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Auto-Carto 2005 Research Symposium

Forword

E. Lynn Usery and K. Eric Anderson

The Auto-Carto series of meetings began in 1974 at the U.S. Geological Survey National Center in Reston, Virginia, establishing a record of scholarly research in cartography and geographic information systems that became the foundation of geographic information science (GIScience). The Auto-Carto meetings occurred about every two years, culminating with Auto-Carto 13 in 1997.

By 2005, eight years had expired since the last Auto-Carto meeting and the Cartography and Geographic Information Society Board of Directors was searching for a venue for a scholarly meeting that would be focused on cartography, geo-visualization, and GIScience. With the widespread use of the Internet and the World Wide Web occurring in those eight years, cartography and GIScience had changed dramatically, and the need for a scientific research meeting was again of paramount concern. Recognizing both the need and the changes, the Board decided to hold another Auto-Carto meeting, but rather than continuing the series as Auto-Carto 14, the Board convened the Auto-Carto 2005 Research Symposium. The Symposium was held in March 2005 in Las Vegas, in conjunction with the annual meeting of the American Congress on Surveying and Mapping (ACSM) which had been one of the sponsors of earlier Auto-Carto meetings.

The symposium was an intellectual success, drawing top researchers in cartography and GIScience from the U.S. and around the world. It began with a keynote presentation from Karen Siderelis, Associate Director of the USGS Geospatial Information Office, on the research needs for a National Spatial Data Infrastructure. Dr. Jonathan Raper of City College London gave the second keynote address, on the current move of cartography and GIScience from professionals to the masses, and the need for research to make this transition. The next two days included 50 presentations, with 40 full papers submitted. By all accounts the

presentations were excellent, and authors were invited to submit their papers for review in *Cartography and Geographic Information Science* journal's review process. Of the 40 papers submitted, 17 passed the rigorous *CaGIS* review process and are being published in this special issue of the journal.

The Auto-Carto 2005 Research Symposium certainly captured the intellectual energy of the earlier Auto-Carto conferences and we invite you to sample that energy in the papers presented in this issue of*Cartography and Geographic Information Science*.

We hope you will also join us for Auto-Carto 2006, which will be held June 25-28, 2006, in Vancouver, Washington, at the Heathman Lodge in conjunction with the University Consortium for Geographic Information Science (UCGIS) Summer Assembly. Joining the Auto-Carto 2006 meeting will be the International Cartographic Association Commissions on Generalization, Geo-Visualization, and Map Projections, each of which will hold a workshop on June 25, prior to the beginning of the Auto-Carto 2006 sessions.

After the 2006 Symposium, the CaGIS Board plans to hold the Auto-Carto Research Symposium every two years, in even years, so as not to coincide with the ICA conference. We hope you will thoroughly enjoy this special content issue of Cartography and Geographic Information Science and that you will join us in future Auto-Carto Research Symposia.

VISUALIZATION, WEB SERVICES, MOBILE MAPPING, AND GIS

Visualization of Qualitative Locations in Geographic Information Systems

Xiaobai Yao and Bin Jiang

A qualitative location (QL) refers to the reference of a spatial location using linguistic terms such as qualitative descriptions and qualitative spatial relations with other geo-referenced features. Qualitative locations will be increasingly more popular in the future, driven by theoretical, technological, and database developments. Multiplicity and uncertainty are two innate characteristics of QLs. In other words, a QL often has multiple target locations (multiplicity), and the target locations sometimes cannot be pinpointed exactly due to the qualitative nature (uncertainty) of the qualitative descriptions and relations. The presence of

the characteristics imposes research challenges on visualization of QL in geographic information systems (GIS). In response to the visualization challenges we discuss four strategies—namely proportional symbol mapping, fog map, fuzzy 3D surface, and fuzzy-logic-based animation—for the visualization of QL referents in GIS. These strategies combine conventional mapping and advanced interactive visualization methods. Each of them is suitable for one or more scenarios, depending on the presence of either one or both of the two characteristics. All illustrations and related animations are also available at http://www.ggy.uga.edu/people/faculty/xyao/VisQL.html. **Keywords**: Visualization, qualitative location, uncertainty, GIS

Gradation as a Communication Device in Area-Class Maps

Barry Kronenfeld

This paper proposes a methodology to assess gradation as a cartographic tool for communicating information in area-class maps. The communication model is used as a theoretical foundation, suggesting distinction between errors that occur in encoding and decoding of geographic information. The proposed methodology begins with the determination of a target level of encoding error. Map alternatives are constrained to achieve this target, with gradation considered as one variable in the map production process. The result is a series of maps of equal encoding accuracy but varying in the degree of gradation represented. The individual maps of the series can then be evaluated in terms of decoding accuracy. The methodology is demonstrated by producing a series of alternative forest region maps of New York, Pennsylvania, and New Jersey based on U.S. Forest Service data on tree genus distributions. The series ranges from a 4-class graded area-class map to a 13-class crisp map. The results show gradation to be a viable alternative to the proliferation of map classes as a means of cartographic communication.

