Visualization

Lecture Eleven

Forms of Visualization

- Visualization as a means of data exploration
- Visualization for Analysis
- Visual Representations & Graphic Display

Why Visualization?

- The basic belief that 'seeing' is a good way of understanding and generating knowledge.
- Humans have a very well developed sense of sight.
  - More than 50% of a human brain's neurons are used in vision.
  - Humans see in 3-D and full color.

Michael Zeitlin (1992) of Texaco:

"…it was impossible to look at all the (geological) data at once before the advent of high speed parallel processing, 3D graphics and … visualization. Today we can grasp enormous amounts of information…In other words we see – and use – more of our data and process it with visual pattern recognition as the basis of our interpretation."

Quoted in M. Wood. 1994. "The Traditional Map." in *Visualization in Geographic Information Systems,* Edited by Hilary Hearnshaw & David Unwin. John Wiley & Sons.

Thru visualization we turn raw data into information

Raw Data → Information = Insight (ideally)

Human Cognition & Visualization

- Cognition refers to processes in human beings like perception, attention, learning, memory, thought, concept formation, reading, and problem solving.

- You can't develop useful geographic visual representations without an understanding how we (humans) perceive space.

- Understanding how we see and organize the world around us allows us to create visuals that play to our cognitive strengths and allows us to learn things more intuitively.

GeoVisualization

"Geovisualization is both a process for leveraging these data resources (spatial data) to meet scientific and societal needs and, together with the broader discipline of Geographic Information Science (GIScience), a *field of research and practice* that develops visual methods and tools to support a wide array of geospatial data applications."

Alan MacEachren et al. 2003. Draft Paper Submitted to Computer Graphics & Applications

Dimensions of GeoVizualization

Users

Expert Ideation ↔ Public Communication

Intent

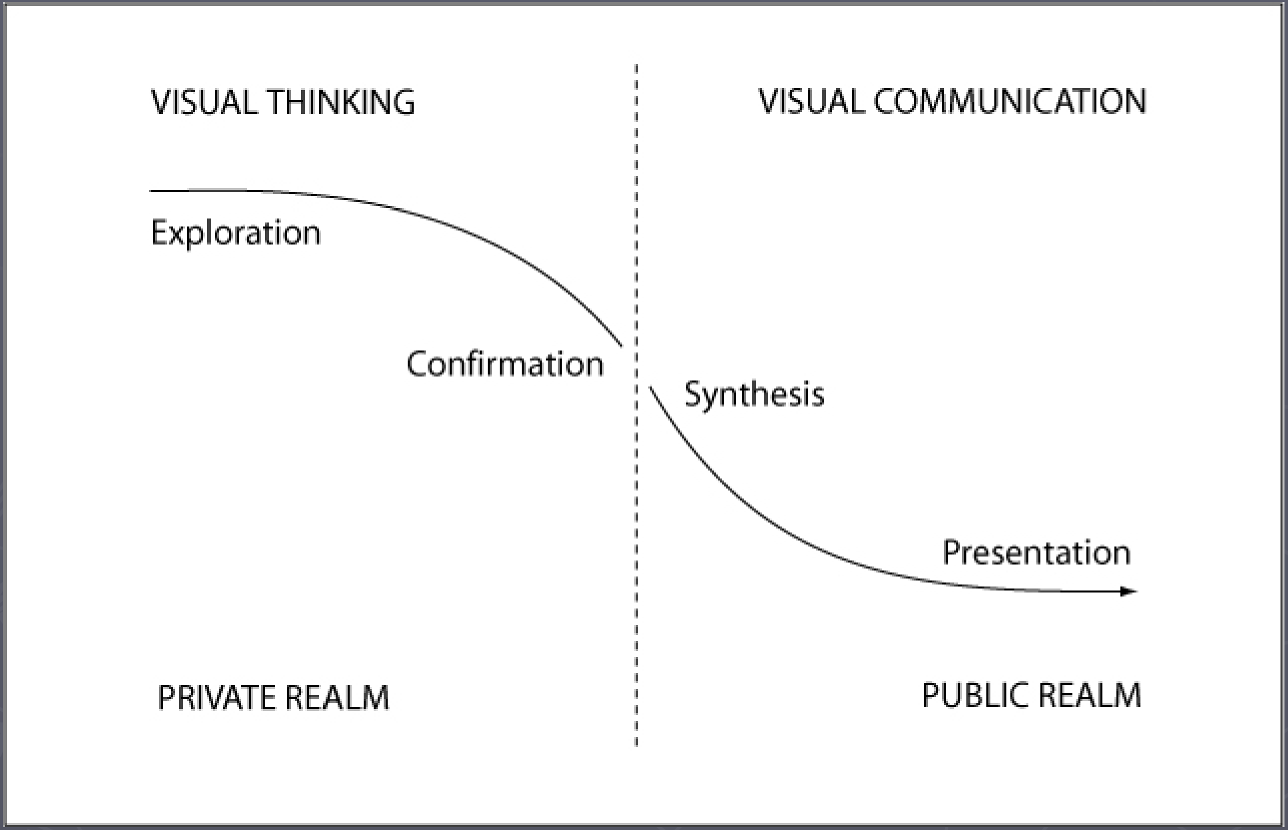
Knowledge Construction ↔ Info Sharing

Interactivity

Low ↔ High

DiBiase's Model

Range of Map Uses in Geographical Inquiry



Adapted from MacEachren et al. 1994. "Advances in Visualizing Spatial Data." in *Visualization in Geographic Information Systems,* Edited by Hilary Hearnshaw & David Unwin. John Wiley & Sons.

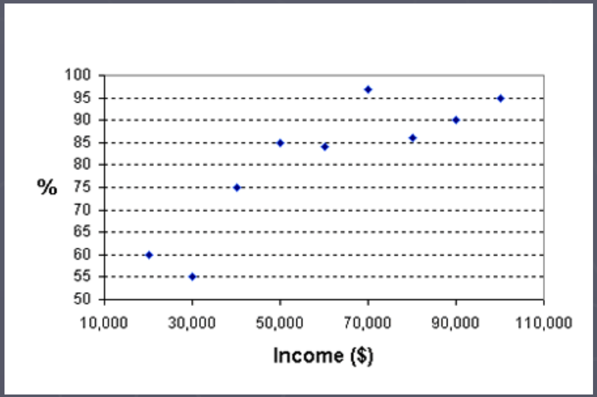
Exploratory Spatial Data Analysis
- Informal Inference -

- Exploratory Analysis does not require testing of predefined hypotheses…instead it can be used to identify patterns or hidden structure in datasets, which can suggest new research directions/questions.

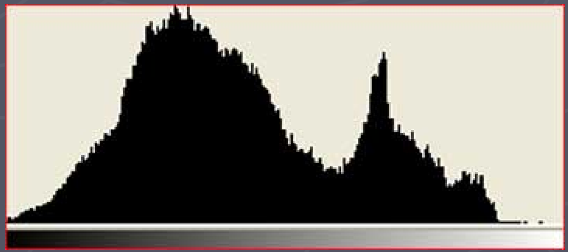
ESDA Methods

- Visual Methods
  - Cartographic representation (maps).
  - Scatterplots and Histograms (charts or graphs).
- Less Visual Methods
  - Summary Statistics (spatial and aspatial)
  - Data mining – Cluster Analysis*; Neural Networks*

    * Data mining results can be mapped if data is spatial.
- Both of these have in common that they allow you to quickly see structure or patterns in a dataset.



Ratio of car ownership to income



histogram of a remotely sensed image

ESDA and Visualization

- For any spatial data set, what we want to known is are they any important identifiable geographical patterns.

- Typical questions one might ask about the spatial distribution of spatial data:
  - Is it clustered?
  - Is it dispersed?
  - Is it random?
  - Is there evidence of spatial autocorrelation?
  - Are there any spatial outliers?
  - Are there any spatial trends?

For more info see Chapter 8 in: Fotheringham et al. 2000. Quantitative Geography. Sage Publications: London

Limitations of ESDA and Visualization

- Informal inference (ESDA and visualization) is less rigorous than formal inference.
- Results (or insight) generated using this approach are often intuitive and subjective…the researcher often generates conclusions by integrating prior/local knowledge.
- Visual interpretation can be affected by scale (depends on data…think about areal data and MAUP)
- This means that the same data can be used to generate different results by different researchers.

