Merits and Demerits of GIS and Geostatistical Techniques

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Chapter 2

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Chapter Outline

2.1 INTRODUCTION

The geographical information system (GIS) is simply a collection of hardware, software, geographical information, and individual designs kept in an arranged order that is available for capture, storage, update, manipulation, analysis, and display in any required data form (Singh and Fiorentino, 1996; Alameen and Ramadan, 2015). According to Burrough (2001), GIS defines absolute location and has the ability to relate coordinates with particular domain information. This technology incorporates database operations such as query with statistical analysis derived from the maps. The functional operative system of GIS is able to carry out analysis through spatial and nonspatial data. Nonspatial data can be merged with spatial data using GIS as a platform with the help of relational database management system (RDBMS). Obviously, GIS provides the interactive graphic interface and also support with nonspatial database. The terminology geostatistical encompasses taking measurements from a map or sophisticated geocomputations-based analysis about geographic data.

GIS proves effective for original and uniformity calculations using a geostatic database. Geostatistics are widely used with GIS operations in many fields, such as spatial and nonspatial, adopted by interpolation techniques (Derya and Fatmagul, 2016). One interpolation technique, termed deterministic, obtains the surfaces that are created by measured points on the expansion of matches. This method of inverse distance weighted or the smoothing points is termed trend surface analysis. In addition, geostatistical interpolation based on prediction surface modeling, termed kriging, faces the potential for errors or uncertainty from the prediction. GIS and geostatistical methods are strong alternatives for interpolation and analysis of spatial data (Inna and Alksei, 2016).

GIS can be applied to any mode of life. It is significantly used in multidisciplinary subjects, such as nature, wildlife, culture, wells, springs, water bodies, fire hydrants, roads, streams, and so on. The support of attributes can evaluate also find the domain quantity and density for the selected area could be evaluated and displayed. Apart from these applications, GIS can be tailored according to the requirements and needs of end users.

Modern remote-sensing methods can be integrated with GIS technology to portray real-time environment. This involves various science disciplines adapting to different geographic approaches to satisfy the user community, as shown in Fig. 2.1.

The goal of this chapter is to understand GIS and geostatistical techniques and approaches for spatial and nonspatial analysis through which the advantages and disadvantages of GIS to store, select, manipulate, explore, analyze, and display georeferenced data can be known (Singh and Fiorentino, 1996). The geographical data models are represented as point, line, and polygons in an irregular sampling of databases with a set of spaced locations represented as x, y, and z coordinates. A number of continuity data points arranged in a closed manner is termed as polygon. It bounds the pair of x and y set of data (Longley et al., 2011). The regular spacing measurements that are carried out in the observations of a digital elevation model can be utilized or digitized as contours and isohyetal data.

GIS and Geostatistical Techniques for Groundwater Science. https://doi.org/10.1016/B978-0-12-815413-7.00002-X

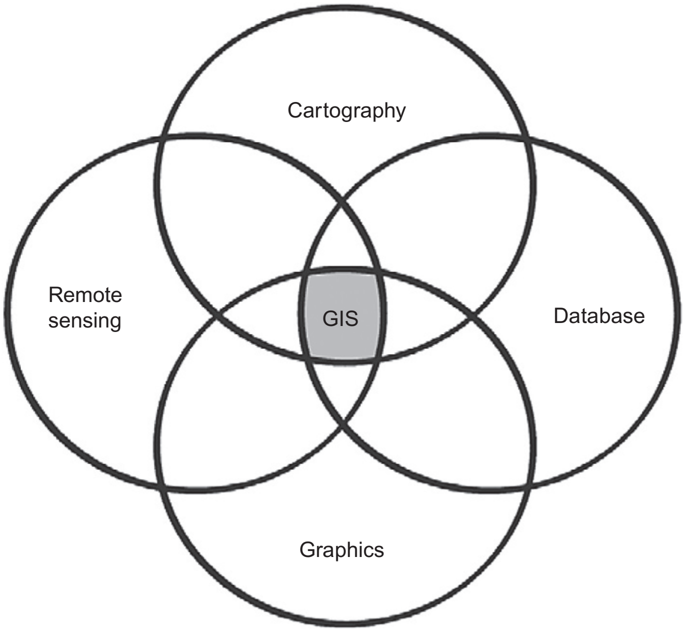

FIG. 2.1 Interrelationship between GIS disciplines.

The remotely sensed data grouped as a irregular triangle system produces a TIN model of elevation (Singh and Fiorentino, 1996; Gupta, 2005; Hengl, 2007; Lillesand et al., 2009; Burrough, 2001; Longley et al., 2011). The geostatistical methods assume the spatial variation in a random process and also spatial auto correlation. The different location landscape of the continuous surface can be justified by interpolation (Anderson, 2014; Inna and Alksei, 2016; Clark, 1987; Danilov et al., 2018). The geostatistical analysis can be adapted to find the predicted landscape of group of and similar entities (Inna and Alksei, 2016).

