Visual analytics and geo-attribute spaces

Position paper
on
Computation and Visualization for the Understanding of Dynamics in Geographic Domains

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Thinking and reasoning about the size, shape, distribution, and scale of spatial-temporal phenomena are at the heart of geography. The application of computation and visualization to geographic problems is not new but has now reached a point when we are able not just to use existing tools from other disciplines (e.g. statistics and computer science) but really shape and develop methods that are unique and specifically designed with geographic information in mind.

An increasing emphasis, both from the professional and the research communities, is currently put on developing tools to handle a wider range of data uncertainties such as subjectivity, vagueness and issues of relevance. The way we reason about our environment would be very restricted if we do not allow for an explicit recognition of these uncertainties and find ways to capture, describe, formally represent, and reason with geographic data in this manner.

As authors of this position paper, we both are well versed in new approaches within geocomputation, visualization and cognitive semantics. In a recent line of papers Dr. Ahlqvist has outlined a framework for representing and reasoning with the deeper semantics of geographic concepts such as the dynamics of land cover and land use. Further developments will focus on spatial analysis on semantically rich data as a way of computing with words. Dr. Kwan, on the other hand, has conducted considerable research on the spatial and temporal dynamics of people's daily activities and travel through 3D geovisualization and geocomputation. One of her recent projects (3D-VQGIS) extended the capabilities of existing GIS for the 3D visualization and qualitative analysis of geospatial data. Our research expertise and experience would be an important element in contributing to research leadership pertinent to the themes of the workshop. The following research synopsis outlines our main interests in and visions for semantics, multiple perspectives, fuzzy ontologies, visual analytics and spatial analysis.

Most current approaches to ontology as a way to represent and reason with geographic terms suffer from their reliance on crisp classes, properties and relations paired with a first-order logic mode of reasoning. Our vision of computational means to work with an explicit recognition of the inherent imperfection of geographic data calls for something radically different. A semantic theory for geographic information could help develop a comprehensive representation that not only includes geographic space-time but also

include cognitive, conceptual spaces as an integral part. In our current work we have developed a formal specification of uncertain concept spaces that can represent geographic terms using fuzzy and rough set based constructs. Initial experiments have looked at various forms of using these representations to explore the subjectivity of land cover and land use categories as well as their temporal dynamics. A true integration of these spaces would allow us to extend theory and methods developed for analysis of space-time into semantic spaces, an area that opens tremendous opportunities to extend the computational toolkit for nominal geographic information analysis into spatial analysis and visualization of geo-attribute spaces.

The proposed representation turns ontologies from being crisp and organized descriptions to disaggregated collections of vague formal statements, something we could tentatively call fuzzy ontologies. One of the underlying motivations for seeking a continuous representation of semantics is that discrete logics and ontologies embody an ontological version of the modifiable areal unit problem. These developments calls into question of there is a true distinction between attributes concepts, and objects, or between events and processes, or if these notions are just an effect of scale. As one example, the ongoing process of exurbanization seen around many cities can also be looked at as an event in history. Both views are valid and relevant for specific purposes but there is an inherent vagueness in any such distinction, which needs to be represented both formally and visually.

The use of visual analytics for enhancing our understanding of space-time dynamics thus faces various data uncertainties. An important source of these uncertainties is human subjectivity that is associated with human social and behavioral dynamics (for example, in the domain of individuals travel activities). Spatial knowledge of human subjects is often imprecise and vague, and georeferencing in everyday life is seldom based on any specific coordinate systems or precise locational information of geographical entities and their boundaries. It is difficult to visualize human experiences and spatial knowledge without taking into account the ways in which a particular person reason about and make decision pertinent to spatial relations. As human spatial experience is qualitative and fuzzy in nature, often expressed in terms of imprecise geographical reference and spatial boundaries, it is important that computation and visualization of human dynamics take individual perspectives into account (especially in terms of dealing with people's emotions and feelings associated with particular places). Although recent research on qualitative georeferencing and geosemantics has shed light on many aspects of this problem, much research is still needed in this direction.

Regarding the future of computation and visualization for analyzing human social and behavioral dynamics, we believe it is critical to work closely with experts in allied fields (e.g. computer scientists and arts/animation experts) – as interaction with these experts would enhance our ability to leverage cutting edge research in those fields within geography. We are currently at close interaction with faculty that work on individual, daily perceptions of local environments and personal life trajectories up to physical models of vegetation and climate dynamics over thousands of years. Further, it is also important to conduct thorough analysis of how relevant and usable a particular solution

or application is. A further vision is to bring back art into the science of modern geovisualization. The combination of science and art – a traditional hallmark of cartographic visualization - has until now received scant attention in computational visualization. We believe, with the increased demand for individualized and subjective capabilities of future systems, that artistic skills and knowledge is essential for richer and more expressive geovisualization.