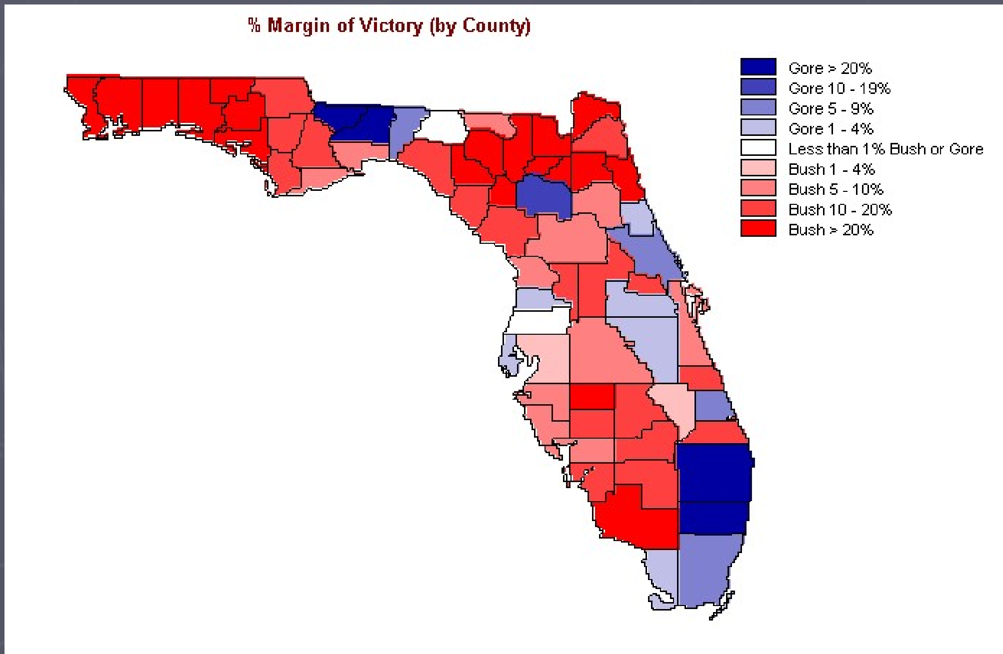
GISc and Visualization

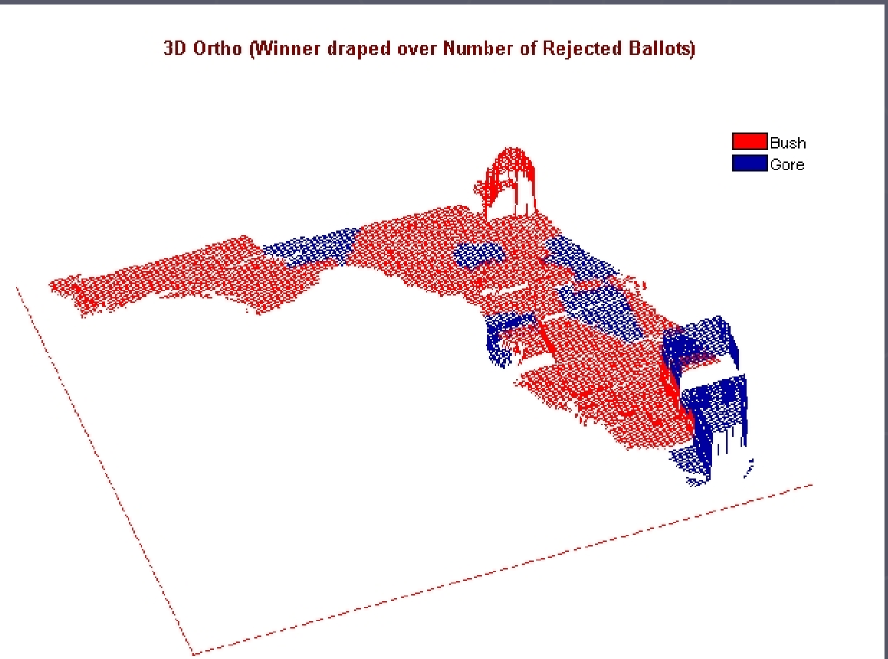
- GIS offers a means through which large amounts of data can be stored, manipulated, analyzed, and displayed efficiently.
  - Consider the example of choropleth mapping using GIS software versus doing it manually. Now if data is available in the right format one can make many of these maps in a short period of time.

- In the past you could think up ideas to map, but it took long hours of work to realize them…making them very expensive to produce. This meant exploratory forms of analysis using maps weren't always feasible.

2000 US Presidential Election Outcome Decided in Florida

Would a Recount Have Changed the Outcome?





Visualization with Conventional (2-D) Maps

- Point Data
  - Dot Maps
  - Proportional Symbol Maps
- Areal Data
  - Choropleth Maps
- Other
  - Cartograms
  - Isarithmic Maps

Visualizing Election Results

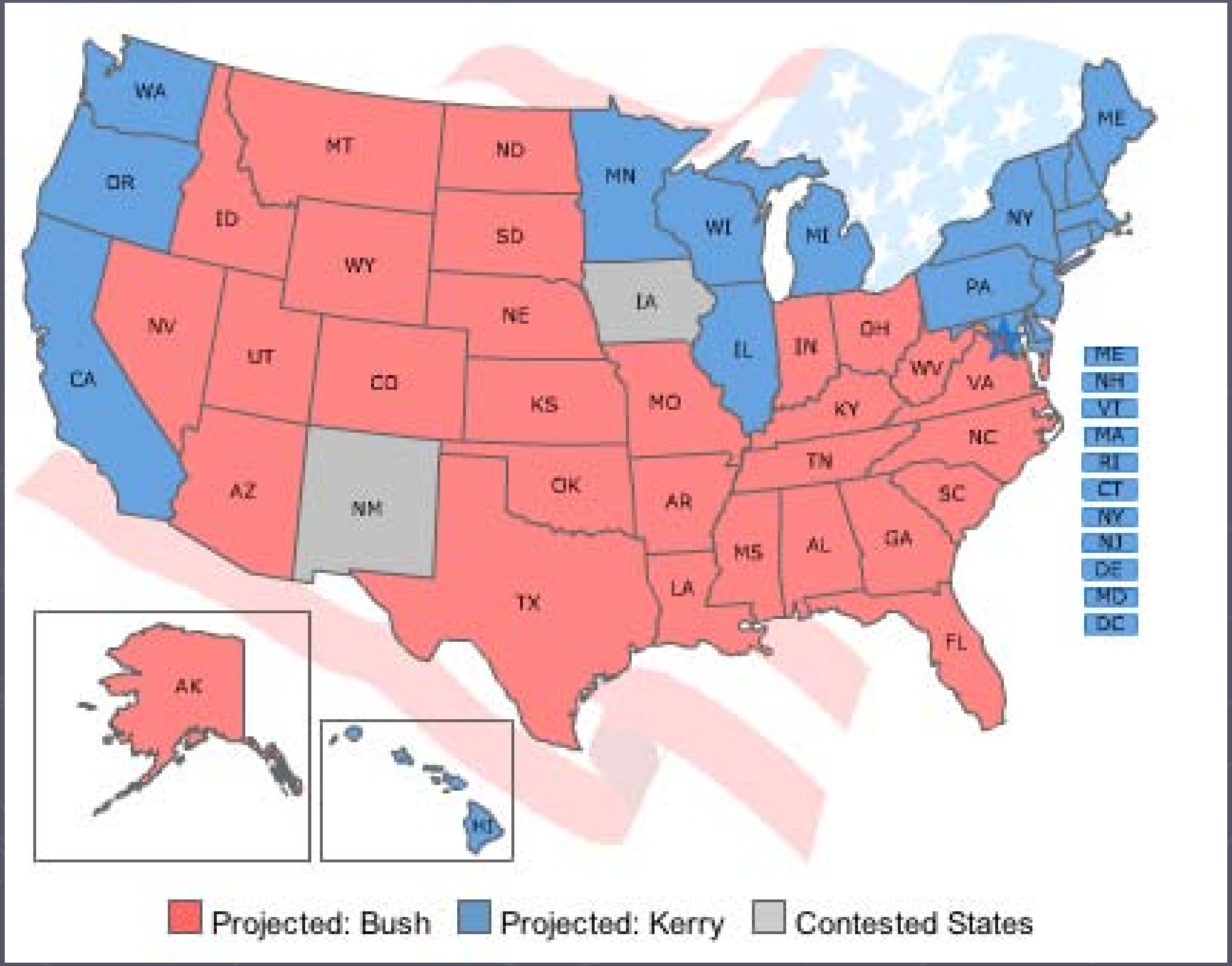
The US Presidential Election 2004 (Bush vs. Kerry)

The next several slides are design to illustrate how the various mapping approaches can effect how you visualize the election results…and what information you perceive.

This is especially true if you have no prior knowledge of the area being mapped…context is very important in visualization.

