Visualizing Historical Narratives: Geographically-Integrated History and Dynamics GIS

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Position paper for the National Endowment for the Humanities workshop "Visualizing the Past: Tools and Techniques for Understanding Historical Processes," 20-21 February 2009, University of Richmond, Virginia, USA

Computational thinking has enabled many new scientific discoveries through the development of new algorithms, simulation models, visualization, and novel approaches to summarize the patterns and structure of complex systems. In contrast to the natural sciences, the historical social sciences (anthropology/archaeology, economics, geography, history, and sociology) pose additional challenges because data are often qualitative, vague, inconclusive, and highly uncertain. Existing computational methods reach their limits quickly with data for the historical social sciences. The authors are developing geographically-integrated history methods to overcome these limits by addressing the importance of "place" to integrate data as the foundation of knowledge creation about how humans, events, and environments were connected to form historical narratives within and across places. Narratives are considered one of the unique and effective forms of knowledge and communication. Narratives enhance the understanding of causality by relating it to time and place and of the exceptional, such as the emergence of new forms, and they illuminate the factors producing innovation and entrepreneurship (Bruner, 1985; Hexter, 1971). Dynamics GIS (geographic information systems) and related information and visualization technologies will provide the backbone for

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understanding geographically integrated complex systems within which social networks developed historically (Yuan, 2008).

The geographically-integrated history paradigm posits that (1) the history of any place is shaped in significant ways by the way the place is connected to other places and by the changes in these connections over time (Owens, 2007); (2) historical periods are complex, dynamic, nonlinear systems that are spatially large, and in more recent centuries, global in extension, and that sometimes become unstable, leading to a phase transition, bifurcation, and the organization of new systems (Puu, 2003; Rosser, 2000); and (3) within such systems, people and places are connected by self-organizing networks that are the sources of innovation and the emergence of new forms (Burt, 2004; Fujita, Krugman & Venables, 1999; Grabher, 2006; Newman, Barabási & Watts, 2006). Although useful for keeping track of the connections of social network to place and for spatial analysis and visualization, GIS suffer from four defects that interfere with their use as a basis for transforming the historical social sciences. First, GIS is difficult for historical researchers and their students to master. Second, current GIS are largely static, and because they are based on space defined by polygons, they deal poorly with temporal factors of actant change and movement that are essential to historical study. Third, current GIS software does not permit dealing simultaneously with the interactions of more than a few variables. And finally, much significant historical data are qualitative, imprecise, contradictory, incomplete, uncertain, and otherwise messy and, therefore, difficult to represent in current GIS (Gregory & Ell, 2008).

The authors' goal is to develop computational methods and data models, coupled with new GIS frameworks, to address complex, dynamic, nonlinear systems of social networks by geographically integrating historical data of many kinds to form narrative knowledge. To transform the research paradigm within the historical social sciences, different products will be presented in freely distributed forms that will provide interested researchers and their students with access without having to climb over prohibitively high learning thresholds. These products will include collaborative protocols, ontologies, tools, algorithms, database models of various types with data included, metadata models, digital gazetteer models, examples of mathematical modeling to make use of qualitative and different types of flawed data, and an elementary instructional book for self-guided tutorial in GIS or for classroom use (an adaptation for the historians of Watry & Ames, 2007). Much of this material will be tested through use in the core courses of Idaho State University's innovative, GIS-based graduate program in geographically-integrated history. Thus, our final product will be not only advances on a series of interrelated research fronts (described below) but also web-based education materials for classroom use and self-training.[8]

The authors' unusual intellectual partnership is a product of an ongoing research collaboration as part of the European Science Foundation's EUROCORES (European Collaborative Research) Scheme's program "The Evolution of Cooperation and Trading" (TECT). Owens formulated a multinational, multidisciplinary TECT project entitled "Dynamic Complexity of Cooperation-Based Self-Organizing Commercial Networks in the First Global Age [1400-1800]" (Crespo Solana & Owens, 2008; Owens, 2008).[9]

The authors concentrate their efforts to analyze and visualize historical narratives on the first global age (1400-1800) because this complex, dynamic, nonlinear system has disappeared and its outcomes can be used in an iterative process to improve our understanding of the system itself and of any models and simulations that are created. We focus specifically on cooperation-based commercial networks because since the 1960s much economic history has centered on the ideal types "markets" or "institutions". As it has become apparent that neither model produces effective understandings of economic growth, entrepreneurship, and innovation, researchers have placed increasing emphasis on the analysis of multi-dimensional social networks (Grabher, 2006; Schulte Beerbühl & Vögele, 2004). However, due to the absence

[8] Distribution will be through the existing *MapWindow* web site (www.mapwindow.org/), directed by Ames, and will likely take a form similar to that of the DARPA Agent Markup Language (DAML; www.daml.org/) web site, which is important for the authors' research.