Keywords: Gradation, area-class maps, communication model

Combining Usability Techniques to Design Geovisualization Tools for Epidemiology

Anthony C. Robinson, Jin Chen, Eugene J. Lengerich, Hans G. Meyer, and Alan M. MacEachren

Designing usable geovisualization tools is an emerging problem in GIScience software development. We are often satisfied that a new method provides an innovative window on our data, but functionality alone is insufficient assurance that a tool is applicable to a problem *in situ*. As extensions of the static methods they evolved from, geovisualization tools are bound to enable new knowledge creation. We have yet to learn how to adapt techniques from interaction designers and usability experts toward our tools in order to maximize this ability. This is especially challenging because there is limited existing guidance for the design of usable geovisualization tools. Their design requires knowledge about the context of work within which they will be used, and should involve user input at all stages, as is the practice in any human-centered design effort. Toward that goal, we have employed a wide range of techniques in the design of ESTAT, an exploratory geovisualization toolkit for epidemiology. These techniques include; verbal protocol analysis, card-sorting, focus groups, and an in-depth case study. This paper reports the design process and evaluation results from our experience with the ESTAT toolkit.

Generalization Services on the Web—Classification and an Initial Prototype Implementation

Dirk Burghardt, Moritz Neun, and Robert Weibel

Much progress has been made in the field of web-based cartography through standards developed by the Open Geospatial Consortium (OGC). While automated access and presentation of cartographic data have been defined, the services for automated generalization are yet to be standardized. This paper aims to show advantages of applying the service concept to generalization and suggests several classification schemas of generalization services at different levels of granularity. A detailed explanation of a real implemented Generalization Service is provided. We show how software developers can make their generalization functionality available as a service and how these services can be accessed dynamically. For the implementation, the open source Java Unified Mapping Platform (JUMP) was extended to work as a framework

for generalization. Generalization services could be used in different application scenarios, for instance as a middleware component extending a web map service with adaptive zooming or as stand-alone services supporting the production of topographic maps by national mapping agencies. They may also allow the development of a common research platform, where researchers would have access to a common generalization framework.

The Roles of Web Feature and Web Map Services in Real-time Geospatial Data Sharing for Time-critical Applications

Chuanrong Zhang and Weidong Li

Many time-critical applications such as emergency response, location-based services, and real time traffic management need instant access to diverse data to make quick decisions and take instantaneous actions. However, two issues block time-critical applications to quickly acquire and integrate spatial data over the web: (1) the heterogeneity of existing GIS systems, and (2) the file-level data sharing systems over the web. This research examines current open standards, protocols, and technologies capable of solving the two issues for real-time spatial data sharing over the web. Focusing on investigating the role of Web Feature Services (WFS) and Web Map Services (WMS), this research has developed a solution for real-time geospatial data sharing at the feature level over the web. A prototype has been implemented to query, extract, create, delete, update, and map geographic features stored in web-accessible OGC (Open Geospatial Consortium) simple feature datastores for transportation emergency applications. The prototype results show that the OGC WFS and WMS play important roles in real-time geospatial data sharing and exchange from heterogeneous sources at the feature level for time-critical applications. The WFS and WMS eliminate time-consuming data translation and facilitate reuse of existing geospatial data over the web. Several issues related to the solution are also discussed in the paper.

Map Design Evaluation for Mobile Display

Julie Dillemuth

How to effectively represent spatial information on handheld mobile devices is a key question, given the increasing use of personal digital assistants (PDAs) and cell phones concurrent with the development of location-based services. The mobile use of digital maps on small displays presents new capabilities and challenges that differ from using paper maps in a mobile setting or viewing digital maps on a desktop computer. This research addresses these issues through a study that evaluated maps on a mobile device used for a field-based navigation task. Map representations at two levels of generalization were compared by analyzing subject performance in a pedestrian route-following task, in which a handheld computer was used as a navigation aid. Subject time and accuracy as well as interaction with the mobile device during the task were measured. The results carry implications for map design for small, mobile displays and identify factors that affect the use of maps while moving. Maps are and will increasingly be used on small displays in mobile contexts for a variety of purposes and in many different environments. The requirements and preferences of mobile users, as well as how these maps are used in different contexts, must be understood in order to inform more effective designs.