The Worst Representation

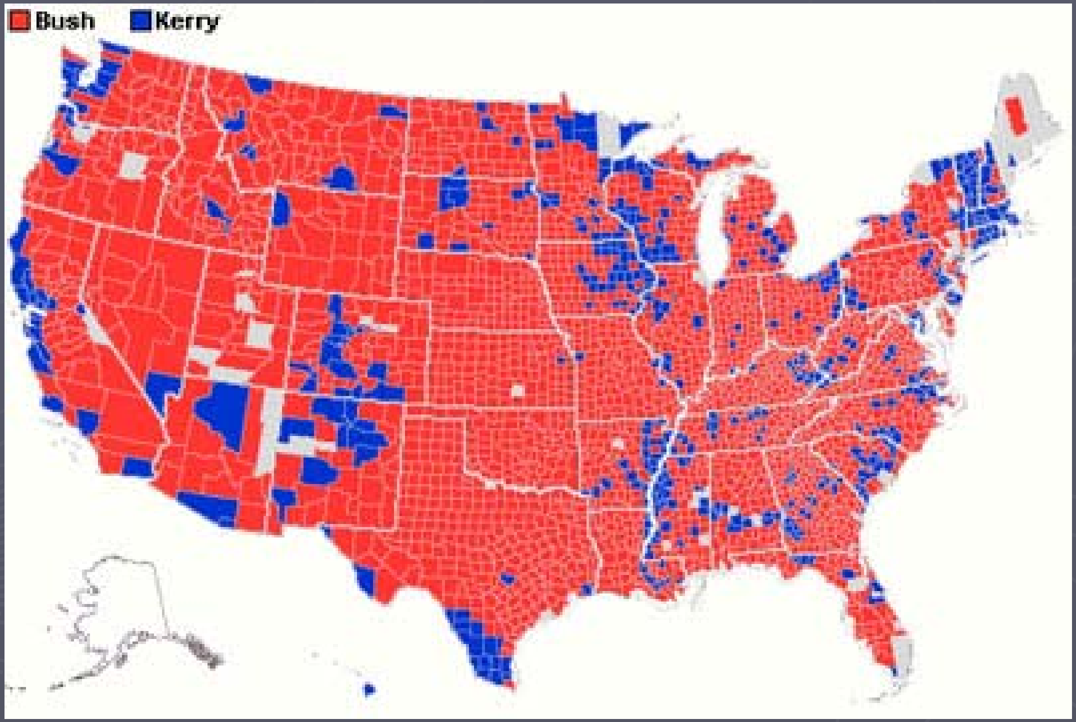
The Common Morning After Map – Low Resolution



