~~Geovisualization and Multimedia~~ → Geovisual Analytics & Multimedia (?) Group. *Alan MacEachren, May Yuan, Randolph Franklin, {Maria Zemankova}; and, for bits of time: Mubarak Shah , Peggy Agouris*

Original label implies a focus that is too narrow. Key “visual” challenges within GSTI are ones that go well beyond rendering and communicating or even the “traditional” *geovisiaulization* foci on data exploration, hypothesis generation, and analysis. ***Core goals are theory, methods and technologies that support visually-enabled, geo-spatio-temporal information retrieval, analytical reasoning, insight, decision-making, and subsequent implementation of decisions.***

These goals address a wide range of application domains (from environmental science, through public health and crisis management, to education) and users (from scientists, through epidemiologists, crisis managers, urban planners and other professionals, to the educators and individual public users wanting to understand risk to their property of flooding, assess a neighborhood in which they may buy a house, or help their child with a school lesson).

Issues:

- Cutting across all of the groups:
  - There needs to be a more sophisticated conceptual approach to space-time. As pointed out in presentations, a simple conceptualization as a 4D Cartesian space is not adequate (at best, and perhaps seriously misleading).
  - Temporal components of data must be addressed in a more fundamental way – current approaches consider time events, time spans, and time cycles – but do not effectively support analysis of space-time pattern or geo-temporal processes, nor do they handle multi-scale analysis effectively.
- Need to support more “analysis” – not just browsing, exploration, hypothesis generation
- More integration of geovisualization, SciVis, InfoVis, etc. would yield synergies

- A recurring, unsolved issue is communicating “uncertainty” (or certainty, reliability, …) to users – there has been solid research, some core principles exist, and there are some key successful examples (the hurricane cones of possible path), but there is no “solution” yet; issues:
  - how to get “uptake” – many potential users resist explicit depiction of uncertainty/certainty
  - how to represent uncertainty related to underlying info structure, e.g., you know elevation at point 325ft. +/- 50 ft., the elevation at pt. B nearby is 328ft. +/- 50 ft. – but, we know that point B is downstream from point A.
  - how to represent uncertainty for more than simply geospatial data, e.g.: dynamic processes, interpretations from volunteered information for which the source is not know, for hypothesis based on multiple sources of evidence, etc. Related to this, how might geographic and temporal constraints (based on real-world knowledge) be used to support data verification

from: MacEachren, A. M., A. Robinson, S. Hopper, S. Gardner, R. Murray, & M. Gahegan. 2005. 'Visualizing Geospatial Information Uncertainty: What we know and what we need to know', **Cartography and Geographic Information Science**, 32(3), pp. 139-160.

- Understanding the components of uncertainty and their relationships to domains, users, and information needs
- Understanding how knowledge of information uncertainty influences information analysis, decision making, and decision outcomes
- Understanding how (or whether) uncertainty visualization aids exploratory analysis
- Developing methods for capturing and encoding analysts' or decision makers' uncertainty
- Developing representation methods for depicting multiple kinds of uncertainty
- Developing methods and tools for interacting with uncertainty depictions
- Assessing the usability and utility of uncertainty capture, representation, and interaction methods and tools

- Educational implications/applications of "Google Earth" and related efforts:
  - can these tools be used to support education about science, math, geography, and related domains – if so how?
  - are there potentially negative implications of these technologies – stimulate one mode of learning at the expense of others; prompt the wrong conceptual metaphors, etc?
- We know very little about the ***relationships between dynamic visual representations of geospatial and geotemporal information and human analytical reasoning processes*** – this is relevant to applications in science, education, and real-world decision-making.
- We lack a strong ***theoretical basis for design of visual interfaces*** to geospatial information – this corresponds directly to the call in the DHS Visual Analytics research agenda for a "***science of interaction***" – this science is needed here and will be fundamentally different when interfaces support access to info about space and time.

- In relation to challenges in **interaction**, we are currently unable to easily capture insights seen in interactive geospatiotemporal displays – e.g., an analyst interacts with parameters that adjust spatial, temporal, and attribute components of a display as well as parameters related to scale, which variables are represented, etc. … they see a space-time "pattern" that they decide represents a recurring hot spot of crime in a city – we cannot answer the following:
  - how does the analyst interact with the visual display to specify what in the display is the "object" that they consider to be a hot spot, when it exists, what its pattern of change over time is?
  - How is the "object" stored in a database and later retrieve; how is it specified as an exemplar for a query into a larger database for more like it?
  - This is an area where we need coordination between efforts in geovisual analytics for geospatiotemporal information and those related to semantics, ontologies, and spatial language.

- Multimedia challenges:
  - As we have seen in Mubarak Shah's work, some of the challenges of matching a moving video sequence in the world to locations in the world (thus to map the path of the video) have been solved. Challenges that remain include: viewpoint matching issues, dealing with rotation, translation, feature matching
  - A related challenge is to fuse video of movement in the world, geographic databases, and narrative, e.g., to address situations with partial video and partial narrative during a journey.
  - … or, to generate video from narrative – e.g., a description of travel through a city as the base for extracting video clips from Google Street View
  - Another area of active development, but with a range of continuing challenges is to generate annotations of non-text artifacts (images, video); strategies that retrieve and fuse information from multiple sources are promising.

