A technology of dynamics

- Real-time, continuous monitoring
- The state of the world at all times
  - the state of the transportation network
  - the state of human health
  - the state of the environment
- Sensor networks
  - static
  - carried on moving objects
  - humans as sensors



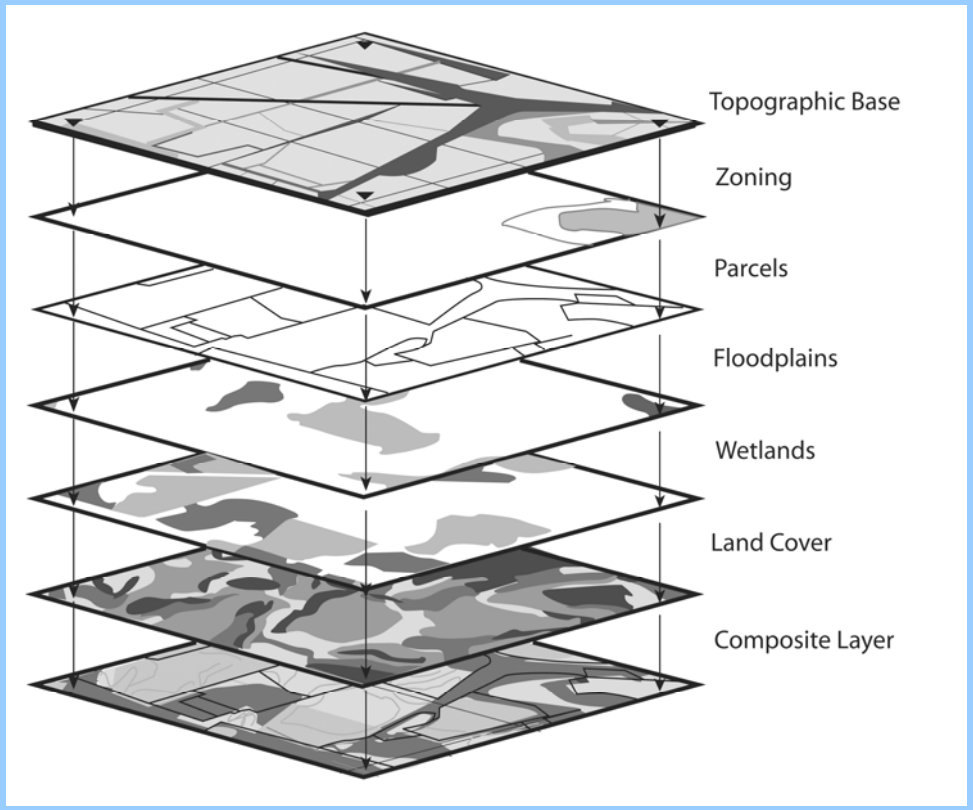
The third (and fourth) dimension

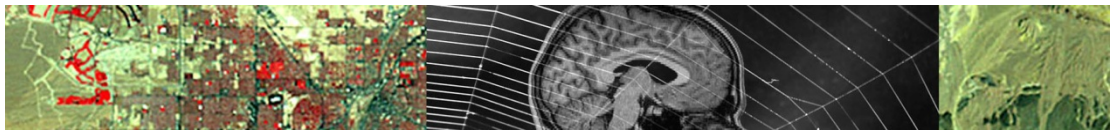
- The third spatial dimension
  - data acquisition
  - positioning
- The conceptual problem
  - the map as metaphor
- The attribute dimension