2.2 BASIC PRINCIPLES OF GEOSTATISTICAL METHODS

Geostatistical analysis for interpolation can be achieved by similarity, i.e., inverse distance weighted values and radial functions as the degree of smoothing. Both methods can be used for a mathematical approach to create surface and uncertainty predictions for a better understanding of the surface based on the available information (Setianto and Triandini, 2013; Hengl, 2007; Burrough, 2001; Nas, 2009). Modern GIS modeling and analysis can be obtained through three-dimensional visualization and by understanding the quality of modeling (Jangwon et al., 2017; David, 1996).

The sample point's elevation distribution and surface characters will depend the predicted distance value from nearby points and if they form reasonable accuracy in interpolation (Fig. 2.2). This implies the concept of decrease and increase of weight of value with respect to location prediction. The interpolation method adapted by which accuracy prediction with the help of statistical relationship and auto correlation among the measured points (Clark, 1987).

Spatial measured points and predicted location can be utilized through auto correlation in geostatistics using the ordinary kriging method. Kriging analysis is similar to inverse distance weighting for which the surrounding measured values are derived in location prediction (Setianto and Triandini, 2013; Dobesch et al., 2007).

The semivariogram explains the relationship and difference between the measured and predicted values with the help of spatial auto correlation and distance measurement. The distance between the two locations can be calculated using distance (Hengl et al., 2007; Clark, 1987).

The formula to determine the semivariance at any given distance (Eq. 2.1):

$$\text{Semivariance} = \text{Slope}^{*}\ \text{Distance} \tag{2.1}$$

where, Slope is the slope of the fitted model and Distance is the distance between the pairs of locations.

The empirical semivariogram defines a line that provides the best fit in the points. In addition, the line that is formed with the weighted square between each point represents the variations and distance which are derived from the quality of data (Fig. 2.3).

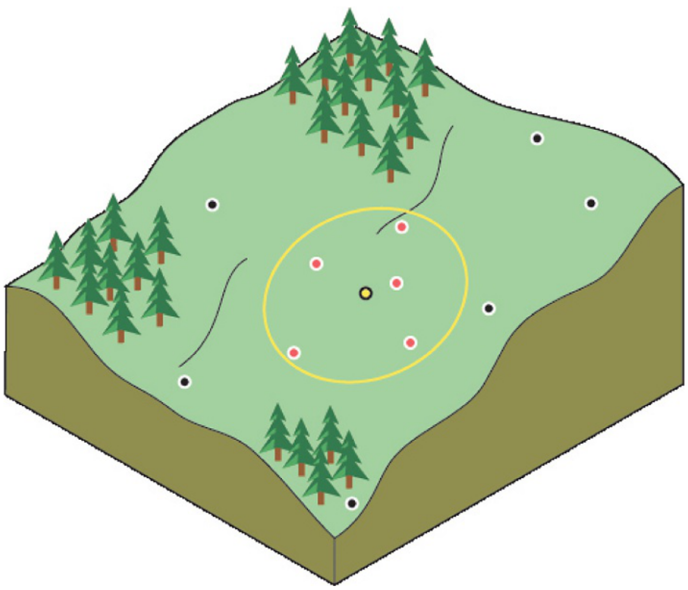

FIG. 2.2 Inverse distance weighting (IDW). http://pro.arcgis.com.

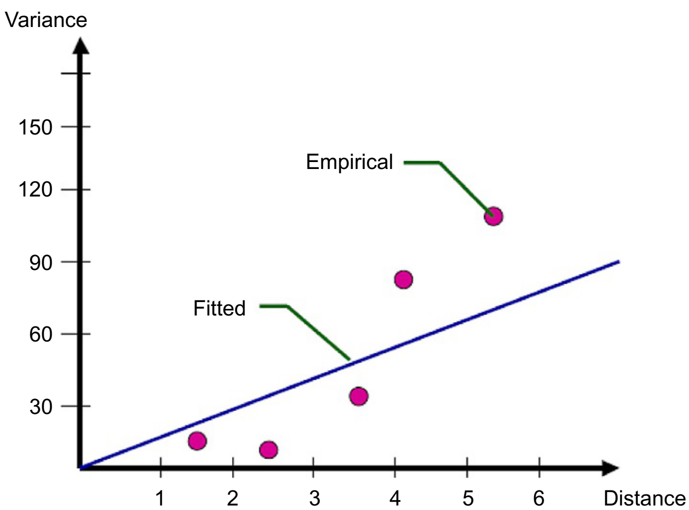

FIG. 2.3 Empirical semivariogram. http://pro.arcgis.com.

Splines are one of the mechanical interpolation techniques preferred for polynomial measurement, which includes an amount of smoothing (Hengl, 2007).

2.3 MERITS AND DEMERITS OF GIS

GIS is a computer-based application for mapping and analyzing geographically referenced data in the form of digitized three-dimensional operations. The use of GIS has become inevitable in almost every geospatial application. The end-user community is interested in exploring the economic and deliberate value of GIS due to the benefits of this rapidly growing technology. The fundamental advantages of GIS can be generalized as shown in the following section.

It is easy to visualize the spatial information represented by GIS output maps with clear legends and different groups of coloring and patterns. Thus the novice users of GIS could be comfortable with its application. Expert use of the GIS application is highly supportive in all kinds of environment.

