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Using spatial and 3D analysis instruments in a G.I.S. project

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Abstract. The GIS technology is used in all fields for which the spatial information is relevant, that means in all fields that use the geographical map for stocking, analyzing and representing the data which are processed. No matter what is the field, any GIS application includes a spatial data base (a digital map) and a soft which exploit these data bases. The digital map must contain the spatial data specific to any field whose it is designated to this application. In order to furnish some useful information, this data base must be actual, which means it must represent correctly the terrain (geographic space) that is always under changing. This exploitation soft is made from many functions of analyzing the spatial data contained into the digital map and of visualizing the resulted information, specific to the application field.

Keywords: GIS, spatial analysis, 3D, slope, surface, TIN, vector, raster

1. DATA MODELS USED IN A GIS

The information system is based on data which are available in various forms:

- spatial objects are represented by identifiers. They can relate to points, lines or areas (Fig. 1) administered in **vector form**. The identification and organization of these objects in coordinate and vector form is subdivided into feature or object classes. This includes their spatial or topological relations in two or three dimensions.

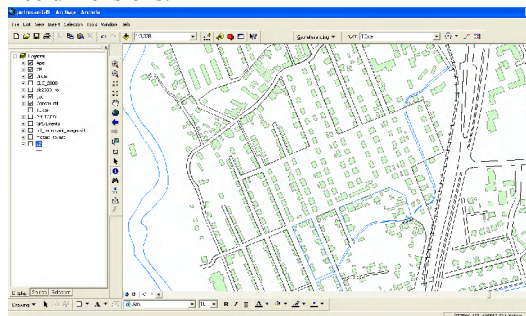


Fig. 1 Vector data

- data in **raster form** (Fig. 2) are also included. A pixel may be assigned an object code, or it may

simply consist of grey levels of an image or a digital elevation model.

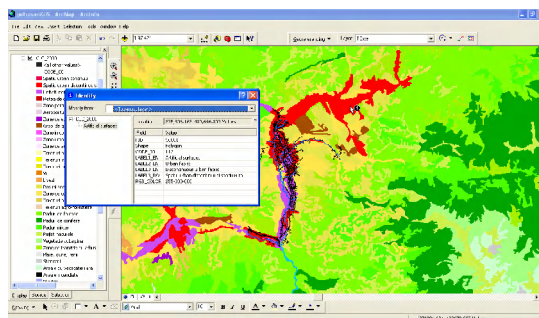


Fig. 2 Raster data

The vector or the raster data are also linked (Fig. 3) to non-graphic information specifying place names and object numbers, which in databases may further be linked to a great variety of coded or alphanumeric attributes (e.g. owners of a parcel, inhabitants of a house, characteristics of a utility feature, statistical data for a defined area).

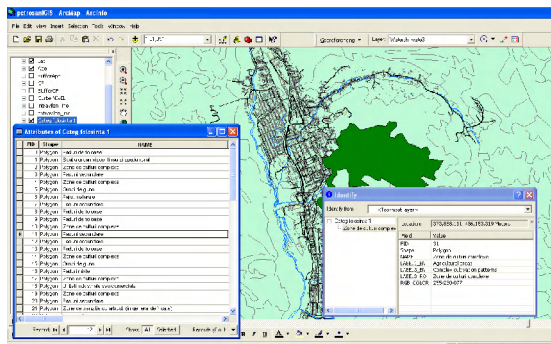


Fig. 3 Attribute links

In both models the geographic data of a certain territory are organized on many *layers* or thematic coverage.

2. SPATIAL ANALYSES

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The most important feature of a GIS consists in its capacity to make spatial analyses, which means to process the spatial data (geographical data) with the purpose to obtain information (reports) regarding the studied area. With this feature of spatial analyze is different the software dedicated to GIS over the software like the CAD. The processing of spatial data is made based on some algorithms specific by using own operations for these such data.

A geographic information system must include some facilities for answering to the following 5 general questions:

- **LOCALIZATION: "What is at....?"**

This question follows to identify the objects/phenomena placed at such geographic position specified through name, postal address or geographic coordinates.