Location as common key

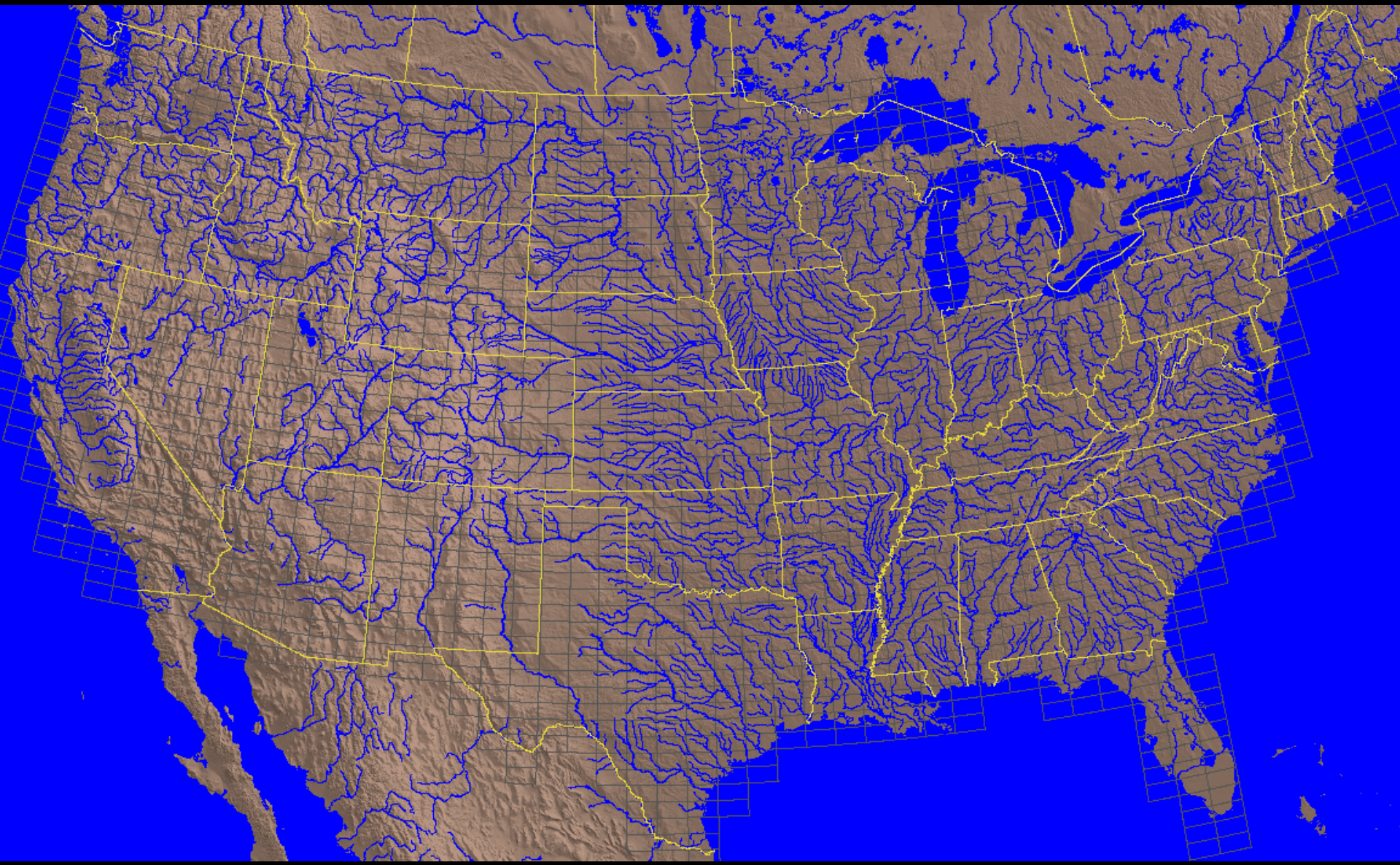
- The stack of layers

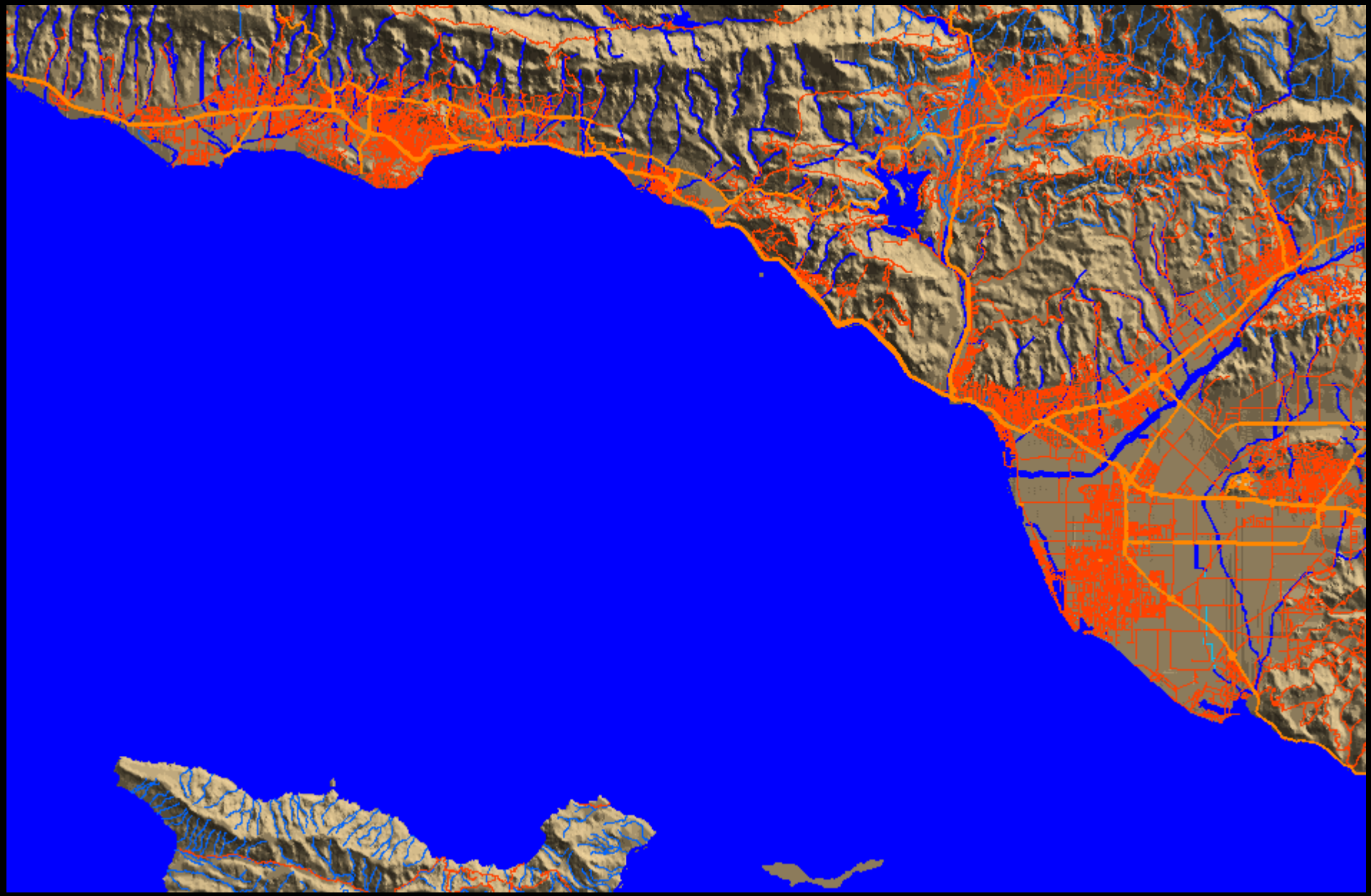


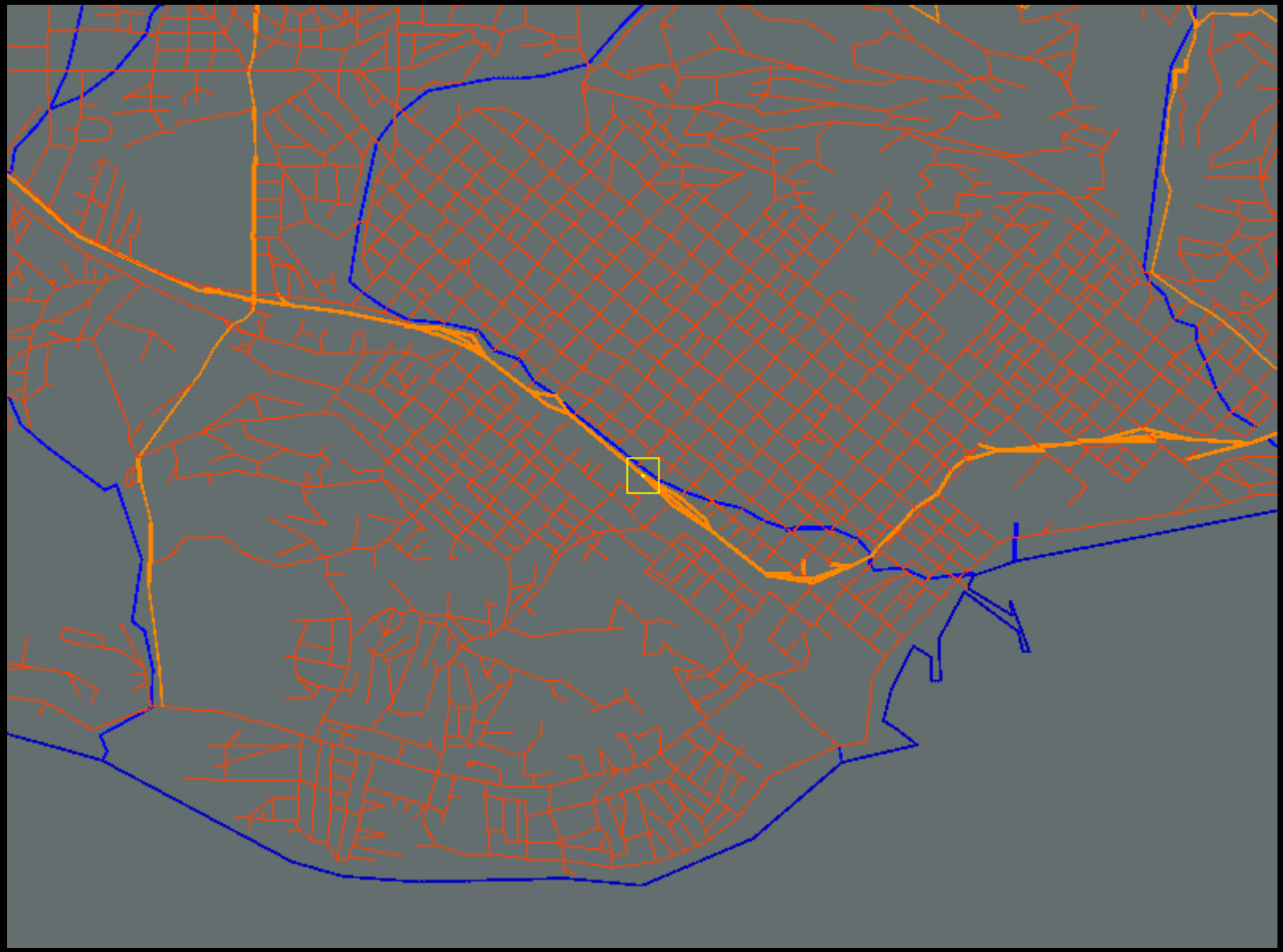


But in reality…

- Spatial databases are organized as layers
  - horizontal integration not “vertical”
  - property *z* about all places
  - rather than all properties about location **x**
    - “tell me everything about location **x**”
  - overlay must be invoked explicitly
    - graphical overlay or topological overlay
  - many mashups are merely graphical overlay
    - a *visual* spatial join







That location is:

