

The University Consortium for Geographic Information Science

Research Priorities



GRADATION AND OBJECTS WITH INDETERMINATE BOUNDARIES

THE PRIORITY

A formal ontology for categorical gradation in geographic space and for objects with indeterminate boundaries, together with computational representations, is needed to extend the capabilities of GIS and geospatial computation.

DESCRIPTION OF RESEARCH CHALLENGE

Standard GIS data models deal either with geospatial objects with distinct (crisp) boundaries, or with single-valued fields of continuous numerical variation. However, these models are inadequate for many types of phenomena, including examples from both physical (soil formations, plant communities) and human (neighborhoods, ethnic communities) geography. This problem was recognized some time ago (Chrisman 1982, Goodchild and Dubuc 1987) and was the subject of an important book (Burrough and Frank 1996). Although some solutions were proposed in the Burrough and Frank book and elsewhere, almost a decade later GIS users do not have solutions or ready-to-hand methods. The lack of computational methods to handle objects with indeterminate boundaries may be the

most significant gap in the representational power of current GIS software.

The problem of categorical gradation is not identical to the problem of objects with indeterminate boundaries, but the two problems have a hand-in-glove relationship. Solutions to the gradation problem will automatically provide some solutions to the problem of objects with indeterminate boundaries, since being part of an object is itself a categorical spatial variable.

Current representations of spatial entities are either object- or field-based. Object-based representations include points, lines and polygons, while fields can be represented by raster grids, TINs or polygon coverages. These representations are not adequate for capturing the nature of many important geographical phenomena.

IMPORTANCE OF RESEARCH CHALLENGE

The delineation of spatial entities themselves is fundamental to any subsequent analysis, but often involves transformation from a conceptual entity that is initially defined without reference to the spatial domain. For example, a desert may be defined in

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terms of rainfall or habitat suitability for typical "desert" species, and its spatial extent determined through a process of analyzing the distribution of environmental characteristics throughout a spatial domain. This process of deriving a spatial entity based on a conceptual definition may involve significant loss of information if the available spatial entity types are not appropriate to the conceptual domain. This suggests a need for spatial representations that conform to common conceptual models of continuous, distributional phenomena.

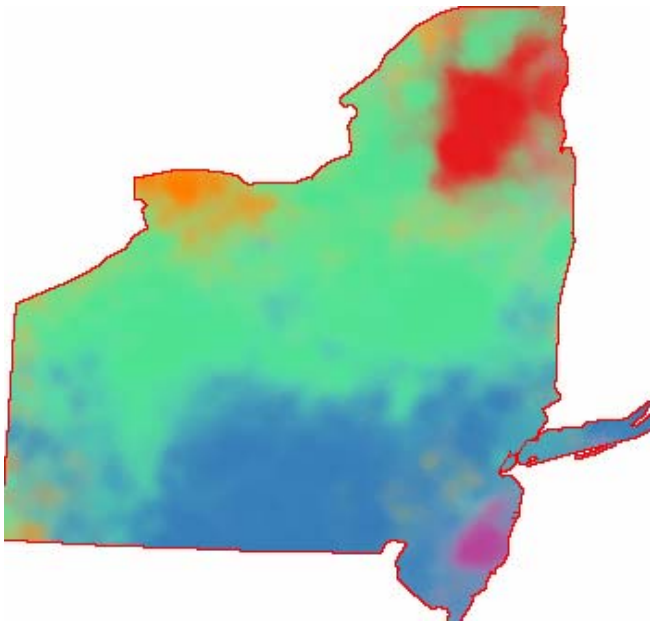


Figure 1: Gradation of Forest Type in Part of Eastern North America (after Kronenfeld 2001)

Entities with indistinct boundaries are found in both environmental (e.g. mountains; see Smith and Mark 2002), and social science (e.g. neighborhoods (Montello et al. 2001)). Spatial gradation, or entities with graded boundaries, may be seen as the spatial reflection of the fact that categories typically show cores of prototypical members, and gradients of similarity based on family resemblance to the core. Ontological and representational formalisms for graded spatial entities thus must be developed to correspond to the conceptual entities utilized in the environmental and social sciences.

EMINENT RESEARCH QUESTIONS

Research is needed to characterize and categorize different types of gradation. Some of the issues to be addressed include uncertainty versus gradation (probability, fuzziness, etc.); individual fuzzy objects versus continuous-valued classification of a spatial domain; rules of mutual exclusivity between fuzzy objects; studies of how people delimit objects with indeterminate boundaries, or reason about them in various contexts; and development of queries and other GIS functions involving categorical coverages with gradation, and/or objects with indeterminate boundaries.

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