DATA MODELS AND ALGORITHMS

Towards a 3D Feature Overlay through a Tetrahedral Mesh Data Structure

Edward Verbree, Arno van der Most, Wilko Quak, and Peter van Oosterom

The use of 3D features within GIS has been increasing due to the need to represent, query, manipulate, and analyze man-made objects in relationship to other 3D features related to the surface of the earth. This will yield an increased use of 3D boundary representations of the features. The spatial relationship between two or more features is often evaluated using a geometrical overlay of these features, which reveals whether these features overlap and—if they do—to which extent. We present the design of a 3D overlay algorithm which overlays 3D triangulated boundary representations through a constrained tetrahedral mesh. The intersections between the constrained facets of the 3D features are calculated on the fly and within a restricted neighborhood. We can identify and reconstruct the overlaid parts of the 3D boundary

representation within the tetrahedral mesh. The implementation is based on the Computational Geometry Algorithms Library, which proved to have the functionality needed but also has its limitations.**Keywords:**Triangular mesh, tetrahedral mesh, overlay algorithms

A Prototype Temporal GIS for Multiple Spatio-Temporal Representations

Yanfen Le

Development of a temporal geographic information system (GIS) and spatio-temporal data modeling are key to incorporating time into geographic information science. This paper describes how to design and develop temporal GIS that will work with spatio-temporal data represented in various data models, and it introduces a prototype temporal GIS with a case study. In temporal GIS, the integration of multiple spatio-temporal representations is based on common spatial and temporal reference systems. In other words, a map window of temporal GIS visualizes spatio-temporal data valid at the same time within one spatial area. To achieve such visualization, separate data editing and query modules are required for each spatio-temporal data model (STDM). In the temporal query interface, after a user specifies a time, the system automatically hires correspondent modules to retrieve spatio-temporal data valid at that time. Besides temporal queries common to all STDMs, each module may provide additional temporal query capabilities specific to that STDM. In the case study, I implement a prototype temporal GIS for three STDMs. The examples of query and visualization, which use three datasets (census data, land use/land cover, and elevation data) demonstrate the prototype temporal GIS can integrate multiple temporal representations.

Keywords: Temporal, GIS, multiple, representation

Variable-scale Topological Data Structures Suitable for Progressive Data Transfer: The GAP-face Tree and GAP-edge Forest

Peter van Oosterom

This paper presents the first data structure for a variable scale representation of an area partitioning without redundancy of geometry. At the highest level of detail, the areas are represented using a

topological structure based on faces and edges; there is no redundancy of geometry in this structure as the shared boundaries (edges) between neighbor areas are stored only once. Each edge is represented by a Binary Line Generalization (BLG)-tree, which enables selection of the proper representation for a given scale. Further, there is also no geometry redundancy between the different levels of detail. An edge at a higher importance level (less detail) does not contain copies of the lower-level edges or coordinates (more detail), but it is represented by efficiently combining their corresponding BLG trees. Which edges have to be combined follows from the generalization computation, and this is stored in a data structure. This data structure turns out to be a set of trees, which will be called the (Generalized Area Partitioning) GAP-edge forest. With regard to faces, the generalization result can be captured in a single tree structure for the parent-child relationships—the GAP face-tree. At the client side there are no geometric computations necessary to compute the polygon representations of the faces, merely following the topological references is sufficient. Finally, the presented data structure is also suitable for progressive transfer of vector maps, assuming that the client maintains a local copy of the GAP-face tree and the GAP-edge forest. **Keywords:** Map generalization, topological structure, planar partition, client/server, progressive data transfer, geo-information system

Supporting the Comparison of Choropleth Maps Using an Evolutionary Algorithm

Ningchuan Xiao and Marc P. Armstrong

Choropleth maps can be used to compare the patterns exhibited by different spatial variables. In this paper, we develop an evolutionary algorithm that can be used to generate classifications that allow a user to explore the spatial patterns of multiple choropleth maps in terms of their visual correlation and the equality of area contained in each class. Synthetic and census data are used to demonstrate the effectiveness of our approach. **Keywords**: Choropleth mapping, visual correlation, multi-objective optimization, visualization

Exploring the Hidden Potential of Common Spatial Data Models to Visualize Uncertainty

Julian Kardos, Antoni Moore, and George Benwell

Common Spatial Data Models (SDMs) such the vector, raster, and quadtree have well understood and widely practiced conventions of storage and visualization. This paper explores what happens when the conventions of visualization are not strictly adhered to, and the SDMs are used in an atypical fashion. A framework based on a quasi similarity measure is presented, which quantifies (in terms of "distance") the relationship between the storage format and the visualization output, following an accepted protocol. This research used a transformation process (*Tp*) to define this distance. Then, the atypical use of the quadtree SDM to represent choropleth spatial boundary uncertainty and attribute uncertainty was quantified using the same framework. This research shows that if a SDM is used outside of its original context, then the distance between the storage format and its visual output can alter; in our case, the distance decreased. This result was interpreted as evidence for the creation of a new spatial data structure. The formalization of the relationship between an SDM and its visual output will be valuable for future exploration of the non-conventional visualization of common SDMs. **Keywords**: Spatial data model, storage, display, uncertainty, transformation

