Geographic information systems (GIS)

Software components:

The shortest distance, d, of a point, P, from a straight line becomes:

$$d = \frac{Ax_p + By_p + C}{\sqrt{A^2 + B^2}}$$

Two lines

$$A_1x_i + B_1y_i + C_1 = 0$$

$$A_2x_i + B_2y_i + C_2 = 0$$

may be intersected. The point of intersection has the coordinates:

$$x_i = \frac{B_1C_2 - B_2C_1}{A_1B_2 - A_2B_1}$$

$$y_i = \frac{C_1A_2 - C_2A_1}{A_1B_2 - A_2B_1}$$

The straight lines are parallel if $A_1B_2 - A_2B_1 = 0$.

They are perpendicular if $A_1A_2 + B_1B_2 = 0$.

The distance, d, between the parallel straight lines is:

$$d = \frac{C_1 - C_2}{\sqrt{A_1^2 + B_1^2}}$$

The equation of a circle is:

$$x_i^2 + y_i^2 + Ax_i + By_i + C = 0$$

or

$$(x_i - x_o)^2 + (y_i - y_o)^2 = r^2$$

Using the tools of analytic geometry, these formulations may be expanded to second and higher order curves.

In three dimensions, the equivalent terms become:

Distances:

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$

The direction cosines:

$$\cos \alpha_x = \frac{(x_i - x_j)}{d_{ij}}$$

$$\cos\alpha_y = \frac{(y_i - y_j)}{d_{ij}}$$

$$\cos\alpha_z = \frac{(z_i - z_j)}{d_{ij}}$$

The spatial angle between directions with the direction cosines α_x, α_{xy} , α_{xz} and $\propto_x^-$, $\propto_y^-$, $\propto_z^-$ is:

$$\cos\beta = \cos\alpha_x \cos\alpha'_x + \cos\alpha_y \cos\alpha'_y + \cos\alpha_z \cos\alpha'_z$$

The equation of a plane determined by three points becomes:

$$Ax_i + By_i + Cz_1 + D = 0$$

or

$$\begin{vmatrix} x_i & y_i & z_i & 1 \\ x_1 & y_1 & z_1 & 1 \\ x_2 & y_2 & z_2 & 1 \\ x_3 & y_3 & z_3 & 1 \end{vmatrix} = 0$$

A straight line in three dimensions is defined by two independent linear equations

$$A_1x_i + B_1y_i + C_1z_1 + D_1 = 0$$

$$A_2x_i + B_2y_i + C_2z_1 + D_2 = 0$$

or

$$\frac{x_i - x_1}{x_2 - x_1} = \frac{y_i - y_1}{y_2 - y_1} = \frac{z_i - z_1}{z_2 - z_1}$$

A distance, d, between a point, P, and a plane is given by:

$$d = \frac{Ax_p + By_p + C_p + D}{\sqrt{A^2 + B^2 + C^2}}$$

So far, most GIS systems have been limited to two-dimensional geometry.

Elevations have, however, been included as attributes. One therefore speaks of a two-and-a-half-dimensional capability. The elevation information may be introduced on a case-by-case basis, if a special is desired and programmed.

Translations, Δx and Δy, are possible by:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} x + \Delta x \\ y + \Delta y \end{pmatrix}$$

Rotations by an angle α are determined by:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

Scale change by a scale factor, λ, is executed by:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \lambda \begin{pmatrix} x \\ y \end{pmatrix}$$

Raster systems

Raster data consist of a regular 2D grid of square cells. The grid is characterized by a (geocoded) origin, its (geocoded) orientation and the raster cell size, which for imagery corresponds to a pixel (picture element) size. Other information, such as elevation levels or thematic data, may also be arranged by a scheme of regular tessellation. Raster systems may also be arranged in three dimensions. The 3D cell becomes a cube (a voxel). The attribute of the cell describes the thematic information (grey level, elevation, thematic object content). Raster coverages may be in regular (square, rectangular) or irregular dimensions. Each raster data set constitutes a layer. There may be many layers for the same area.

The geometric accuracy of raster data is limited by the cell resolution.

A mixed-cell problem may exist. Due to limits in resolution, there is a possibility of mixed pixels.

While raster models reflect what is present, vector models more accurately define the whereabouts. Raster topology is defined by the eight neighbouring pixels surrounding a particular pixel. Neighbouring cells carrying the same attribute define a connection component. In this way linear objects may be recognized by the connection components.
Raster data operations are possible in the following ways:

- ✓ Geometric transformations, which permit geocoding via digital (differential) rectification and the presentation of perspective views including its geometric resampling algorithms.
- ✓ Radiometric transformations, which include all types of digital image processing (filtering, multispectral classification, image analysis).

Databases

A database is a self-contained, long-term organization of data for flexible and secure use. It consists of the data and of a database management system, the software to manage the data. A database permits a strict separation between data and an application. It has a well-defined interface for application programs. The user of a database is not concerned with the internal data organization, but he or she can change

the data location without changing the application program. The database management system provides efficient access to the data with security checks.

The internal view of a database is the physical memory allocation. The conceptual view concerns the logical data organization and the external view to the user is the graphic user interface. Databases are used in a large variety of applications (banking, reservation systems, libraries, business). GIS can take advantage of these developments.