Chapter VIII
Spatiotemporal Analysis

THE ANALYSIS OF SPATIAL FREQUENCIES

As we have suggested many times throughout the book, the general form of an archaeological problem seems to be “*why* an archaeological site is the way it is?” If we translate it into the spatial domain, we should be asking “*where* social agents performed their actions and work processes on the basis of the observed relationships between the actual locations of the social action material traces?,” or more precisely, “why those archaeological materials have been found *here* and not *elsewhere*?” Consequently, the automated archaeologist should *infer* where social agents performed their actions and work processes based on the observed relationships between the actual locations of the supposed material consequences of social action. This is the domain of application for a spatial analysis: to infer the location of what cannot be seen based on observed things that are causally related to the action to be placed. Knowing where someone made something based on what she did, is an inverse problem with multiple solutions, which can be solved using some of the methods and technologies already presented.

It is important to realize that “location” is a property of social acts, but it is not a *cause* in itself. Social action is produced *in* physical space, but it also contributes to the formation process of such space. The characteristics of space as a dimension, rather than the properties of phenomena, which are located in space, are of central and overriding concern. Consequently, “place” can only be understood according to what is performed at each place and at each moment. Social actions should be analyzed as conditioned and/or determined by other actions, because they have been performed in an intrinsically better or worse spatiotemporal location for some purpose because of their position relative to some other location for another action or the reproduction of the same action (Barceló & Pallarés, 1998). Some of the actions performed near the location increase the chances of one type of action and decrease the chances of others. What we are looking for is whether what happens in one location is the cause of what happens in neighboring locations (Barceló, 2002, 2005; Barceló, Maximiano & Vicente, 2005; Mameli, Barceló & Estévez, 2002).

The automated archaeologist’s objective is then to analyze where, when and why a social action “varies from one location (spatiotemporal) to another.” Social action is never performed isolated or in an abstract vacuum. To solve this archaeological problem, the intelligent machine will correlate different social actions, and describe how the spatial distribution of material effects of some action, and hence the place where the action was originally performed, has an influence over the spatial distribution of the material effects of other(s) action(s).

In seeking to understand a spatial pattern in observed data, it is important to appreciate that it might arise either from region-wide 'trends' (first-order variation) or from correlation structures (second-order variation), or from a mixture of both. In the first order case, the spatial frequencies of archaeological features vary from location to location due to changes in the underlying properties of the local environment. For example, frequencies of archaeological artifacts may be influenced by variations in terrain. In the second order case, frequencies of archaeological data vary from location to location due to local interaction effects between observations. For example, material consequences of social action tend to happen in areas where the social action has been performed. We should assume a second order pattern in the data is due to some process that varies spatially. That means that patterns arise due to variations in social actions performed at discrete locations.

The question that also arises is whether the social action displays any systematic spatial pattern or departure from randomness either in the direction of *clustering* or *regularity*. Randomness at the spatial level can be the result of post depositional alteration, and should be detected before social action at the spatial level can be explained. We need tools and methods to differentiate diverse spatial ways in which an action can be performed at different places. Questions that are more interesting include:

- Is the observed clustering due mainly to natural background variation in the population from which intensities arise?
- Over what spatial scale does any clustering occur?
- Are *clusters* merely a result of some obvious a priori heterogeneity in the region studied?
- Are they associated with proximity to other specific features of interest, such the location of some other social action or possible point sources of important resources?
- Is material evidence that aggregates in space also clustered in time?

All these sorts of questions serve to take us beyond the simple detection of non-randomness. Discriminating between random, clustered, and regular patterns of observed spatial frequencies of archaeological features is a fundamental concern, because it will help us to understand the nature of the causal process (social actions) involved. The actual evidence of the presence of a social action should be statistically different from the random location of its material traces through different spatial and temporal locations.

To infer the cause (social action performed at the spatial level) from the effect (the spatial frequency of material evidence measured at some finite set of locations), we have to rebuild the real frequency that was generated in the past by the social action. This theory forms the underpinnings of geostatistics. Geostatistics applies the theories of stochastic processes and statistical inference to spatial locations. It is a set of statistical methods used to describe spatial relationships among sample data and to apply this analysis to the prediction of spatial and temporal phenomena (Fotheringham et al., 2000; Haining, 2003; Lloyd & Atkinson, 2004).

NEURAL NETWORKS FOR SOLVING THE SPATIAL INTERPOLATION PROBLEM

If the intelligent robot has not previous information about how observed spatial frequencies of archaeological observables might have been formed, then estimates of the parameters defining the best function between input (frequency of material traces at the spatial level) and output (placement

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