An Artificial-Neural-Network-based, Constrained CA Model for Simulating Urban Growth

Qingfeng Guan, Liming Wang, and Keith C. Clarke

Insufficient research has been done on integrating artificial-neural-network-based cellular automata (CA) models and constrained CA models, even though both types have been studied for several years. In this paper, a constrained CA model based on an artificial neural network (ANN) was developed to simulate and forecast urban growth. Neural networks can learn from available urban land-use geospatial data and thus deal with redundancy, inaccuracy, and noise during the CA parameter calibration. In the ANN-Urban-CA model we used, a two-layer Back-Propagation (BP) neural network has been integrated into a CA

model to seek suitable parameter values that match the historical data. Each cell's probability of urban transformation is determined by the neural network during simulation. A macro-scale socio-economic model was run together with the CA model to estimate demand for urban space in each period in the future. The total number of new urban cells generated by the CA model was constrained, taking such exogenous demands as population forecasts into account. Beijing urban growth between 1980 and 2000 was simulated using this model, and long-term (2001-2015) growth was forecast based on multiple socio-economic scenarios. The ANN-Urban-CA model was found capable of simulating and forecasting the complex and non-linear spatial-temporal process of urban growth in a reasonably short time, with less subjective uncertainty. **Keywords**: Constrained cellular automata, artificial neural network, urban growth

Design Considerations for Haptic and Auditory Map Interfaces

Matt Rice, R. Daniel Jacobson, Reginald G. Golledge, and David Jones

Communicating spatial information to the blind and visually impaired using maps and graphics presents many difficulties. Past research has offered advice to cartographers on topics such as tactile areal, point, and line symbolization; on perceptual problems related to dense linear features on tactile maps; and on the relationship between categorical data, measurement theory, and tactile discrimination. With this previous work as a foundation, we describe our research efforts with haptic and auditory maps—the Haptic Soundscapes Project. Haptic Soundscapes maps allow blind and visually-impaired individuals to feel map features through force feedback devices and hear auditory cues that add both redundant and complementary information. Recent experimental work by the authors has led to several recommended practices for cartographic data simplification, object size discrimination, shape identification, and general interface navigation. The authors also present haptic and auditory mapping examples to illustrate design ideas, algorithms, and technical requirements. Future prospects for automated haptic and auditory map creation are discussed and presented in the context of the past work in generating maps for the blind and visually impaired from cartographic data.

ACCURACY, REPRESENTATION, AND INTERPOLATION

Assessing Resampling Accuracy of Categorical Data Using Random Points

Jeong Chang Seong

Tissot's Indicatrix and regular grids have been used for assessing map projection accuracies. Despite their broad applicability for accuracy assessment, they have limitations in quantifying resampling errors caused by map projections. This is due to the structural uncertainty with regard to the placement and pattern of grids. It is also difficult to calculate the absolute amount of resampling error in each projection. As an alternative to traditional testing methods, the use of random points was investigated. Specifically, random point generation, resampling with spherical block search algorithms, resampling accuracy with a perfect grid, and resampling accuracy with eight projections were investigated and are discussed here. Eight global referencing methods were tested: the equal-area cylindrical, sinusoidal, Mollweide, Eckert IV, Hammer-Aitoff, interrupted Goode homolosine, integerized sinusoidal projections, and the equal area global gridding with a fixed latitudinal metric distance. The resampling accuracy with a perfect grid is about 75 percent. Results showed the sinusoidal and the integerized sinusoidal projections and equal-area global gridding to achieve the highest accuracies. **Keywords**: Resampling accuracy, map projection, random points, global raster database

Lidar Elevation Data for Surface Hydrologic Modeling: Resolution and Representation Issues

Christopher P. Barber and Ashton Shortridge

This paper is concerned with the application of high spatial resolution elevation data derived from light detection and ranging technologies (lidar) to surface hydrologic modeling. In recent years, airborne lidar technology has been employed to develop high accuracy digital elevation models (DEMs) with horizontal resolution on the order of a few meters. As with any spatial data product there are limits to the lidar's practical use that vary with the intended application. This paper considers

potential issues and challenges for the use of lidar-derived DEMs in surface hydrologic modeling applications, such as characterizing flow direction and power, identifying sub-basins in a watershed, and calculating upstream contributing area and other variables. We compare results using conventional 30m DEMs and 6m lidar for a high relief study area and a low relief study area. Results are more comparable between these data sources, regardless of hydrologic operation, for the high relief area, while the similarity of results in the low relief area is dependent upon the particular operation. Post-processing on the lidar data successfully removed such flow obstacles as bridges that might have artificially impeded surface flow. An exploration of the effect of spatial resolution on results suggests that cell size is a more significant factor than production method.