[9] Owens' project leadership and participation are funded by the U.S. National Science Foundation (Award No. SES-0740345; $394,000; 2007-2010).

of adequate computation concepts, data models, and tools, this newer research does not capture adequately the dynamism of overlapping networks within a complex, nonlinear system.

The authors will reach their goal of developing computational methods and data models coupled with new GIS frameworks to address complex, dynamic, nonlinear systems of social networks by geographically integrating historical data of many kinds to form narrative knowledge through five interrelated activities.

1) Connections will be established among crucial concepts (e.g. social networks, business cycles, climate change). This is no trivial task within this domain (History) because existing ontologies are not, in their current forms, satisfactory. We conceive of the first global age as an open, complex, dynamic, nonlinear system that was composed of the sub-systems characteristic of spatially large geographic regions. Although these sub-systems can be described in terms of hierarchy and nonlinear dynamics, the hierarchies were largely segmented ones within which horizontal links at each level were frequently stronger than vertical links, which compromised hierarchical governance and served as a principal basis of nonlinear dynamics in human systems. These segmented hierarchies are particularly notable in economic and political institutions, which depended on a high level of cooperation in order to function. System stability depended on a small number of variables, which we will identify, that were close to instability (Haken, 1983; Puu, 2003; Rosser, 2000). These sub-systems were linked and crossed by multiple self-organizing social networks that frequently connected with each other in irregular patterns (Ikegami, 2000; White, 1992). Because these networks were the major source of innovation and the emergence of new forms, and ultimately of system instability, discontinuity, and bifurcation, they are the principal focus of narrative construction. The meaning of any one of these concepts when applied to a particular unit of time depends on its connections to the other concepts. This ontological research will underpin the development of dynamics GIS, the means to represent and link complex entities within databases, agent-based simulations for testing temporal GIS design and the elaboration of complex historical narratives for knowledge creation when data are incomplete, and text-mining to extract associations among events and places through self-organizing map techniques.

2) The authors are developing algorithms and tools for using historical data that are vague, uncertain, and incomplete and qualitative data within a computational context. For example, Coppola and Owens have begun a collaboration to apply fuzzy logic to the representation of different levels of trust in cooperative relationships within 16th-century commercial networks. Besides serving as an exploratory technique for understanding networks, this fuzzy modeling serves to link incidents and axioms with concepts (e.g. trust) and their relations (e.g. commercial networks) for ontology development.

3) For the creation of dynamics GIS for the production of narrative knowledge, new means for the representation of data for organizing, storing, manipulating, and recovering them for exploration using computational tools must be developed in interaction with the first two tasks. Our focus in this area is the development of Kantabutra's Intentionally-Linked Entities (ILE) database system (Kantabutra, 2007). Preliminary results suggest that ILE provides the means to represent complex entities, such as space-time blocks linking actant interactions that are frames and elements within which historical social scientists can enter pieces of information to build up stories. Moreover, ILE can serve to link interpretations to concepts and to establish a relational context establishing the meaning of a concept at different time periods, thus becoming a *conceptbase*.

4) Building on the first three tasks, the authors will develop new forms of modeling and simulation to represent the inferences of domain experts and create intellectually useful abstractions that increase understanding of complex reality. Because they also promise help in overcoming disadvantages of current GIS, the project will give early attention to multilevel modeling (Luke, 2004), fuzzy rule-based modeling (Zadeh, 1997), and neural networks (an area of expertise of Coppola and Kantabutra).

5) From the beginning, the master metaphor for GIS has been the map. For the dynamics GIS it will create, the authors will develop new metaphors beyond the map for temporal GIS and new forms of visualization. Effective visualization, taking into account both human cognition and art, is necessary for the reduction of the cognitive weight when the alternatives are numerous and surpass the capabilities of human reason and for the understanding of the evolution of the networks and their geographic environment/sub-systems. Moreover, the development of effective visualizations for the comprehension and communication of

the spatial-temporal form of the world and its processes will be fundamental for the implantation of this type of research within the historical social sciences because of the traditional dependence of these disciplines on text as the means of presenting results.

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