Source: CBS & ESRI

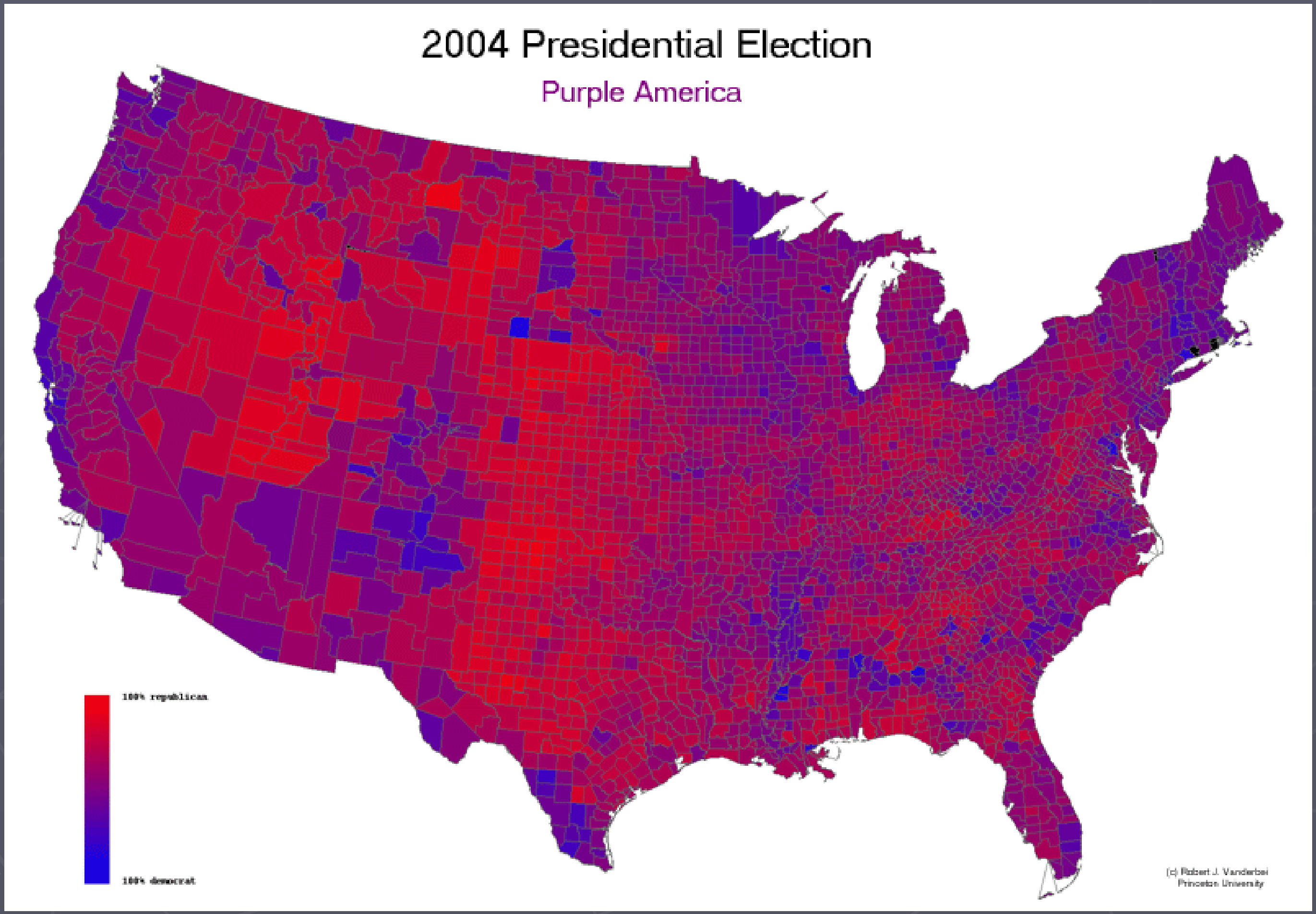
A Better Representation

Higher Resolution Data shows more Localized Patterns



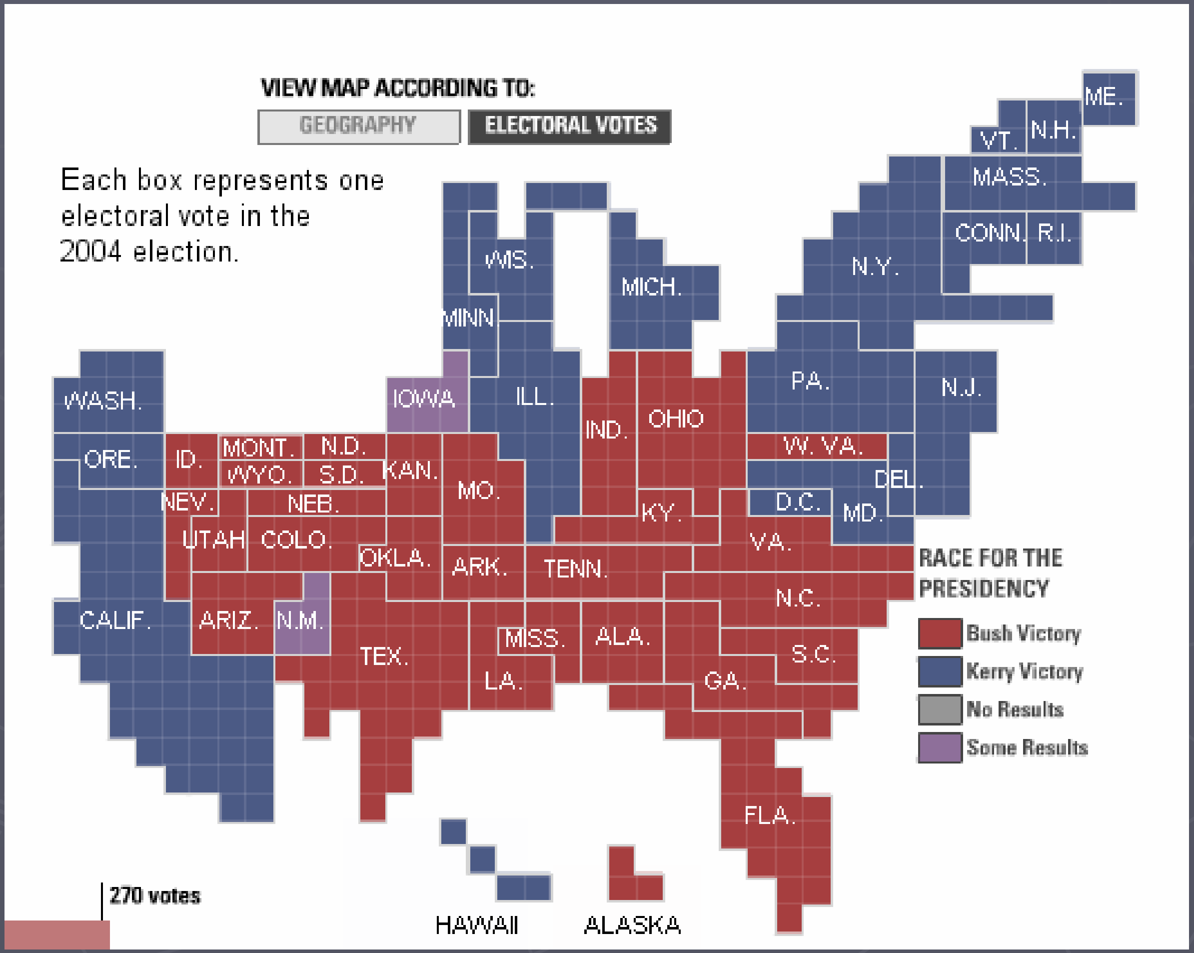
An Even Better Representation

No Longer Simply Red vs. Blue



An Alternative Mapping – The Cartogram

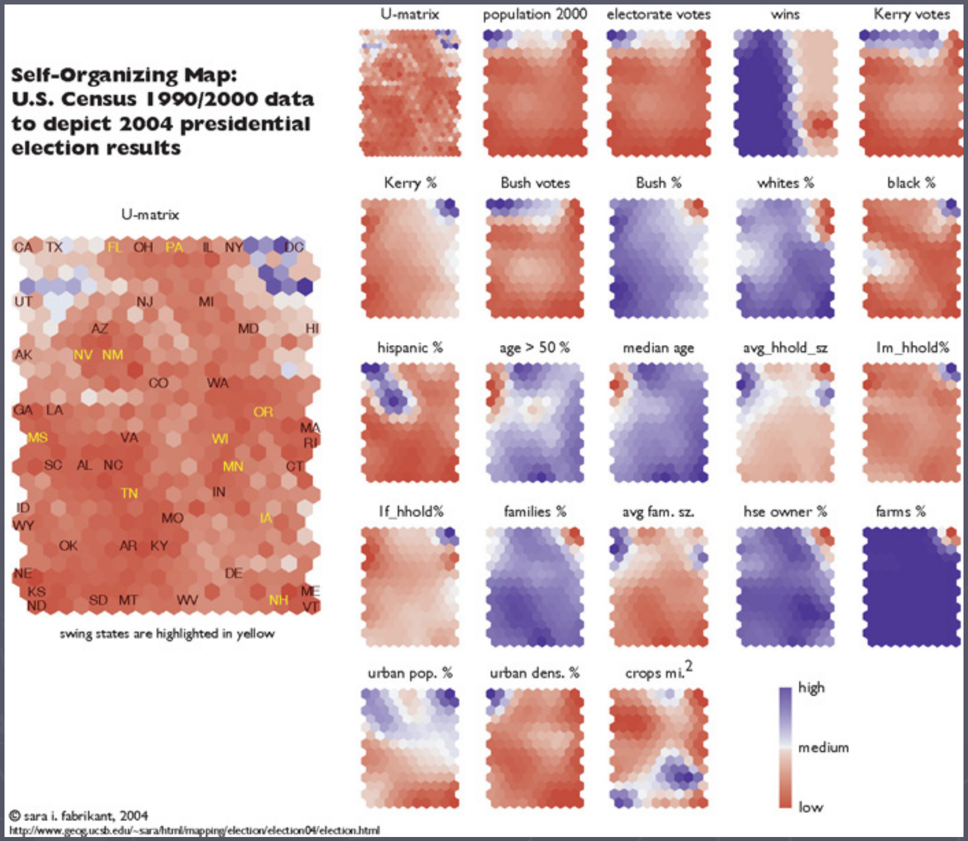
This map retains the Red vs. Blue theme but adjusts for Relative Electoral Votes



Source: New York Times

This Map is Kind of Silly

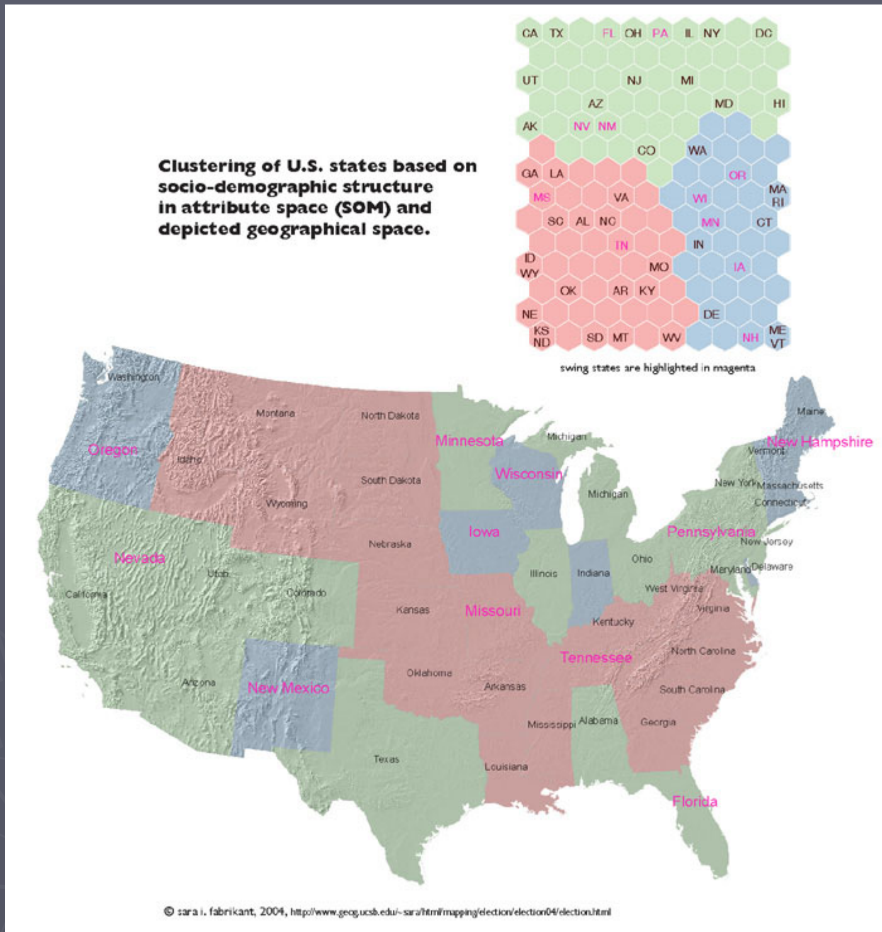
But it uses Proportional Symbols



- A map can be used as a spatial metaphor. In this case it does not map actual geographic locations but instead relationships in attribute space.
- This example is called The Self-Organizing Map (SOM), which is in essence a representation created by a neural net that re-arranges a state's location in a hexagonal grid according to its socio-demographic similarity with other states.
- States that resemble each other socio-demographically are placed closer to one another in the SOM than less similar states.

Source: Sara Fabrikant - University of California (Santa Barbara)

http://www.geog.ucsb.edu/~sara/html/mapping/election/election04/election.html



- This shows the previous slide's data mapped out geographically after being grouped using k-means clustering

- This allows the viewer to see the data further classified into 3 socio-demographic groups and to see how they are oriented in geographic space.

Source: Sara Fabrikant - University of California (Santa Barbara)

http://www.geog.ucsb.edu/~sara/html/mapping/election/election04/election.html

Beyond the Conventional

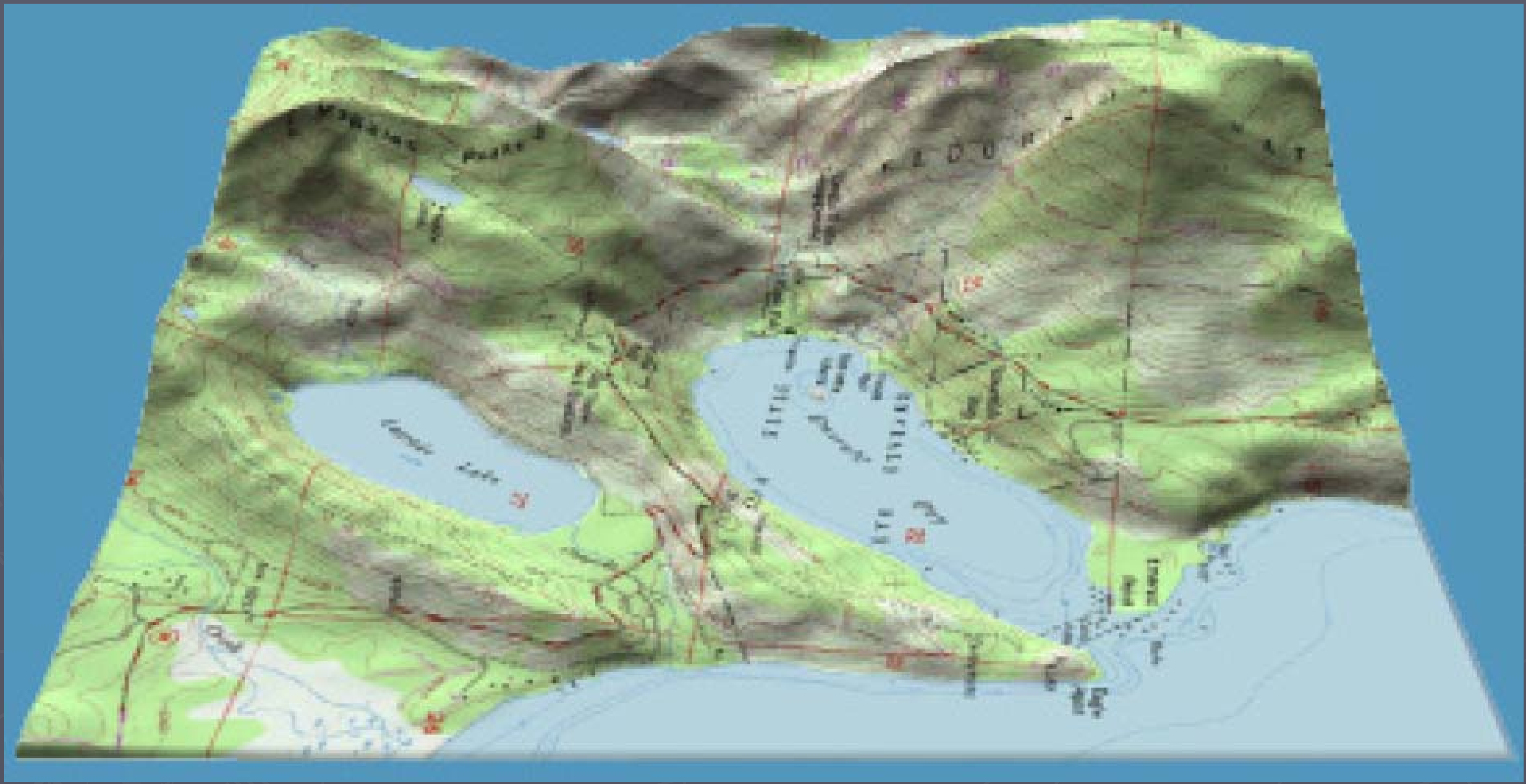
- Visualization (or GIS) is about more than conventional (2-D) maps – although they are still the most common form of output.