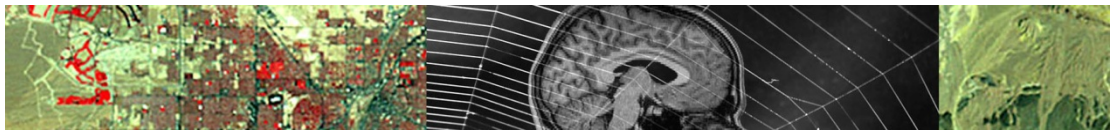
Latitude/Longitude 34.4176°N, 119.7092°W
The legal description is San Bernardino T4N,R27W,sec21 CA
UTM zone 11 (X,Y) 251011, 3811790
Note: the pixel size at that location is 99 by 87 m.

The elevation is 59 m (193 ft)
The gradient is: 2.5 percent
The aspect direction is: 345.8 degrees or N
The local roughness is: 1.3 or average
The location as decimal degrees (X,Y;Z) = -119.7092, 34.4176; 59 m

The hydrologic unit code is 18060009 , the Omernik ecoregion number is 8

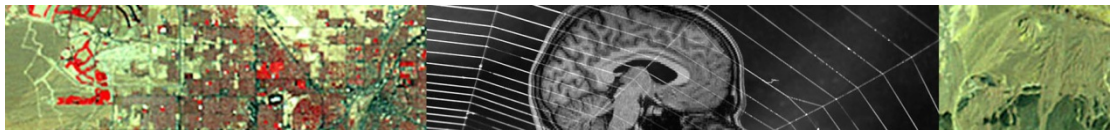
Nearby named places (in order by distance)

1. Wilson School; California: Santa Barbara Co. -119.7096, 34.4192 at a distance of 180 m
2. Santa Barbara; California: Santa Barbara Co. -119.6982, 34.4208, (50 ft) at a distance of 1072 m
3. Harding School; California: Santa Barbara Co. -119.7213, 34.4164 at a distance of 1121 m
4. Lincoln School; California: Santa Barbara Co. -119.6963, 34.4186, (40 ft) at a distance of 1191 m
5. Alameda Plaza; California: Santa Barbara Co. -119.7052, 34.4281 at a distance of 1220 m
6. Santa Barbara Junior College; California: Santa Barbara Co. -119.6968, 34.4222 at a distance of 1249 m
7. Honda Valley head; -119.7185, 34.4092 at a distance of 1266 m
8. Lincoln School; California: Santa Barbara Co. -119.6949, 34.4194 at a distance of 1330 m
9. McKinley School; California: Santa Barbara Co. -119.7010, 34.4075 at a distance of 1352 m
10. Lavigia Hill; California: Santa Barbara Co. -119.7152, 34.4047, (459 ft) at a distance of 1536 m



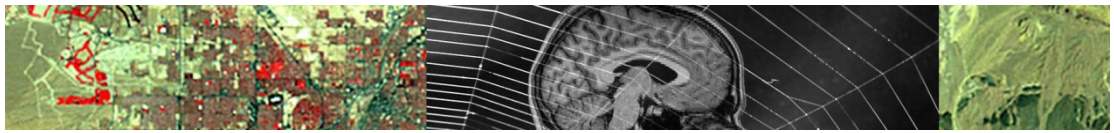
The spatial join

- Using location as a common key to link tables
- All location references are subject to uncertainty
  - measurement error
  - vagueness in feature identification
  - indeterminate limits
- The *probabilistic* join



The challenge of education

- As the technology becomes easier to use
  - as everyone utilizes geospatial technology
- What does *everyone* need to know?
- Critical spatial thinking
  - an understanding of the fundamental concepts behind the technology
- What characterizes a spatial thinker?



A call for participation

- Technology will continue to advance and pose interesting and challenging research questions
- The domain of geographic information science is well defined and bounded
- Comparisons with other spaces will stimulate creative thinking in GIScience
- Much has been accomplished, but much more remains to be discovered and developed