- **CONDITION "Where is it?"**

This question follows to find the exact position of an object/phenomenon or an ensemble of specific requirements (for example: deforested area of minimum 2000 square meters with soil good for construction of buildings, situated at at least 100 m away from the road).

- **TENDENCIES: "What was modified since ...?"**

This question follows to evidence the modifications from a geographic area during a period of time.

- **PARTICULARITIES: "What particularities are made in the area ...?"**

This question presumes a complex analyze searching some links type cause-effect (for example: is the cancer a major cause of the death for the residences from the nuclear units?) or some anomalies appeared at a certain moment in an area with known features.

- **MODULATION: "What would happen if ... ?"**

This question presumes a complex analyze following the anticipation of the impact of an event (to add / eliminate/ transform an object/phenomenon) over the surrounding environment (for example: what could happen if it is built a new road, deposit of wastes, etc.? or if a toxic substance enters accidentally into the pumping station of the potable water?).

The main spatial operations are: Operations on a single layer; Operations on multiple layers; Statistic analyze; Network analyze; Analyze of the surfaces – making the digital model of the terrain.

Spatial and 3D analysis tools from ArcGIS software allows modeling of key factors in solving critical problems frequently encountered in practice, such as: global climate changes, prudent use of energy, rational use of natural resources, equitable planning of new towns and transportation systems.

Using GIS software to combine different sets of data helps to create complex scenarios and allow the testing of more hypotheses.

Below are presented the most important spatial and 3D analysis instruments which can be found ArcGIS software.

2.1. MAPPING DISTANCE

The **distance mapping functions** are global functions. They compute an output raster dataset where the output value at each location is potentially a function of all the cells in the input raster datasets.

- **Straight Line Distance functions** describe each cells relationship to a source or a set of sources.

The Straight Line Distance function measures the straight line distance from each cell to the closest source (the source identifies the objects of interest, such as wells, roads, or a school). The distance is measured from cell center to cell center.

Example of usage: What is the distance to the closest town?

The Straight Line Allocation function assigns each cell the value of the source to which it is closest. The nearest source is determined by the Straight Line Distance.

Example of usage: Which town am I closest to?

The Straight Line Direction function computes the direction to the nearest source measured in degrees.

Example of usage: What is the direction to the closest town?

- **Allocation** function allows to identify which cells belong to which source based on closest proximity (in a straight line).

- **Cost Weighted Distance mapping** finds the least accumulative cost from each cell to the nearest, cheapest source. Cost can be money, time, or preference.

Example: Finding the least-cost route for a road

The Cost Weighted Distance function modifies the Straight Line Distance by some other factor, which is a cost to travel through any given cell. It produces an output raster in which each cell is assigned a value that is the least accumulative cost of getting back to the source.

For example, it may be shorter to climb over the mountain to the destination, but it is faster to walk around it.

The Cost Weighted Allocation function identifies the nearest source cell from each cell in the cost-weighted distance raster based on accumulated travel cost.

The Cost Weighted Direction function provides a road map, identifying the route to take from any cell, along the least-cost path, back to the nearest source.

The Distance and Direction raster datasets are normally created to serve as inputs to the pathfinding function, the shortest (or least-cost) path.

- **Shortest Path function** determines the path from a destination point to a source. Once you have performed the Cost Weighted Distance function, creating distance and direction rasters, you can then compute the least-cost (or shortest) path from a chosen destination to your source point.

The shortest path travels from the destination to the source and is guaranteed to be the cheapest route (relative to the cost units defined by the original cost raster).

2.2. INTERPOLATION

Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data: elevation, rainfall, chemical concentrations, noise levels, and so on.

Inverse Distance Weighted (IDW) estimates cell values by averaging the values of sample data points in the vicinity of each cell. The closer a point is to the center of the cell being estimated, the more influence, or weight, it has in the averaging process.

This method assumes that the variable being mapped decreases in influence with distance from its sampled location.

For example, when interpolating a surface of consumer purchasing power for a retail site analysis, the purchasing power of a more distant location will have less influence because people are more likely to shop closer to home.