- Other types:
  - 3-D Mapping (image drapes)
  - Interactive / Dynamic Maps
  - 3-D Rendering (e.g. Architectural Rending)
  - Geological Subsurface models
  - Virtual Reality / Augmented Reality

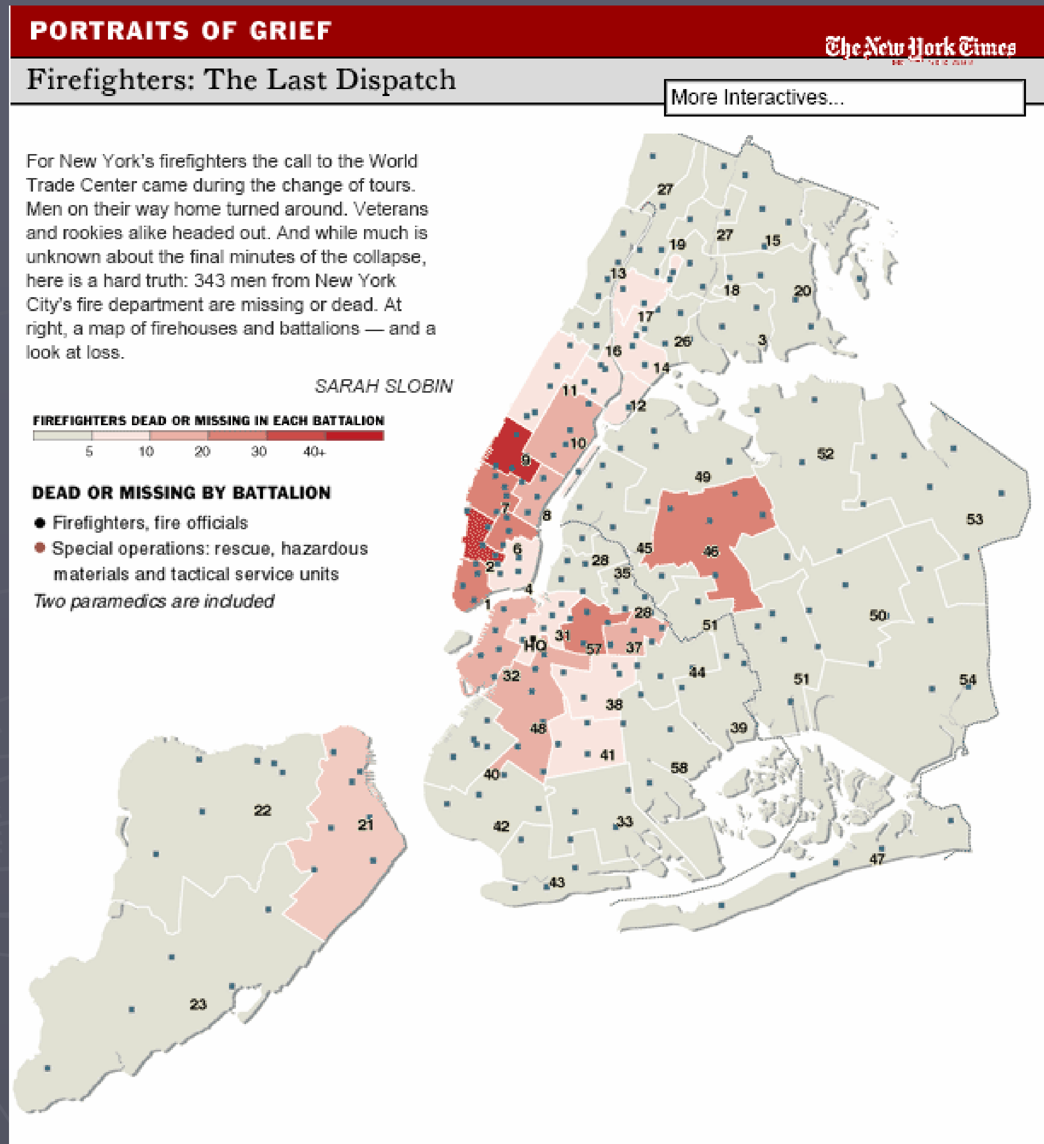
Image Draping (3D)

- Image draping is the most "traditional" geospatial visualization area.

- There are three key steps to create visualizations in image draping packages:
  - Users first open a file that contains georeferenced elevation data.
  - Users then can select a drape file, such as a satellite or aerial photograph or thematic map, to drape over the elevation data (although this isn't required).
  - The mouse, joystick and/or dialog box is used to locate the "camera."



Interactive / Dynamic Maps



Website: http://www.nytimes.com/library/national/index_DISPATCH.html

Architectural Rendering

- This is a well-known category of visualization.
- Usually used to create buildings and images rather than to customize public space or geographical properties.
- After a structure's skeleton is created, the next task is associating different materials (e.g., brick, paneling, etc.) with each surface. Finally, camera parameters are defined and a fly-through is created.

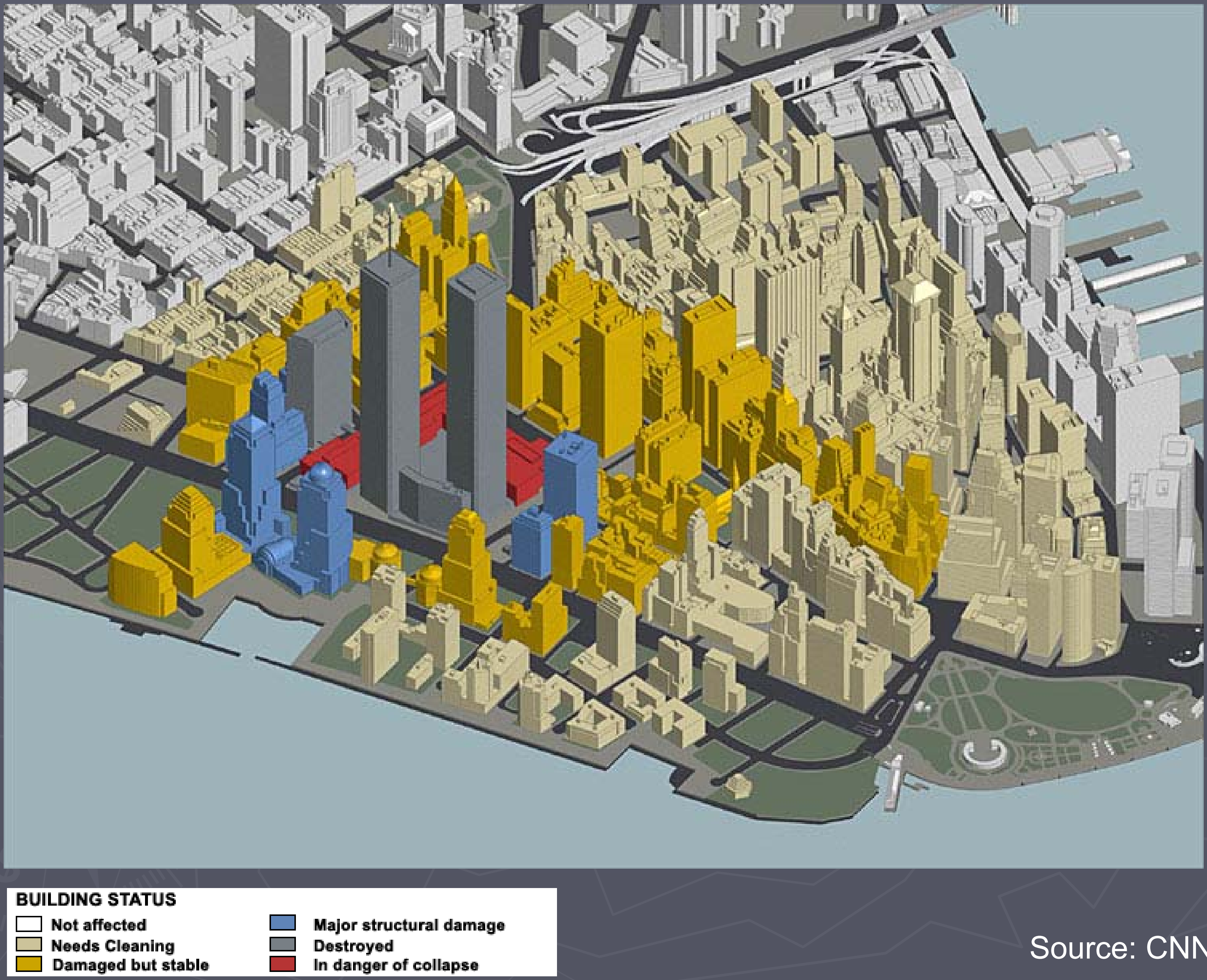
Architectural Rendering Continued

- Virtual buildings can be placed into a 2-D photograph with a single viewpoint, but it's also possible to populate an entire 3-D city with virtual buildings and "fly through" the images.