A Comparative Analysis of Areal Interpolation Methods

Kevin Hawley and Harold Moellering

Over the years many approaches to areal interpolation have been developed and utilized. They range from the simple 2-D areal weighing method which uses only the spatial Z variable being processed, to more sophisticated approaches which use auxiliary variable(s) to provide more specificity to the results. In the research reported here, four promising approaches are implemented and comparatively tested. These approaches have widely varying conceptual foundations, and different auxiliary variables, if used. The areal weighing reflects many earlier methods which assumes uniform distribu tions of the spatial Z variable, and does not use any auxiliary variable. Tobler's pycnophylactic method uses a volumetric preservation approach, which assumes spatial Z variable is heterogeneously distribut ed, but does not use any auxiliary variable. The traditional dasymetric method of Wright is used with remote sensing spectral data of land use. Xie's road network hierarchically weighted interpolation uses the road network as the auxiliary variable, and assumes that population density is related to the class of the road, and to the density of the road network. The research design implemented here uses Census population distributions at different levels in the hierarchy as the source and target variables analyzed. The source zone population is taken at the Census Tract level, and the target zones are

specified at the Census Block Group level in the hierarchy. The first two tests use only the Census population Z data, and no auxiliary variables, whereas the next uses remotely sensed land use data as the auxiliary data variable, and the fourth test utilizes the road network hierarchy as the auxiliary variable. The paper reports on the findings from these tests, and then interprets them in a spatial setting in terms of accuracy and effectiveness. This research points to the network method as the most accurate of the areal interpolation methods tested in this research.

SOCIETY AND HISTORY

Communities of Scholars: Places of Leverage in the History of Automated Cartography

Nicholas R. Chrisman

The search for "origins" in the history of technology is often disappointing. Each origin uncovers some predecessors vanishing into the mists. More importantly, the distinct competitors turn out to be much more entwined than imagined. This paper will describe the community into which automated cartography emerged. Being "first" is only something that is apparent in retrospect. It makes sense to remember a bit more about the pre-history of geographic information systems, not just to get the history right, but to understand how the events of prior periods influence the way the technology develops. Current developments may owe much to forgotten or misremembered pasts. This paper examines the 1960s with the development of the Canada Geographic Information System (CGIS) by Roger Tomlinson. It then turns to the circumstances that preceded the development of CGIS, particularly at the University of Washington. From this examination, it is apparent that the construction of a community is more important than determining who did what first. This community emerges from documents and artifacts of the period.

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Visualizing Geospatial Information Uncertainty: What We Know and What We Need to Know

Alan M. MacEachren, Anthony Robinson, Susan Hopper, Steven Gardner, Robert Murray, Mark Gahegan, and Elisabeth Hetzler

Developing reliable methods for representing and managing information uncertainty remains a persistent and relevant challenge to GIScience. Information uncertainty is an intricate idea, and recent examinations of this concept have generated many perspectives on its representation and visualization, with perspectives emerging from a wide range of disciplines and application contexts. In this paper, we review and assess progress toward visual tools and methods to help analysts manage and understand information uncertainty. Specifically, we report on efforts to conceptualize uncertainty, decision making with uncertainty, frameworks for representing uncertainty, visual representation and user control of displays of information uncertainty, and evaluative efforts to assess the use and usability of visual displays of uncertainty. We conclude by identifying seven key research challenges in visualizing information uncertainty, particularly as it applies to decision making and analysis. **Keywords:** Uncertainty, geovisualization, representation, decision making, usability

Assessment of Simulated Cognitive Maps: The Influence of Prior Knowledge from Cartographic Maps Robert Earl Lloyd

Real cognitive maps encoded by humans are difficult to study using experimental methods because they are a product of complex processes whose content and timing cannot easily be known or controlled. This paper assesses the value of using neural network model simulations for investigating cognitive maps. The study simulated the learning of mapped city locations in South Carolina from reference sites in the three primary regions of the state using Kohonen self-organizing maps. The learning performances of models were considered based on available

prior knowledge. Bi-dimensional regression analyses were used to assess the congruity of the simulated cognitive maps with a cartographic map and with sketch maps produced by human subjects. Error analyses indicated differences between central and peripheral reference sites. The cities known by subjects living at a central location were more evenly distributed in space and associated with significantly smaller errors. Models that learned combined state boundary and interstate highway information as prior knowledge or simultaneously with city locations consistently produced the best simulation results. The results indicated simulated cognitive maps could be used effectively to study the acquisition of spatial knowledge. **Keywords:** Cognitive maps, simulations, sketch maps, spatial learning, self-organized maps

System Design Considerations for the Development of an Electronic Statistical Atlas

