Ontology of Topographic Eminences for the National Map

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Topographic Eminences

Topographic eminences form a fundamental superordinate category of landforms, including all convex shaped topographic landforms that rise above their immediate surroundings. People are known to recognize a wide variety of eminences in the landscape. However, there is a huge gap between how people cognize natural landscape features, including eminences, and how they are currently represented in geospatial information systems. Most geographic data dictionaries, gazetteers, and national map standards merely list feature types (e.g., mountain, hill, butte, mesa) in lieu of representing the semantics of feature types commonly recognized by people. Specification of the semantics of some popular feature types is limited to simplistic definitions not useful in any kind of taxonomy or ontology development. Clearly, a successful National Map project will need an ontology of eminences, and underlying object based topographic database models to support ontology based information retrieval.

Affordance Based Ontology of Eminences

Research has clearly shown that landform cognition is strongly influenced by linguistic and cultural background (Mark and Turk, 2003). A comprehensive ontology of eminences will therefore be unavoidably pluralistic. Such ontologies and strategies for meshing together such ontologies are unlikely to be available for quite a few years. We contend that a universal, cross cutting ontology of eminence will be much simpler and more useful to the National Map if it corresponds primarily to experiential cognitive models of the landscape. Gibson (1979) introduced the idea that humans respond to certain environmental cues or visual "affordances" to develop a shared sense of their surrounding environment. Lakoff (1990) proposed the idea of experiential realism to assert the existence of a mind independent 'real world' and to explain why because of similar corporeal existence, we all are similar in how we experience reality. Based on these ideas, we assert that a relatively shallow, but universally applicable ontology of eminences can be developed from consideration of fundamental spatial properties such as geometric form, topological and mereotopological properties, and the scale dependence of these eminence properties.

One such universally recognized affordance is that eminences are "attached" to the landscape; unlike other objects, their convex form is inextricably linked to their spatial extent. The affordance based ontology of eminence therefore requires specification of the perceptually valid extent. We have developed prototype methods for identifying and delineating eminences from digital elevation models. Our algorithms can be customized through intuitive parameters such as topographic prominence, isolation, elevation, slope, and visibility. Two types of delineation algorithms were developed and tested for the glacial White Mountains region in New England and for arid areas in New Mexico. There is sufficient evidence of the utility of our approach in extracting eminences that correspond to topographic features listed in the USGS maintained GNIS database (Sinha 2008). We have also found that when eminences are classified based on their form (shape and size) and mereotopological properties, the spatial distribution of the eminence classes

matches closely to that of feature types inferred on basis of common noun referents that are part of feature names (e.g., *Mount* Washington, Sugar *Hill*, Nell's *Peak*).

Vertically Integrated Multi-Tiered Ontology

Based on our success in eminence delineation and characterization, we strongly advocate explicit integration of topographic features and the raster elevation layer of the National Map through a scale dependent, three tier ontology. The lowest level of the ontology requires the specification of the elevation layer and its derivative fields (e.g., slope, aspect, curvature); the second tier introduces geomorphometric feature primitives (e.g., peak, pass, crest, ridge) that can be extracted from the elevation and derivative fields. Also included in this mid tier are surface networks that may be constructed by linking the qualitative features into a topologically connected system. The specification of the semantics of these feature primitives is relevant only for their utility as parameters for algorithms that both define and delineate eminences. The delineated eminences become part of the uppermost tier dedicated to the specification of eminences as a fundamental category of landscape objects with consistent geometric, topological and partonomic properties.

This tiered ontology concept is useful because it ensures a seamless integration of the semantics of higher level objects, the process of their realization from lower level features, and the role of the elevation and derivative fields with respect to object based terrain modeling. This approach also allows for object generalization as changing the geographic scale of analysis is possible for any tier through variation of input parameters. Topographic eminence is a superordinate category; ultimately it will need to be extended with more basic (and subordinate) level categories. If the National Map information system adopts the tiered ontology concept, and supports an intuitive ontology specification tool, we believe it will not only be a mere provider of information, but also will become the vehicle of choice for extending topographic feature semantics through more specialized, upper level terrain ontologies.

References

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Biographic Sketch

Gaurav Sinha is currently an Assistant Professor of Geography at Ohio University where he is pursuing his research interests in landscape ontologies, environmental data modeling, and qualitative terrain reasoning. David Mark is a SUNY Distinguished Professor of Geography at the University at Buffalo. His current research is focused on ethnophysiography, and documenting conceptualizations of landscape features in different languages and cultures. That project represents the combination of his long standing research interest in geographic cognition, and his concentration on geospatial cognition. The authors' research thus converges with multiple themes of importance to the Ontology for the National Map (e.g., ontology of topographic features, query formulation and terrain information extraction, integrated vector/raster terrain representation, and ontology driven topographic information systems). Their interest in this specialist meeting is to share their model for linking people's fundamental cognitive models of topographic features to the field based digital elevation model widely used to store topographic variation data.