- Creating each building, however, can be time consuming. An interesting variation of this technique is a recent approach called "site" or "neighborhood" visualization, in which existing photographs are used to quickly create realistic 3-D "fly-able" visualizations.

Examples of Architectural Rendering

Source: Architectural Art – www.architecturalart.com



Source: CNN.com

Subsurface Modeling

- Involves the input of a variety of geological or other subsurface datasets (e.g., well logs) and the creation of plumes or other representations of subsurface phenomena.

- These software packages use complex interpolation and/or link to various subsurface modeling packages that simulate water or chemical flows.

Subsurface Modeling Continued

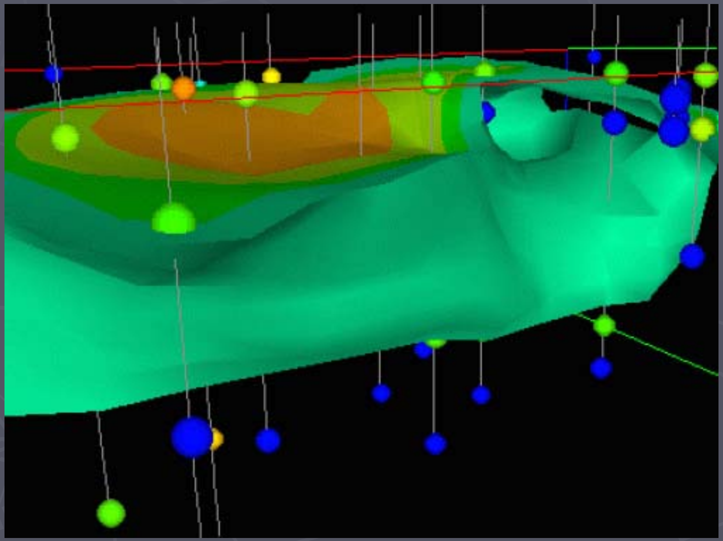
- Subsurface modeling is a special case of visualization that takes sparse data values from sources such as geological profiles or well logs and interpolates a 3-D subsurface solid that can be sliced, diced and viewed from multiple angles.

- A key part of such systems is the interpolation of a volume from a set of individual data points.

- Typically, methodologies such as 3-D kriging are used. After the volumes are interpolated, tools are provided to slice the volumes or identify specific concentration levels.

Subsurface Modeling Continued.

- ESRI's ArcGIS 3-D Analyst also has some subsurface visualization capabilities. A surface and subsurface layer can be displayed together, and features such as water wells can be extruded from one surface to another.



Volumetric model of a plume in groundwater. Spheres indicate the sample locations and concentration.

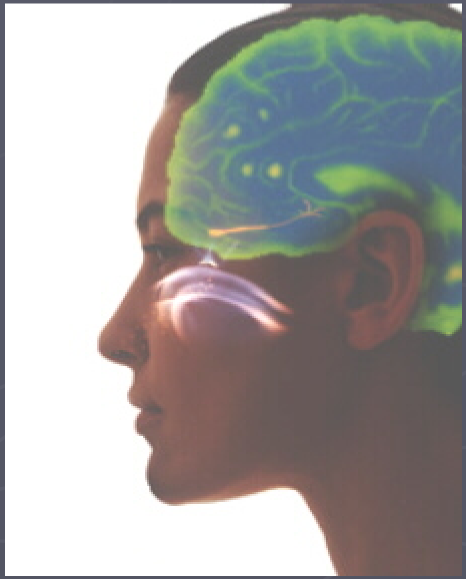
Augmented Reality vs. Virtual Reality

Redrawn diagram from http://www.se.rit.edu/~jrv/research/ar/introduction.html#Section1.2.3

- These systems can be seen to exist on a continuum that with augmented reality near one end emphasizing the real world augmented with computer generated data, and virtual reality on the opposite end being all computer generated.
- Mixed Reality is the middle of this continuum and includes varying amounts both real and virtual data depending on continuum location.

Augmented Reality

- An augmented reality system creates a composite view in which the computer populates a scene with additional information (computer generated data).



- Typically these systems also are interactive in real time.
- Virtual objects must be registered accurately within the real world dimensions.

Image & Video Clips by Jim Vallino - Rochester Institute of Technology
Video - http://www.se.rit.edu/~jrv/research/ar/video.html
Picture - http://www.se.rit.edu/~jrv/research/ar/introduction.html

War goes Virtual and Augmented

Check of the US Navy's Virtual Reality Lab's Website:
http://www.ait.nrl.navy.mil/vrlab/vrlab.html

- **Our Goal:** To be recognized as the Department of Defense's leading research and development laboratory for virtual and augmented reality.
- **Our Mission:** We conduct research and development in emerging virtual and augmented reality technologies to advance Naval warfighting capabilities.

The Virtual Reality Responsive Workbench

Built by US Navy VR Lab in 1994. It was the first of its kind and is a partial virtual reality environment.

- The Responsive Workbench is a virtual reality display which operates by displaying computer generated, stereoscopic images onto the workbench surface, which is viewed by a group of users.
- Using stereoscopic shuttered glasses, the users observe a 3D image rising above the workbench surface. The users can interact with the workbench using a variety of methods including gesture recognition, voice recognition, and 3D graphical user interfaces (GUIs).

The Dragon Battlefield Visualization System

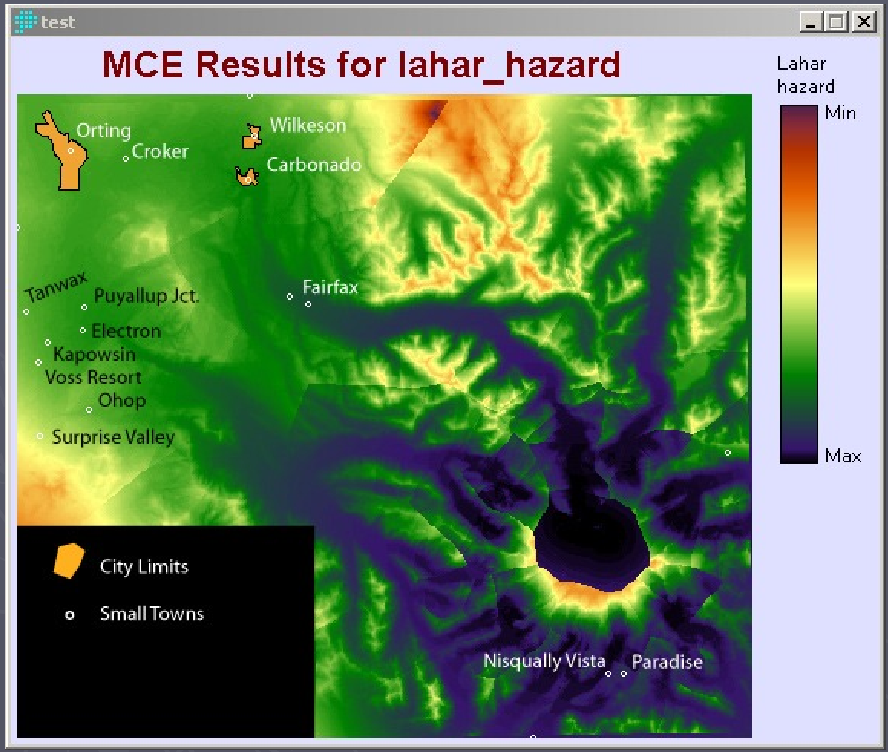
The aim of this system is to display a three-dimensional representation of a battlefield.