IDW has two options: a **Fixed search radius type** and a **Variable search radius type**.

A **fixed search radius** requires a distance and a minimum number of points. The distance dictates the radius of the circle of the neighborhood (in map units). The distance of the radius is constant, so for each interpolated cell, the radius of the circle used to find input points is the same.

With a **variable search radius**, the number of points used in calculating the value of the interpolated cell is specified, which makes the radius distance vary for each interpolated cell, depending on how far it has to search around each interpolated cell to reach the specified number of input points.

- **Spline** estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points.

There are two Spline methods: **regularized** and **tension**.

The **Regularized method** creates a smooth, gradually changing surface with values that may lie outside the sample data range.

The **Tension method** tunes the stiffness of the surface according to the character of the modeled phenomenon. It creates a less-smooth surface with values more closely constrained by the sample data range.

IDW and Spline are referred to as deterministic interpolation methods because they are directly based on the surrounding measured values or on specified mathematical formulas that determine the smoothness of the resulting surface.

A second family of interpolation methods consists of geostatistical methods (such as **Kriging**) that are based on statistical models that include autocorrelation (the statistical relationship among the measured points). Because of this, not only do these techniques have the capability of producing a prediction surface, but they can also provide some measure of the certainty or accuracy of the predictions.

- **Kriging** – a surface interpolation method available in Spatial Analyst. It is a geostatistical interpolation method based on statistical models that include autocorrelation (the statistical relationship among the measured points). **Kriging** weights the surrounding measured values to derive a prediction for an unmeasured location. Weights are based on the distance between the measured points, the prediction location, and the overall spatial arrangement among the measured points.

Spatial Analyst provides two Kriging methods: **Ordinary** and **Universal Kriging**

Ordinary Kriging is the most general and widely used of the Kriging methods. It assumes the constant mean is unknown. This is a reasonable assumption unless there is some scientific reason to reject this assumption.

Universal Kriging assumes that there is an overriding trend in the data (for example, a prevailing wind), and it can be modeled by a deterministic function, or polynomial. This polynomial is subtracted from the original measured points, and the autocorrelation is modeled from the random errors.

Universal Kriging should only be used when you know there is a trend in your data and you can give a scientific justification to describe it.

2.3. THE 3D ANALYSIS

3D Analyst works with real or hypothetical surfaces with two types of surface models: *rasters* and *TINs (Triangulated irregular network)* = A data structure that represents a continuous surface through a series of irregularly spaced points with values that describe the surface at that point (for example, an elevation).

TINs are usually created from a combination of vector data sources. You can use point, line, and polygon features as input data for a TIN. Some of these input features should have z-values, though not all of the features need z-values. The input features to a TIN may also contain integer attribute values that are preserved in the resulting TIN features. These may be used to indicate the relative accuracy of different input data or to identify features such as roads or lakes.

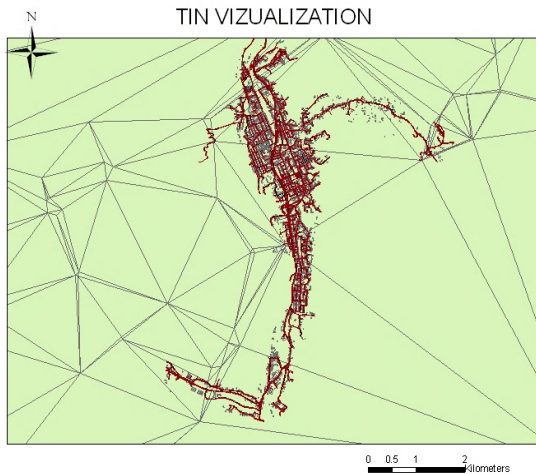


Fig. 4 TIN vizualization

Contours are polylines that connect points of equal value (such as elevation, temperature, precipitation, pollution, or atmospheric pressure). The distribution of the polylines shows how values change across a surface. Where there is little change in a value, the polylines are spaced farther apart. Where the values rise or fall rapidly, the polylines are closer together.

