Space Opera–GIS Basics

Paul H.J. Hendriks
Radboud University Nijmegen, The Netherlands

INTRODUCTION

The term "Geographical Information Systems", commonly abbreviated to GIS, is an umbrella term covering a class of computer based information systems that are typified by their focus on geographical or spatial data and information. The basic notion underlying a GIS is that every object present on the earth can be "geo-referenced", which refers to defining the spatial location of objects by referencing systems (e.g. latitude/longitude or postal zones). The key to specific GIS functionality is that GIS allow connection of geo-referenced data to attribute or non-spatial data of geographical objects. In varying ways and to varying degrees GIS facilitate the steps necessary for acquiring both classes of data and turning them into geographical information, including input (e.g. via GPS or scanning of maps), data processing and analysis (e.g. overlay analysis or shortest path calculation) and display (e.g., on maps).

The history of GIS spans roughly four decades, bringing a story that springs from many origins, and mingles many disciplines. GIS finds its roots in public administration domains and military applications, but has fanned out to many commercial, non-profit and academic areas. From its origins in the nineteen sixties, GIS has grown in size and stature, building on diverse influences concerning concepts and principles, data and issues of spatial infrastructure, software and software vendors, application areas, etc. The GIS landscape contains a multitude of proprietary and public domain GIS software packages (most notably Autodesk's AutoCAD Map, Erdas's Imagine, ESRI's Arc/Info, Intergraph's GeoMedia, Maplnfo and Smallworld). From its ongoing development history GIS emerges not as one sharply delineated concept or class of computer systems. The GIS landscape is as diverse as the multitude of roots from which it originated and the throng of influences that shaped its development.

BACKGROUND

GIS as an umbrella term covers various types of technology, ranging from relatively simple mapping facilities to advanced environments supporting spatial analysis. What combines different manifestations of GIS is that they all draw their operability from functionalities around spatial information, or geoinformation (Goodchild, 2003; Konecny, 2003). Developing an understanding of what distinguishes GIS from other information systems can be achieved by looking at GIS through four windows. Firstly, GIS can be defined through a *database window*, which involves exploring the alternative data models used in GIS and the principles and technical issues involved in defining and linking spatial and attribute data (including temporal data) based on these models. Secondly, an important distinction between different GIS refers to the types of spatial and non-spatial analysis they support, which involves looking at these systems through a *geographical analysis window*. Thirdly, applying a *visualization window* allows to assess the functionality of GIS for making the contents of their database and analysis outcomes visible, in which maps and computer cartography play an important role. Fourthly, GIS can be looked at through a *relevance window*. This fourth perspective, which involves looking at the context of system usage, is crucial for understanding GIS as information systems instead of data systems, as it should allow to understand how and when geographical analysis may make geographical data meaningful, how and when their presentation on maps will be useful, and how and when specific functionalities of GIS are necessary elements for defining GIS.

A DATABASE WINDOW ON GIS

Looking at GIS through a *spatial database* window shows GIS as a dedicated system for acquiring, storing and processing data with a spatial component (Haining, 2003; Shekhar & Chawla, 2003). Building a spatial database requires spatial data modeling and processing. Spatial modeling involves several steps. Firstly, it concerns developing a spatial understanding by distinguishing and relating the elements that define "spatiality", such as "location" or "distance". Secondly, it involves building a *conceptual spatial data model* by translating the spatial perspective into formalized data elements. Thirdly, a *logical spatial data model* must be built, which involves representing and formalizing the elements of the conceptual model in a univocal manner so that these can be entered into an automated system. Fourthly, the logical spatial data model has to be translated into the actual data storage, which refers to choosing a *physical data model*.

As the first two steps most specifically enter the spatial perspective in data modeling, we will focus on these.

Building a conceptual spatial data model consists of identifying spatial objects and characterizing these. Five aspects describe spatial objects:

1. These are objects that are in a certain place or location (aspect: *where* or *absolute location*),
2. with a certain spatial size, appearance, etc. (aspect: *spatial form*),
3. at a certain distance from other spatial objects and in a certain relationship with these (aspect: *spatial relationships* or *relative location*),
4. at a certain moment in time or during a certain period, and possibly subject to change (aspect: *when*), and
5. with other characteristics than spatial and temporal (aspect: *what*).

