DALIA VARANKA
U.S. Geological Survey
Email: dvaranka@usgs.gov

Dalia Varanka is a Research Physical Scientist with the U.S. Geological Survey (USGS). She received her B.A. degree from the University of Wisconsin-Green Bay and her M.S. degree at the University of Illinois at Chicago. Varanka's Ph.D. degree, University of Wisconsin-Milwaukee, focused on the spatial information theory, the history of cartography, and cartography and society. She began her Federal career in 1993 with the U.S. Bureau of Land Management practicing Geographic Information Systems (GIS). She joined the USGS and has been a research scientist since 1999 with the National Geospatial Program. Varanka leads the Geospatial Semantics and Ontology project "The National Map as Knowledge Base" of the Center of Excellence for Geospatial Information Science (https://www.usgs.gov/core-science-systems/ngp/cegis) and teaches Geospatial Ontology and Semantics for the GIS degree program at the Johns Hopkins University Advanced Academic Program. Varanka is the Chairperson of the International Cartography Association Commission on Geospatial Semantics.

Integrating the Sociology of Space with Geospatial Semantic Relation Properties for Data Graphs

Since at least 1980, spatial analysis methods and subfields of geographic information systems (GIS) were critiqued by cultural geographers that their basis in Cartesian frameworks are incomplete. Critiques of GIS and quantitative spatial analysis are predominantly epistemological. Some specific points argued in the science literature were that that the technologies are based on data instead of information; research interpretations were simplistic; and that the culture of techno-specialists fails to accommodate marginalized voices. These critiques bolstered mitigating movements such as Public Participation GIS, Volunteered Geographic Information, and the GeoWeb. However, Critical GIS remained a mostly conceptual practice, lacking a means of connecting objectives to the formal computational environment (Schuurman 2006).

The movement to incorporate multiple representations of the same reality pushed geographic information science (GIScience) toward the study of ontologies (Winter 2001; Peuquet 2002). The dual nature of applied ontologies, namely their ability to accommodate diverse viewpoints and simultaneously act as "boundary object" to be debated so that they reflect a commonly agreed reality (Harvey and Christman 1998) rests primarily on expressions of semantics, relations, and contexts. Research in this area has evolved to include a body of work called geospatial semantic technology that is poised to have a significant impact on GIScience. Semantic technology based on graph data models articulates and addresses the conceptual and formalizes approaches of geographic ontology.

Triple graphs support semantic specification that are responsive to epistemological and ontological aspects of geographic concepts because of specific technical characteristics. The flexibility of the data model, the triple, also called tuple, offers an easy way to convert data from various types and sources for easy reuse of legacy investments, incorporate new data that doesn't conform to any pre-determined design, and reduce data duplication, because objects can have any number of property relations to other entities. Subgraphs can be used as patterns, constraints, semantic classifications, and other semantic structures and are as easily created as typing a text file. Graphs are often used as an integrative technology—a "glue"—to connect complex chains of processing steps where manual intervention is often required at the cost of information loss. Web Ontology Language (OWL) and SPARQL Protocol and RDF Query Language (SPARQL) support relationship discovery that is intuitively tractable for automatic code generation and interface building. Because SPARQL matches each part of the triple pattern to the graph database, custom extracts and specialized queries are easier because processing skips long chains of table "relates" to search and retrieve data. Reasoning technology such as SPARQL not only utilizes advanced techniques, but also contributes back to them by identifying contradictory logical propositions in knowledge tools, and in other ways. Instead of scaling through partitioning of data, semantic technology scales by exchanging information across endpoints across the world.

The responsiveness of semantic technology to users and communities may potentially address issues posed by earlier critical analyses of the broad field of GIS, but this responsiveness seems to others to introduce human bias in knowledge information these systems support. Research is underway in techniques to resolve differences, either by ontology alignments, upper-level frameworks based on philosophical realism, or other formal structures. These integrative structures depend on the design of relations to be effective. For GIS, relations are typically identified as location, geometry, and topology. One challenge is modeling socially constructed spatial relations. The myriad methods by which humans organize space and corresponding data are severely constrained by geospatial data models (Sinton 1978). Spatial relations as defined by geometry are mechanistic and quantified. Euclidean geometry captures ''only limited and highly abstracted aspects of geometry and space'' (Frank and Mark 1991, 149).

Drawing on theoretical analyses from critical GIS, spatial linguistics, and geography, socially constructed relations are different from geometric relations in systematic ways. Spatial regions are made and unmade by social processes that are the ontological relations hidden by simplistic geometric representations but modified by the material world (Wikipedia 2019). Massey (1999) postulated that such relations are characterized by faster and more humanly observable temporal aspects, involving representations of initial conditions, history of adaptation, and outcomes. Ostis (2015) linked sociospatial relations with geometric relations, as with distance and familiarity, boundaries and identities, and density and attraction. This description of socially constructed spatial relations may seem to be synonymous with "environment." The environment is what surrounds or sets conditions within which an entity operates; spatial relations are required for entities to exist and operate in those environments. A more ontological approach to spatial relations research suggests a closer examination of semantics of places and contributes to improved semantic expression of not only “where” things are, but also “why.”

Analyses whether ontology modeling can represent social spatial concepts with databases of instances, especially involving information inheritance, inference, and context, are few or non-existent. A current study at the USGS posits that socially constructed spatial relations address concepts of interactions instead of intersections, human/tool agents instead of physical processes, and broader ranges of geographical outcomes. The hypothesis is that social space can be represented by using patterns of logic relations between sets of entities. The data corpus of spatial relations was extracted from geographic term definitions. The relations were further analyzed as primitives using Case Grammar Matrix models. These findings are being related to other vocabularies such as Web Ontology Language (OWL) properties or Shapes Constraint Language (SHACL). This approach allows a broad range of natural language terms to instantiate ontology sub-types, while supporting inferences to study their logical implications.

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