Lysandros Tsoulos

In the recent history of cartography, atlases deserve a prominent status among cartographic products due to the variety of their thematic content, the rather friendly appearance and their utilization by a wide spectrum of users. Advances in information technology, and more specifically in geographic information systems and digital mapping, have altered the fundamental way of using maps, and thus they have a major impact on every aspect of electronic atlas design and development. Although considerable effort has been made towards the production of electronic atlases, and successful systems are available, there are still a number of factors that must be considered towards the improvement of their design and functional characteristics. This paper elaborates on those factors and suggests a specific approach toward the design and development of electronic atlases, particularly electronic statistical atlases. This approach has been used for the development of the *Statistical Atlas of the European Union* (*STATLAS_EU*), which is intended to provide a user-friendly resource for statistical analysis.

KEYWORDS: Electronic atlas, atlas design and development, graphic user interface (GUI), open source software, Extended Mark-up Language (XML), Geography Mark-up Language (GML)

Creating Buffers on Surfaces

Xingong Li, Christopher M. Larson, and Arthur B. Rex

Creating buffers is an important function used in geographic information systems (GIS) to perform spatial analysis. However, delineating buffers for setbacks in conservation and planning applications is problematical in mountainous areas. A typical vector buffer function in GIS calculates two-dimensional (2D) Euclidean distance (i.e., planimetric distance) instead of surface (or slope) distance and results in an inaccurate representation of buffers when they are verified in the field. A method of delineating buffers on surfaces in the raster data model is presented in this paper. An efficient implementation of the method is achieved through the use of a min-heap and a hash-table based location index. The method is tested and analyzed on both hypothetical and real surface datasets.

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Geovisualization and GIScience

Menno-Jan Kraak and Alan M. MacEachren

Today it is recognized that we can no longer rely upon uni-disciplinary solutions for our most pressing geo-problems. The hard problems require multiple perspectives and different types of expertise. This is reflected in the names and activities of organizations and journals. This journal has evolved, in both name and perspectives, from The American Cartographer via Cartography and Geographic Information Systems into its current shape as Cartography and Geographic Information Science (CaGIS). Similarly, the International Cartographic Association (for which this journal is one of three official outlets) has recently decided to add "The International Society for Cartography and Geographic Information Science" as a subtitle to its name. Over the years, the ICA Commission on Visualization and Virtual Environments has worked together with other disciplines such as those related to scientific visualization and computer

graphics (through the SIGGRAPH CartoProject led by Theresa-Marie Rhyne http://www.siggraph.org/~rhyne/carto/) and information visualization (through a workshop at City University in London that resulted in the recently published edited collection, Exploring Geovisualization).

These ICA Commission activities and related developments have culminated in the term "Geovisualization" and have resulted in the Commission-led international and multidisciplinary research agenda which was published as a special issue of this journal in 2001 (MacEachren and Kraak 2001) . Geovisualization can be described as a loosely bounded domain that addresses the visual exploration, analysis, synthesis, and presentation of geospatial data by integrating approaches from cartography with those from other information representation and analysis disciplines, including scientific visualization, image analysis, information visualization, exploratory data analysis, and GIScience (Dykes et al. 2005).

This special issue is a representation of the Commission's recent activities toward GIScience. It is derived from Commission-sponsored activities included in the GIScience 2004 Conference.

Three of the four papers were given as oral presentations in the main conference and one at the Commission's pre-conference workshop. The former derive from extended abstracts included in the GIScience proceedings. All reflect work in progress related to goals outlined in the Commission's 2001 research agenda.

Geovisualization is becoming a diverse, multidisciplinary field of research and practice. The breadth of research issues was articulated in a 2001 international, multidisciplinary research agenda report published in CaGIS (MacEachren and Kraak 2001). In that report, four cross-cutting themes were articulated:

- To develop the understanding and integrated technologies that make it possible to take advantage of the potential offered by increasingly experiential representation technologies.
- To develop extensible methods and tools that enable understanding of, and insight to be derived from, the increasingly large and complex geospatial data sets becoming available.
- To develop a new generation of geovisualization methods and tools that support group work.

• To develop a human centered approach to geovisualization.

The papers making up this issue reflect each of these themes, and they represent the multidisciplinary perspective on geovisualization fostered by the ICA Commission.

The paper by Döllner, a computer scientist, addresses aspects of theme one. He focuses on strategies for controlling usage of 3D virtual spaces by means of constraints on navigation through the space. The application domain is 3D city models. Much of the focus is on spatial and structural constraints on what can be viewed and how the 3D space can be navigated. Beyond these issues, however, Döllner addresses an additional category of constraints that goes beyond the themes in the 2001 research agenda and which directly relate to other activities in GIScience —constraints associated with digital rights management (ways to govern and authorize the distribution and use of content and services).

