Chapter XVII
Spatial Interpolation

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ABSTRACT

Spatial interpolation is a core component of data processing and analysis in geoinformatics. The purpose of this chapter is to discuss the concept and techniques of spatial interpolation. It begins with an overview of the concept and brief history of spatial interpolation. Then, the chapter reviews some commonly used interpolations that are specifically designed for working with point data, including inverse distance weighting, kriging, triangulation, Thiessen polygons, radial basis functions, minimum curvature, and trend surface. This is followed by a discussion on some criteria that are proposed to help select an appropriate interpolator; these criteria include global accuracy, local accuracy, visual pleasantness and faithfulness, sensitivity, and computational intensity. Finally, future research needs and new, emerging applications are presented.

INTRODUCTION

Spatial interpolation is a core component of data processing and analysis in geographic information systems. It is also an important subject in spatial statistics and geostatistics. By definition, spatial interpolation is the procedure of predicating the value of properties from known sites to un-sampled, missing, or obscured locations. The rationale behind interpolation is the very common observation that values at points close together in space are more likely to be similar than points further apart. This observation has been formulated as the First Law of Geography (Tobler, 1970). Data sources for spatial interpolation are normally scattered sample points such as soil profiles, water wells, meteorological stations or counts of species, people or market outlets that are summarized by basic spatial units such as grids or administrative areas. These discrete data are interpolated into continuous surfaces that can be quite useful for data exploration, spatial analysis, and environmental modeling (Yang and Hodler, 2000). On the other hand, we often think about some kinds of data as continuous rather than discrete even though we can only measure them discretely. Thus, spatial interpolation allows us to view and predict data over space in an intuitive way, thereby making the real-world decision-making process easier.

The history of spatial interpolation is quite long, and a group of optimal interpolation methods using geostatistics can be traced to the early 1950s when Danie G. Krige, a South African mining engineer, published his seminal work on the theory of Kriging (Krige, 1951). Krige's empirical work to evaluate mineral resources was formalized in the 1960s by French engineer Georges Matheron (1961). By now, there are several dozens of interpolators that have been designed to work with point, line, or polygon data (Lancaster and Salkauskas, 1986; Isaaks and Srivastava, 1989; Bailey and Gatrell, 1995). While this chapter focuses on the methods designed for working with point data, readers who are interested in the group of interpolators for line or polygon data should refer to Hutchinson (1989), Tobler (1979), or Goodchild and Lam (1980).

The purpose of this chapter is to introduce the concept of spatial interpolation, review some commonly used interpolators that are specifically designed for point data, provide several criteria for selecting an appropriate interpolator, and discuss further research needs.

SPATIAL INTERPOLATION METHODS

There is a rich pool of spatial interpolation approaches available, such as distance weighting, fitting functions, triangulation, rectangle-based interpolation, and neighborhood-based interpolation. These methods vary in their assumptions, local or global perspective, deterministic or stochastic nature, and exact or approximate fitting. Thus, they may require different types of input data and varying computation time, and most importantly, generate surfaces with various accuracy and appearance. This article will focus on several methods that have been widely used in geographic information systems.

Inverse Distance Weighting (IDW)

Inverse distance weighting (IDW) is one of the most popular interpolators that have been used in many different fields. It is a local, exact interpolator. The weight of a sampled point value is inversely proportional to its geometric distance from the estimated value that is raised to a specific power or exponent. This has been considered a direct implementation of Tobler's First Law of Geography (Tobler, 1970). Normally, a search space or kernel is used to help find a local neighborhood. The size of the kernel or the minimum number of sample points specified in the search can affect IDW's performance significantly (Yang and Hodler, 2000). Every effort should be made to ensure that the estimated values are dependent upon sample points from all directions and to be free from the cluster effect. Because the range of interpolated values cannot exceed the range of observed values, it is important to position sample points to include the extremes of the field. The choice of the exponent can affect the results significantly as it controls how the weighting factors decline as distance increases. As the exponent approaches zero, the resultant surface approaches a horizontal planar surface; as it increases, the output surface approaches the nearest neighbor interpolator with polygonal surfaces. Overall, inverse distance weighting is a fast interpolator but its output surfaces often display a sort of 'bull-eye' or 'sinkhole-like' pattern.

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