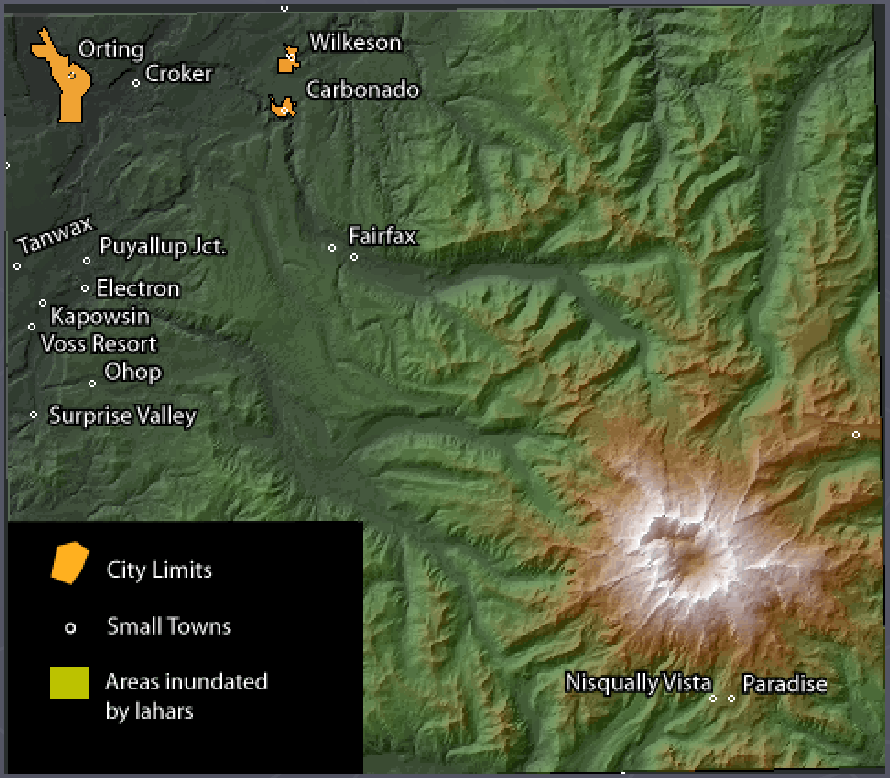
The representation would include a terrain map, entities representing friendly, enemy, unknown, and neutral units, and symbology representing other features such as obstructions or key points in the plan of operations.

Dragon receives electronic intelligence feeds which relate each entity's current status, including such information as position, current speed and heading, current damage condition, and so forth. As these reports are received, Dragon updates the corresponding models on the map.

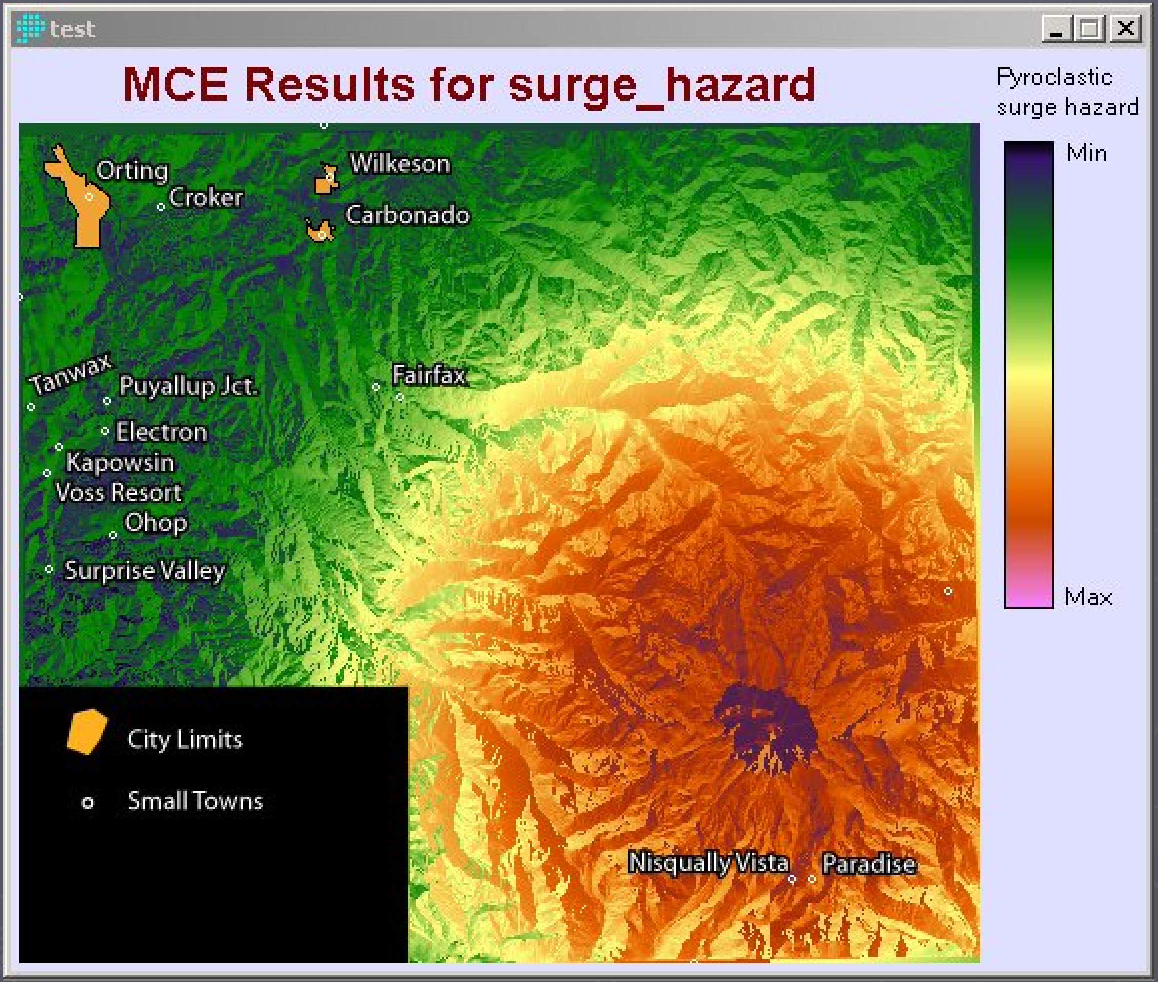
Military planners and decision makers need to be able to integrate a wide variety of information (quickly) into a coherent tactical picture…but current visualization techniques (they list acetate overlays and grease pencils) do not meet this need.

Visualization for Analysis





Source: Michael Peterman – Geog 355 Final Project Fall 2003



Source: Michael Peterman – Geog 355 Final Project Fall 2003

John Snow's Cholera Map

The London Epidemic of 1854

Graphical Excellence

"Excellence in statistical graphics consists of complex ideas communicated with clarity, precision, and efficiency…Graphics reveal data"

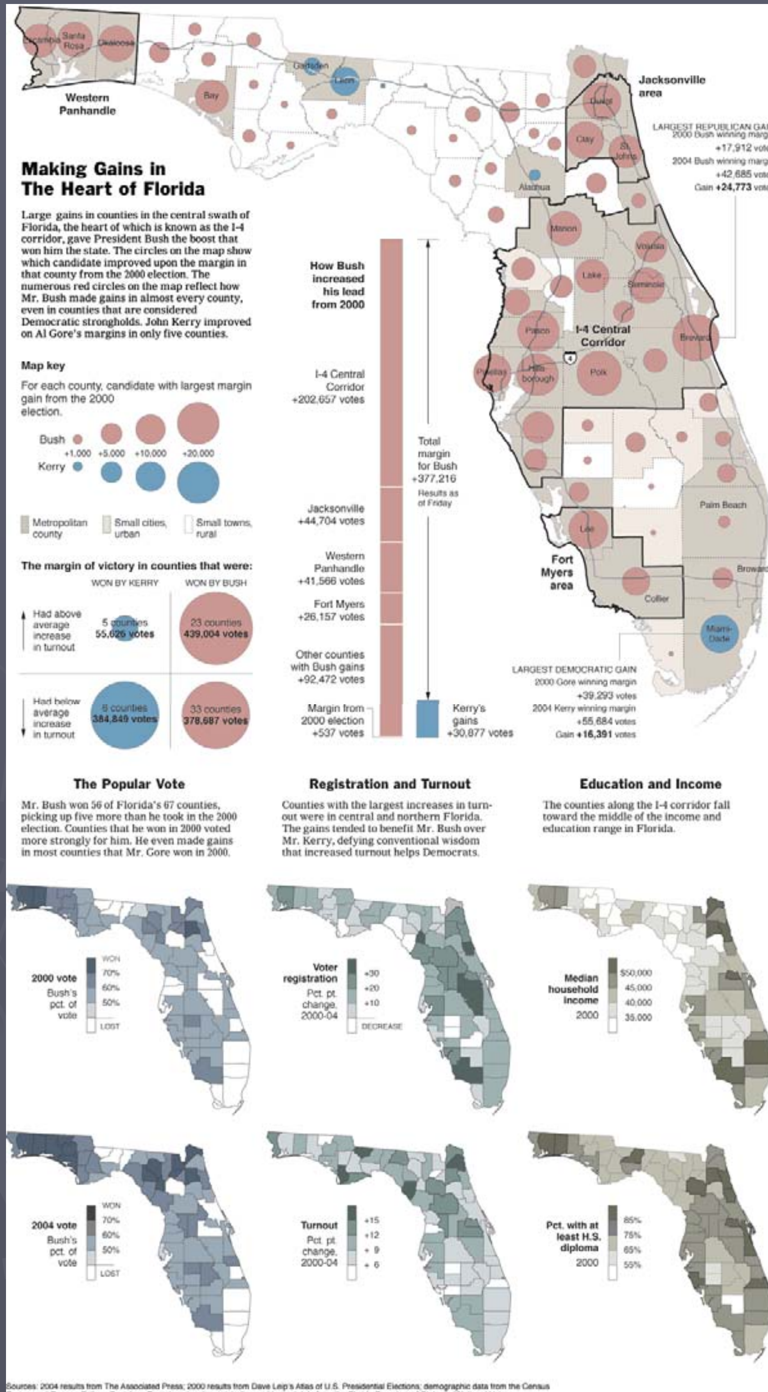
Edward Tufte. 2000. The Visual Display of Quantitative Information. Graphics Press: Connecticut

Escaping Flatland

"We envision information in order to reason about, communicate, document, and preserve knowledge – activities nearly always carried out on two-dimensional paper and computer screen."

