Beyond Pairs: Generalizing the Geo-dipole for Quantifying Spatial Patterns in Geographic Fields

Rui Zhu, Phaedon C. Kyriakidis, Krzysztof Janowicz

Abstract With their increasing availability and quantity, remote sensing images have become an invaluable data source for geographic research and beyond. The detection and analysis of spatial patterns from such images and other kinds of geographic fields, constitute a core aspect of Geographic Information Science. Per-cell analysis, where one cell's characteristics are considered (geo-atom), and interaction-based analysis, where pairwise spatial relationships are considered (geo-dipole), have been widely applied to discover patterns. However, both can only characterize simple spatial patterns, such as global (overall) statistics, e.g., attribute average, variance, or pairwise auto-correlation. Such statistics alone cannot capture the full complexity of urban or natural structures embedded in geographic fields. For example, empirical (sample) correlation functions established from visually different patterns may have similar shapes, sills, and ranges. Higher-order analyses are therefore required to address this shortcoming. This work investigates the necessity and feasibility of extending the geo-dipole to a new construct, the geo-multipole, in which attribute values at multiple (more than two) locations are simultaneously considered for uncovering spatial patterns that cannot be extracted otherwise. We present experiments to illustrate the advantage of the geo-multipole over the geo-dipole in terms of quantifying spatial patterns in geographic fields. In addition, we highlight cases where two-point measures of spatial association alone are not sufficient to describe complex spatial patterns; for such cases, the geo-multipole and multiple-point (geo)statistics provide a richer analytical framework.

Keywords Spatial interaction, Multiple-point (geo)statistics, Geographic field analysis, Spatial pattern, Geo-multipole