Shafer and colleagues (a team of information scientists) consider web-based, visual methods and tools to enable community collaboration. Their work emphasizes synchronous geocollaboration and draws upon and extends recent developments in computer-supported cooperative work. Specifically, they review recent geocollaboration software projects. The emphasis is on the first author's dissertation research and on a commercial system with which another author is affiliated. Using these examples as a base, they outline a set of core design issues for map-based, synchronous, web-based, geocollaboration tools.

The paper by Ahonen-Rainio and Kraak (both cartographers) relates to the themes two and four, that is, extraction from complex data sets and human-centered approaches to geovisualization, respectively. The authors focus on the application of interactive visualization methods to understanding the multiple components of metadata needed to determine suitability of data sets for particular categories of use. Their visualization approach integrates traditional cartographic representations with multivariate visualization methods derived from exploratory data analysis and information visualization.

Guo and colleagues (all geographers) address the second theme. Their focus is on the development and application of methods and tools for knowledge construction from large, multivariate geospatial data sets. Specifically, they detail their work on the development and application of

an integrated visual-computational environment for multivariate data analysis. The environment they describe applies cartographic insights on bivariate color schemes to a dynamically linked set of tools that include a map, SOM, and parallel coordinate plots that depict results of computational clustering. Their application focus is cancer data analysis.

REFERENCES

Dykes, J., A. M. MacEachren, and M.-J. Kraak. (eds). 2005. Exploring geovisualization. Amsterdam: Elsevier.

MacEachren, A. M. and M.-J. Kraak. 2001. Research challenges in geovisualization. Cartography and Geographic Information Science 28(1): 3-12.

Constraints as Means of Controlling Usage of Geovirtual Environments

Jürgen Döllner

In this paper a concept for controlling the usage of geovirtual environments by means of constraints is developed. Constraints serve to improve the usability of geovirtual environments by guarding the navigation and interaction processes of users. In addition, they facilitate the implementation of Digital Rights Management for geovirtual environments. The presented approach distinguishes spatial constraints, structural constraints, and redistribution constraints. Several types of spatial constraints have been identified for navigation in geovirtual environments. To demonstrate their applications, this paper reports on using constraints in virtual 3D city models.

Keywords: Geovirtual environments, geovisualization, 3D maps, 3D city models, navigation, user guidance, usability, constraints

Designing the Next Generation of Distributed, Geocollaborative Tools

Wendy A. Schafer, Craig H. Ganoe, Lu Xiao, Gabriel Coch, and John M. Carroll

Geocollaboration is a new field of research that investigates how technology can support human-human collaboration with geospatial information. This paper considers the design issues inherent in distributed geospatial software. It looks at providing a non-spatial

communication channel, supporting real-time synchronous awareness, designing interaction techniques, establishing common ground, and using floor control and attention techniques. Using examples from existing geocollaboration tools and realistic geocollaboration scenarios, it demonstrates some of the design alternatives for geocollaboration. The paper concludes with a future research agenda describing the complexities in supporting longer-term geocollaboration activities.

Deciding on Fitness for Use: Evaluating the Utility of Sample Maps as an Element of Geospatial Metadata

Paula Ahonen-Rainio and Menno-Jan Kraak

Metadata that describe characteristics of geographic datasets are used to discover potential datasets and evaluate their suitability for intended purposes. Here sample maps are suggested as tools for evaluating datasets. Their usefulness in this process was studied as part of a wider research on visualization of geospatial metadata. First, design concepts were tested with twelve subjects who commented different static presentations of sample maps and multivariate visualizations. Then a prototype of an interactive metadata environment composed of sample maps, textual metadata documents, and a parallel coordinate plot was tested with eighteen subjects whose task it was to select the most suitable dataset from among six alternatives each of which represented the same theme. The subjects determined suitability within a use scenario. The prototype proved to be a valuable tool in the evaluation process, especially because multiple maps could be compared.

Multivariate Analysis and Geovisualization with an Integrated Geographic Knowledge Discovery Approach

Diansheng Guo, Mark Gahegan, Alan M. MacEachren, and Biliang Zhou

The discovery, interpretation, and presentation of multivariate spatial patterns are important for scientific understanding of complex geographic problems. This research integrates computational, visual, and cartographic methods together to detect and visualize multivariate spatial patterns. The integrated approach is able to: (1) perform multivariate analysis, dimensional reduction, and data reduction (summarizing a large number of input data items in a moderate number of clusters) with the

Self-Organizing Map (SOM); (2) encode the SOM result with a systematically designed color scheme; (3) visualize the multivariate patterns with a modified Parallel Coordinate Plot (PCP) display and a geographic map (GeoMap); and (4) support human interactions to explore and examine patterns. The research shows that such “mixed initiative” methods (computational and visual) can mitigate each other’s weakness and collaboratively discover complex patterns in large geographic datasets, in an effective and efficient way.
KEYWORDS: Spatial data mining, geovisualization, self-organizing map (SOM), multidimensional visualization, multivariate mapping, bivariate color scheme

