A comparison of methods for computing cardinal directional relations of polygons.

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Abstract

Spatial relations determine how objects in space interact with each other. In the context of GIS, these relations are represented by algorithms which best approximate those found and experienced in the real world. This research focuses on directional relations between polygons. We examine the impact of spatial properties on commonly used methods for computing directional relations between polygons. Early results of a quantitative comparison of methods reveals that distance has the greatest impact on methods for computing directional relations, and at short distances, changes in spatial properties have method-dependent impacts on computation results.

Background and Relevance

Informally, directionality in spatial relations may be specified in a number of commonly used systems, such as 4 (N, E, S, W) and 8 (+NE, SE, SW, NW) level cardinality, compass bearing (0□ - 360□) and azimuth (0 - +/-180). However, directional relations (DR) among polygons in the plane are often ambiguous and thus difficult to formally state. Complexity is introduced by the spatial properties of polygons such as shape and area, issues of polygon representation such as boundary indeterminacy as well as additional spatial relationships, such as the distance between two polygons. Due to the difficulty in formalizing DR for polygons, it is functionality that is rarely implemented in GIS or spatial database software (Miller and Wentz 2003). However, humans naturally use DR in their description of the world, so systems designed to interface between people and spatial information should have some capability for DR. Examples of such systems include navigation systems, computer vision, and GIS query languages.

The goal of this paper is to quantify the directional relations of two discrete polygons in a two dimensional plane. This limits the problem space sufficiently to enable a quantitative comparison of some commonly used algorithms for computing directional relations of polygons. We assume that a set of directional relations exist for any pair of polygons, and that these relations can be represented in the 4 or 8 cardinal systems. We allow for multiple relations and compare among different methods by using the framework called 'cardinal relations with percentages' (Skiadopoulos et al. 2005).

Methods and Data

Generally, methods for computing DR fall into three broad categories. Centroid-based methods use the centroid of the reference polygon to define the frame of reference for determining the DR to the target polygon (Peuquet and Zhang 1987). Minimum-bounding rectangle (MBR) based methods use MBRs to generalize the geometry of the reference polygon or the target polygon or both (Skiadopoulos et al. 2005). Finally, voronoi-based methods use properties of voronoi diagrams and delaunay triangulation to compute DR between polygons (Yan et al. 2006). We have selected methods from each of these categories to compare in scenarios of varying polygon complexity.

The spatial properties of the DR simulation experiments included size, shape, and orientation. All spatial properties were modified separately, while distance, a spatial relationship, was inherent in all of the experiments. In order to assess the performance of methods in computing DR of disjoint and overlapping polygons, six distances were evaluated: three overlapping and three disjoint. For each distance, spatial properties were modified at three different levels (size, shape, and orientation), and a DR was computed for each. Thus, for each of the six distances, three properties were varied three times, resulting in a total of 54 experiments (a total of 108 including inverse experiments).

Results

Preliminary results indicate that as distance increases between polygons, the degree of power associated with a DR between them is strengthened, and variability across computing methods for DR declines. This is a natural property to emerge, indicating that as polygons become more disjoint, transformations in shape, size and orientation have less impact on the computation of DR, regardless of the method used. However, the inverse is also true, so as distance between polygons declines, and polygons become intertwined, DR are more ambiguous and there is greater variability in the methods of computation.

Conclusions

Computational methods for polygonal DR is generally done on an application-specific basis because the algorithms available for DR computation are impacted by complexity introduced by the wide variety of spatial properties associated with polygon data. In this research, we have attempted to determine the role of spatial properties in some commonly used methods for computing DR. We have shown that the most important driver of accuracy is distance. Thus, our results will inform the selection of a suitable algorithm for application specific implementations.

References

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