GIS can build various themes and is supportive for database operations such as creation, updating, and manipulation. The map accuracy depends on the quality of input data.

GIS offers an influential decision-making tool in the education sector for its administration, policy making, and instruction. For administrators, GIS can offer an approach to visualize and manage systems in their entirety, including monitoring campus safety, mapping campus buildings, surveilling cable and other infrastructures, routing school buses, planning school closures and opening new ones, and outlining strategies for recruitment. For policymakers in education, GIS provides them with tools that can present patterns in educational achievement and guide the targeting of new programs.

Groundwater analysis uses GIS to interpret spatial correlation targeting potential groundwater resources as well as determining water quality. A logical approach can be adapted for the efficient management of water resources, such as surface and subsurface delineations. GIS can be applied to site selection, zoning, planning, and conservation measures.

Geophysical parameters on the subsurface conditions can be incorporated with spatial data and interpolation techniques can be applied to the exploration, assessment, and prediction of groundwater resources, as well as to the selection of an artificial recharge site. The subsurface flow and pollution model guides how to assess hazards and helps in planning the preventive measures with the help of GIS and geostatistical technologies.

GIS methods can predict, assess risk, and identify hazardous locations of natural resources. It further integrates the spatial and nonspatial data to enable better understanding of emergency conditions. It also supports analysis and the creation of preventive and mitigating solutions.

GIS can be used in criminology to identify facts. Some spatial analyses uses underlying social phenomena to identify rates of crime, which necessitates the use of boundary units such as census tracts and police beats. Although some researchers have also recognized that a simple spatial concentration of crime can also be valuable.

GIS creates employment opportunities in education, administration, research, government, and nonprofit organizations.

GIS technologies refine datasets, data models, and the relation between attributes. High standards are achieved with the scope for generation of newer objects on an on-demand basis. It also allows existing attributes to be linked with newly defined datasets (Singh and Fiorentino, 1996).

2.3.1 Disadvantages of Geographic Information Systems

- *Expensive*: GIS setup is complex, in addition to the cost of the equipment, there is the cost incurred in training. Frequent updating of datasets or data models may lead to errors in results.
- *Real-time parameters*: The handling of growing datasets is an overall challenge to the GIS system.
- *Geographical errors increase with larger-scale data*: The quality of the data collected directly affects the accuracy of the end system. Geographic errors will also affect net results since GIS handles large-scale data.
- *Relative loss of resolution*: Every technology has negotiable errors when deployed.
- *Positional accuracy and precision*: Accuracy and precision are the functions of the scale at which a map (paper or digital) is created. The nonspatial data linked to location may also be inaccurate or imprecise. Inaccuracies may result from mistakes of many sorts. Nonspatial data can also vary greatly in precision. Precise attribute information describes phenomena in great detail.
- *Violation of privacy*: The user community is not limited to authorized persons. So there is threat in the usage of data displayed from the GIS system.
- Error-prone interpretation could lead to failure of system implementation thus affecting the economic strategy of the implementer.
- There might be failures in initiating or additional effort required in order to fully implement the GIS but there might be large benefits to anticipate as well.
- There is a lack of trained teachers in the domain. Though GIS and remote sensing have been introduced in some universities across the country, still the subjects have not been taught to the fullest extent. Moreover, a link between secondary education and higher education must be established for a wide spread and its continuity in the system. Prior knowledge of GIS is a prerequisite to train the trainers.

2.3.2 Advantages of Geostatistics Techniques

- The use of geostatistics techniques enhances the distribution of spatial data.
- Kriging, one of the geostatistical techniques, offers convenient management of groundwater resources.
- Expert interpretation of water quality with the support of large-volume datasets as processed through these techniques.
- The model-based approach of these techniques optimizes the accuracy of the obtained results.
- The geostatistical techniques have the ability to reproduce the trend and provide continuity. This feature allows the user to be precise in their interpretation.

2.3.3 Disadvantages of Geostatistics techniques

- Spatial interpolation evaluates physical data in a continuous domain. The result depends on the correctness of the data input.
- The dataset used in the interpolation process might have errors.
- The choice of adapting the geostatistical method relies on several factors like budget, resource availability, user proficiency, etc.
- A systematic sampling pattern cannot be set up because of the changing cell size and missing/unsuitable data.
- Location of points may be a problem with random sampling distribution.
- Adjacent area coverage might not be supported.
- The interpolation method estimates the value for the center of each unmeasured grid cell with predicted assumption.

2.4 SUMMARY

Though GIS could benefit users from different disciplines, imparting the system is considered to be difficult. Hence it clarity is required for implementation in the health sector, for use in environmental and groundwater studies, and to extend into space science. GIS has improved the quality of research in the above areas through the provision of spatial attributes for the areas of interest.

Simple installation of a database connected to the GIS setup would serve the need. GIS and geostatistics can render solid knowledge and consistent accuracy in a geographic database. The operator failed in handling the geostatistical methods would reflect the visualization error in the data.

The geostatistical methods associated with interpolation techniques provide valuable maps with the effectiveness of kriging and develop semivariogram models. Besides the disadvantages of GIS technology, there is huge potential in various applications.

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