- ***Spatial and temporal scale*** is a fundamental challenge:
  - Theory is needed to ground the development of geovisual analytic methods/tools that support ***multi-scale analysis in space, time, and space-time*** (methods tools include those for visualization of data/information and visual interfaces to complementary computational methods).
  - A visualization challenge here is to address the ***generalization/ abstraction problems*** that derive from a need for different representations at different scales (because objects of relevance are different, re-world processes or different, etc. at different scales) while also making it possible to understand connections across geo-temporal scales. Starting points for addressing this include considering a continuum of operations from aggregation, through agglomeration, to narratives {more from May Yuan here}.

- A related visualization challenge is to cope with very large data sets where the fine-grained data of the most detailed scale are orders of magnitude greater than what is displayable; this is complementary to "***overview + detail***" challenges addressed in Information Visualization, but the problems are unique when data are not just attributes (as in the typical InfoVis case) but include attributes by place and time.
- A related challenge is to deal with ***visualizing and interacting with the incomplete and overlapping hierarchies of geographic data*** that may, in part be given; e.g., hierarchies of country, state, county, Congressional District (which nests inside states but divides counties) and, in part, must be extracted from the data (e.g., using computational methods such as self organizing maps or other techniques).

- A major challenge is to **develop geovisual analytics theory, methods, and technologies for *supporting an understanding of process, prediction, and decision-making*** –has components related to developing theory, methods, and tools that lead to better understanding of process and decision-making in the face of uncertainty + those related to education about complex processes
    - One goal is to address the challenges of ***integrating simulation models, visual interfaces to models and data/information visualization methods*** – that link to real-world data that provide a representation of current state (perhaps streaming data from sensor networks). *Issues include*: (a) support for individual and collaborative investigation of what-if scenarios; (b) prediction of future situations given past information; (c) understanding of processes and how they interact with each other across scales – with attention to communicating the certainty in those predictions and sensitivity of models to: model parameters, constraints on data, etc.

- A complementary goal is in education and training – ***how can visual-computational simulation modeling environments be used to teach about complex ecological, climatological, urban system, and other processes***. What do we not know (e.g., about human cognition related to geo-spatio-temporal process; external cognition related to use of visual display to enable reasoning; user interfaces and how they interact with thinking and learning, etc. to accomplish this; about the implications for understanding or bias of human visual steering of models, etc.)?
- There are related ***challenges to developing such environments for training of professionals*** (e.g., crisis managers)

- Educational initiatives that go beyond geovisual analytics:
  - How might we create compelling geo-spatiotemporal problems for science fairs – to stimulate interest in computer-information sciences generally and specifically in geo-spatio-temporal informatics?
  - What programs should our community consider as sources of support for educational initiatives (e.g., NSF’s GK-12 – Graduate Teaching Fellows in K-12 Education) / what new programs could/should be created to support this work – by what organizations (e.g., industry as well as government)
- Applications domains:
  - Health: it is particularly important to integrate visual, statistical (spatial and spatio-temporal), and computational methods here.
  - Applying approaches to UAV data that are increasingly available

- Some broad issues:
  - It is essential to look ***outside the "geo" bounds, e.g., to space-time*** and at the scale of the human body or materials and at astronomic scales
  - To support science, it would be productive to explore the ***synergies between research directed to scientific workflows and the goals here for integrated geovisual analytics environments*** that (through integrated visual-computational methods) support not just one-off tasks (e.g., query of a spatio-temporal database) but a (perhaps complex) process of analysis that may involve many tasks over a period of time.
  - Bottom line – ***the goal should not stop with "visualization" in the sense of "making visible" nor with support for place-based information query – the big challenges are in developing the theory, methods, and technologies that support analytical reasoning, insight, decision-making, and subsequent implementation of decisions.***

MacEachren: Geovisual Analytics challenges for geospatiotemporal informatics

- What is missing?
  - attention to the challenges of <u>using</u> heterogeneous data in real analytical work;
  - attention to challenges of implicit geographic information
- What is next
  - visually-enabled analytical reasoning with a (roughly) geo-referenced social network of 1, 10, or 100-billion records;
  - understanding and integrating *human and computational reasoning* with *large volumes of dynamic geo-spatial/temporal info*
  - representation of geo-spatial/temporal context (a critical underpinning to solving most other questions);
  - moving visual-analytical power to everyday devices / tasks
  - integrating missing bits into the above

Chris McGlone: What is next?

- Improved realism and interactions for 3D models
- Crowd-sourced photogrammetry (distributed acquisition)
- 3D modeling as consumer video camera application
- Video game boxes as photogrammetry/modeling/geospatial data platforms
- Mapping from image sequences
- Continuous mapping instead of discrete updates

Mike Gould

- Multidimensional, multiparticipant virtual earths – from 2D layers to 4D fishbowl