"Escaping this flatland and enriching the density of data displays are the essential tasks of information design."

Edward Tufte. 1990. Envisioning Information. Graphics Press: Connecticut



This map is an example of a Data-Rich display


Kyiv
Lviv
Ternopil
Ivano-Frankivsk
Vinnytsya
Ukraine
Yushchenko's support

Cognitive Research in GIScience
Research Directions / Questions

- NCGIA's Project Varenius is composed of three research panels. One of them was "Cognitive Models of Geographic Space".

- It consisted of three specialist topics:
  - Scale and Detail in the Cognition of Geographic Information
  - Cognition of Dynamic Phenomena and Their Representation
  - Multiple Modes and Multiple Frames of Reference for Spatial Knowledge

- These specialist meetings took place during 1998 and 1999.

Source: University Consortium of Geographic Information Science (UCGIS)
Website: http://www.ucgis.org/ Research Priorities White Paper 1998.

- A sample of the types of issues that researcher at the intersection between geographic information and cognition are asking:
  - How do humans learn geographic information, and how does this learning vary as a function of the medium through which it occurs (direct experience, maps, descriptions, virtual systems, etc.)?
  - How do people use and understand language about space, and about objects and events in space?
  - What are the most natural and effective ways of designing interfaces for geographic information systems?
  - How do people develop concepts and reason about geographical space?
  - How can complex geographical information be depicted to promote comprehension and effective decision-making, whether through maps, models, graphs, or animations?

Source: University Consortium of Geographic Information Science (UCGIS) Website: http://www.ucgis.org/ Research Priorities White Paper 1998.

Applying Cognitive Research in GIS

- An applied example of how GIS uses set theory and set relations to describe geographical phenomena: 9-intersection model.
- Comes from a paper in IJGIS:
  Shariff, A.R.B.M., Egenhofer, M.J. and Mark, D. 1998. Natural-language spatial relations between linear and areal obejcts: the topology and metric of English-language terms. *International Journal of Geographical Information Science* 12(3): 215-245.

Research Rationale

- Need to bridge the gap between computational technologies and cognitive models of spatial relations.
- Topology is less technically important in computational work but is being recognized as more important in cogntive realm where the metric less important.
- Right now $\rightarrow$ metric (geometric) is emphasized over topology.

Integrating cognition at the algorithmic level

- Authors wanted to create GIS with more intuitive interfaces allowing users to do queries by (i) sketching possible relationship and (ii) describing their questions in natural language.
- But they needed to know how humans perceived relationship between spatial entities.

Method

- Asked 34 human subjects to make sketches of 59 English-language terms describing SR.
- Their model use derived simple sentences to describe spatial scenarios and to process spatial inquiries based on these formulations.
- Their motto: “*topology matters, metric refines*”.

9-intersection model

- 9-intersection model described by Egenhofer and Herring, 1991 describes all possible topological relationships between two point sets *A* and *B*.
- The set of possible relations includes set intersections of *A*'s interior, its boundary and exterior with *B's interior, boundary and exterior.*
- The set of possible topological relations is called the *–9-intersection* model.

The 9-intersection model of Shariff, Egenhofer and Mark

$$I = (A,B) \begin{pmatrix} A^{\circ} \cap B^{\circ} & A^{\circ} \cap \partial B & A^{\circ} \cap B^{-} \\ \partial A \cap B^{\circ} & \partial A \cap \partial B & \partial A \cap B^{-} \\ A^{-} \cap B^{\circ} & A^{-} \cap \partial B & A^{-} \cap B^{-} \end{pmatrix}$$

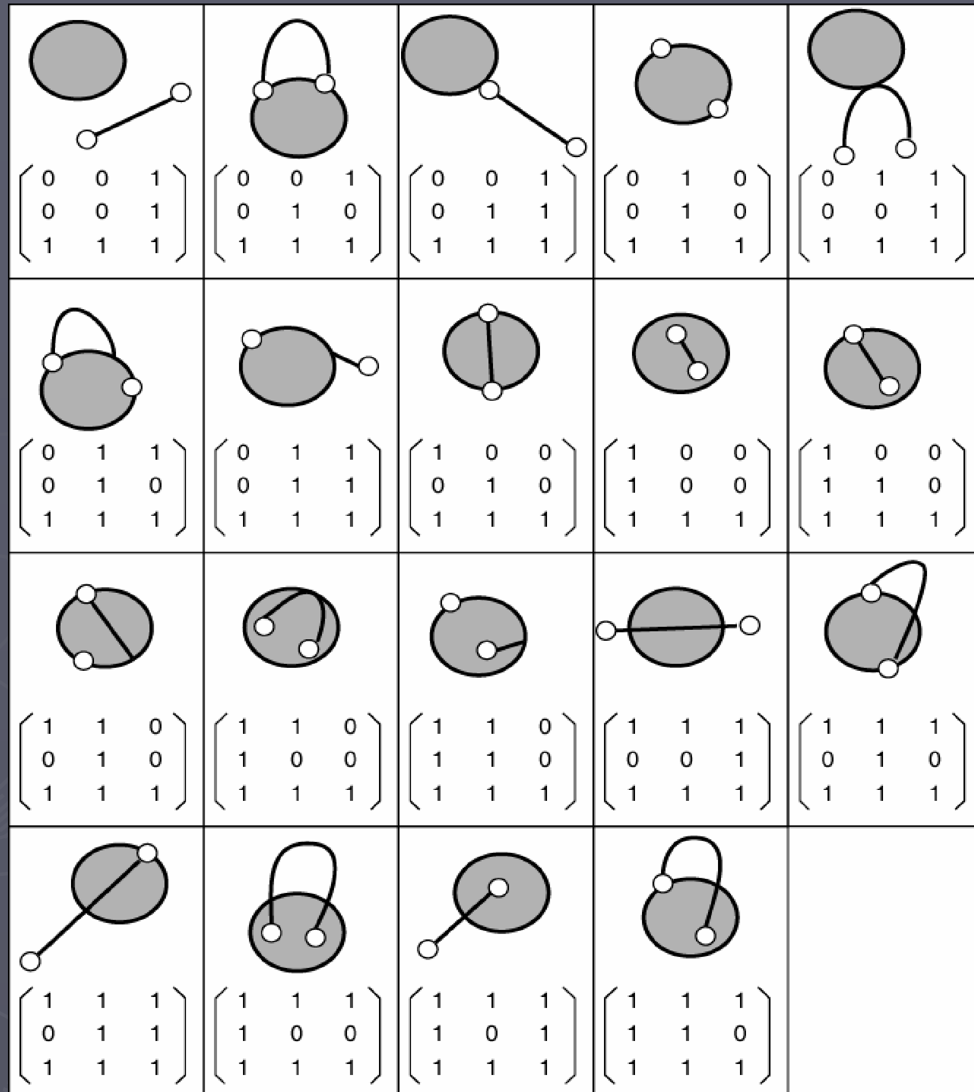
A and *B* are both point sets. A° is *A*'s interior . A^{-} *is A's* exterior. ∂A is *A's* boundary. B° is *B*'s interior . B^{-} *is B's* exterior. ∂B is *B's* boundary.

The 9-intersection model captures information on the topological relations between spatial entities and formalizes those - rather than metrics. Relations encoded by the model are later subject to metric *modification*. The initial spatial relations are, however, maintained in a manner amenable to description, following the premise of cognitive research that topology trumps metrics.

When each of the nine intersections between two point sets, A and B are coded empty (0) or not empty (1), 512 different topological relations can be derived. Clearly, this is a finite set but nevertheless large enough to describe most spatial relations.
The significance of the model is in its inherent recognition of the need for consistent representational structures between conceptualization and implementation.

Range of the model

- 512 different topological relations can be realized from this model, given that all intersections will either be empty (O) or not empty (1).
- **NOTE**: some of the 512 cannot be realized because of the unique dimensions of the objects. In the case of a single, one dimensional line and a simple region (2-D, no holes, no weird concavity) in R^2 , there will be 19 different scenarios.



Geometric interpretations of the 19 line region relations that can be realized from the 9-intersection model developed by Egenhofer and Herring in 1991. Each of the geometric alternatives is referred to by the decimal number that results from the string comprised of the first two rows of the intersection matrix.

19 line region relations

- The 19 relations are referred to by their line-region (LR) number: the conversion of the first two rows in the intersection matrix from a binary number to a decimal number.
  The bottom row is ignored, in this case, because it always produces three 1s for line-region relations in R^{2}.
- The 9-intesection model is effective at separating out **large-scale topological differences** in scenarios while metric space is useful for refining those descriptions.