A basic distinction between conceptual spatial data models is whether they represent spatial objects in 2D or 3D. Commonly, four basic types of two-dimensional spatial objects are distinguished: points, lines (or specific collections of points), areas (objects identified by lines beginning and ending in the same point) and surfaces. Combinations of these basic classes and their characteristics may produce new types of spatial objects, such as spatial patterns, spatial structures, or spatial networks. For instance, a spatial network such as a road network or a network of pipelines, results from understanding points as nodes and lines as connections between nodes, and may be expanded to include areas and surfaces as well. Data models for representing these objects can be distinguished into raster models (based on fixed units of space) and vector models (based on combinations of points and lines). Three-dimensional spatial data models or geomorphometrical models, which are less common in GIS, aim to represent the height dimension of space in a more sophisticated form than by using contour lines. The most commonly used models are the triangulated network (TIN) and the digital elevation model (DEM).

Connecting the five aspects specified above with spatial objects involves three issues: firstly, defining the spatial data (aspects 1, 2, 3); secondly, defining the non-spatial data (aspects 4 and 5); and thirdly, linking spatial and non-spatial data. The non-spatial are typically called the attribute data in GIS, which include temporal data (see Christakos, Bogaert, & Serre, 2001). Describing absolute location (aspect 2) is called georeferencing. A basis distinction is between continuous (e.g., LATLONG) and discrete (e.g., postal zones) georeferencing.

Working with spatial data in GIS presumes a choice of spatial data model, facilities for getting data into the system based on that data model, and functions for processing data. Some GIS have chosen one spatial data model as the basis of their functionality for handling spatial (e.g., leading to a distinction between raster and vector GIS); others offer combinations of models and facilities for linking these. As to data input GIS users no longer need to collect all data themselves because many commercial datasets are available (e.g., based on postal zones or road networks), as well as spatial data sets built in academic or other public domain projects (see Rigaux, Scholl, & Voisard, 2002; Walford, 2002). Data input has been revolutionized by the Global Positioning System (GPS), which allows inputting both 2D and 3D spatial data from satellite data (e.g., Konecny, 2003). GIS typically contain functions for additional processing of data input from external data sets or from input devices (GPS, digitizers, etc.), such as geometric transformation (translating among methods of map projection), edge matching (ensuring that features crossing adjacent map sheets have the same edge locations, attribute descriptions and feature classes), and standard attribute editing functions (e.g., reclassifying objects based on their attribute data).

A GEOVISUALIZATION WINDOW ON GIS

The window of *visualizing spatial information* shows GIS as a system to present spatial data and information, e.g. via maps (Cartwright & Hunter, 2001). Geovisualization, and therefore also the use of maps in GIS, can refer to GIS output or input. Geovisualization as input refers to taking the visual form as the starting point for communication with GIS or further analysis steps within or outside of GIS (Maceachren & Brewer, 2004). For instance, maps can be used as interactive devices for defining queries for showing and exploring the contents of the database, e.g., to detect errors (Andrienko, Andrienko, & Gitis, 2003), or for starting a new geographical analysis. Using maps in GIS in an interactive sense presumes that the map is linked with a set of controls (e.g., it can be made clickable) allowing to change the content of the map or to take the content of the map as a step toward building a new map (e.g., Cartwright & Hunter, 2001).

Geovisualization as output refers to showing the GIS's contents, such as the data contained in the spatial databank, or the outcomes of spatial analysis. GIS can be used for producing, showing and interpreting maps and other visualizations. Producing maps involves generating data with a spatial footprint, and showing these in a new or updated map. Producers of atlases and road maps use GIS to facilitate updating the frequent changes in the location of objects (e.g., changes in the street networks, or the usually less frequent changes in the boundaries between administrative units). Geographical analysts that perform their analysis in analysis modules linked to GIS

Related Content