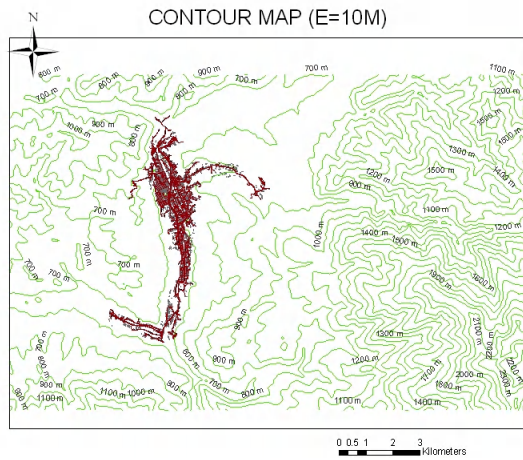


Fig. 5 Contour Map

The **Slope** function calculates the maximum rate of change between each cell and its neighbors for example, the steepest downhill descent for the cell (the maximum change in elevation over distance between the cell and its eight neighbors). Every cell in the output raster has a slope value. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. The output slope dataset can be calculated as percent slope or degree of slope.

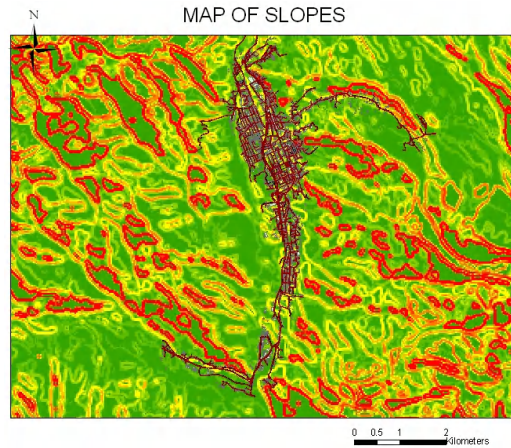


Fig. 6 Map of slopes

Aspect identifies the steepest downslope direction from each cell to its neighbors. It can be thought of as slope direction or the compass direction a hill faces. It is measured clockwise in degrees from 0 (due north) to 360 (again due north, coming full circle). The value of each cell in an aspect dataset indicates the direction the cells slope faces. Flat slopes have no direction and are given a value of -1.

The **Hillshade** function obtains the hypothetical illumination of a surface by determining illumination values for each cell in a raster. It does this by setting a position for a hypothetical light source and calculating the illumination values of each cell in relation to neighboring cells. It can greatly enhance the visualization of a surface for analysis or graphical display.

Azimuth is the angular direction of the sun, measured from north in clockwise degrees from 0 to 360. An azimuth of 90 is east. The default is 315 (NW). **Altitude** is the slope or angle of the illumination source above the horizon. The units are in degrees, from 0 (on the horizon) to 90 degrees (overhead). The default is 45 degrees.

Viewshed identifies the observation points that can be seen from each cell in the input raster. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. If you have only one observer point, each cell that can see that observer point is given a value of 1. All cells that cannot see the observer point are given a value of 0.

For example, From which locations on the landscape will the landfill be visible if it is placed in this location? or What will the view be like from this road?

The **Steepest Path** tool calculates the direction a ball would take if released at a given point on the surface. The ball will take the steepest path downhill until it reaches the perimeter of the surface model or it reaches a pit - a point all surrounding areas flow into. The result is a 3D graphic line added to the map or scene.

The **Steepest Path** tool can evaluate the integrity of a TIN surface model, for example, to find paths

that end unaccountably or meander off in a direction different from runoff on the actual site.

3. CONCLUSIONS

To accomplish the digital maps and to introduce the GIS systems into local community sectors will increase the level and quality of their decisional process. Being very used in different fields, and starting from the information necessary to any citizen and till environment protection, from the marketing strategies to resources administration, the GIS marked a revolution in solving the problems. The quality information means quality decisions. And GIS offers this possibility, transforming some simple information in real information and offering the interactive access to them.

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