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Abstracts

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Climate Forecast Maps as a Communication and Decision-Support Tool: An Empirical Test with Prospective Policy Makers

Toru Ishikawa, Anthony G. Barnston, Kim A. Kastens, Patrick Louchouarn, and Chester F. Ropelewski

This paper reports an empirical study of communication issues concerning climate forecasts. Students in a professional master’s degree (MPA) program in environmental science and policy participated in the study as prospective policy makers. Participants viewed a set of currently issued precipitation forecast maps, and answered questions designed to assess, in the context relevant to agricultural and environmental decision-making, their understanding and evaluation of the maps. Participants failed to understand some aspects of the information shown on the maps, in the current design, as the map makers intended. In particular, participants had difficulty understanding probability forecast maps and distinguishing probabilistic three category forecasts and the amount of precipitation. Most participants evaluated the degree of

agreement between the forecast and observation as “agree only slightly” or “agree somewhat.” More than half of the participants were not inclined to use the forecasts in agricultural decision-making. Implications for improvement in design for better communication are discussed.
KEYWORDS: Cartographic communication, climate forecasts, probabilities, uncertainty, decision making, policy makers

Cubic Map Algebra Functions for Spatio-Temporal Analysis

Jeremy Mennis, Roland Viger, and C. Dana Tomlin
We propose an extension of map algebra to three dimensions for spatio-temporal data handling. This approach yields a new class of map algebra functions that we call "cube functions." Whereas conventional map algebra functions operate on data layers representing two-dimensional space, cube functions operate on data cubes representing two-dimensional space over a third-dimensional period of time. We describe the prototype implementation of a spatio-temporal data structure and selected cube function versions of conventional local, focal, and zonal map algebra functions. The utility of cube functions is demonstrated through a case study analyzing the spatio-temporal variability of remotely sensed, southeastern U.S. vegetation character over various land covers and during different El Niño/Southern Oscillation (ENSO) phases. Like conventional map algebra, the application of cube functions may demand significant data preprocessing when integrating diverse data sets, and are subject to limitations related to data storage and algorithm performance. Solutions to these issues include extending data compression and computing strategies for calculations on very large data volumes to spatio-temporal data handling.

Individual Differences in Map Reading Spatial Abilities Using Perceptual and Memory Processes

Robert Earl Lloyd and Rick L. Bunch
Central to spatial intelligence are the capacities to perceive the visual world accurately, to perform transformations and modifications upon one’s initial perceptions, and to be able to re-create aspects of one’s visual experiences, even in the absence of relevant physical stimulation.

One can be asked to produce forms or simply to manipulate those that have been provided [Gardner 1983, p. 173].

The above quote is from a book on multiple intelligences that argues spatial intelligence is one of seven human intelligences. By this definition, the two main expressions of spatial intelligence are related to being accurate and using memory. Individuals can demonstrate their spatial intelligence in many ways. Some individuals might excel at navigating in unfamiliar environments while others are better at remembering the locations of landmarks in familiar environments (Galea and Kimura 1993; Silverman et al. 2000). The sex of an individual may reflect some environmental variables that are expressed through genetic factors. Both natural and sexual selection have been suggested as evolutionary processes that separate females and males on the basis of spatial abilities (Ecuyer-Dab and Robert 2004). The purpose of the current study is to consider the variation of a spatial ability related to map reading that might be explained by both biological and environmental variables. The basic problem was to conduct a map reading experiment that would require subjects to use both perceptual and memory processes. The research objective of the study was to model the variation of the efficiency of human performance on map-reading tasks with variables related to the nature of the task and the map readers.

Deriving New Minimum Cost Pathways from Existing Paths

Denis J. Dean

Without a priori cell traversing cost data, conventional GIS-based techniques cannot be used to find minimum cost paths from specified starting points to specified ending points. However, in one class of problems where these costs do not exist a priori, it may be possible to derive them. This class of problems is characterized by the presence of an existing minimum cost path that is subject to the same traversing cost mechanics as the new path that is being contemplated. This study developed and evaluated linear programming-based techniques for deriving both isotropic and anisotropic traversing costs from existing minimum cost pathways. The derived costs can then be used to find minimum cost routes for new pathways that are subject to the same cost mechanics as the existing pathways. The techniques presented here were

evaluated by applying them to situations found in the forest road network of the Arapaho and Roosevelt National Forests (ARNF) in Colorado. In 18 of the 19 situations evaluated, the predicted routes generated using the techniques presented here agreed with actual roads found in the ARNF.
KEYWORDS: Cost spreading, linear programming, minimum cost paths, isotropic costs, anisotropic costs