Introduction: what is spatial analysis?

Topics

- Definitions
- Queries in GIS
- Relation between GIS and other sciences
- Projection systems and mutual transformation using GIS
- Concept of data base.
- Methods of tables connection
- Spatial analysis in GIS.
- DEM production using GIS
- Selective applications in GIS

- Spatial analysis is in many ways the crux of GIS because it includes all of the transformations, manipulations, and methods that can be applied to geographic data to add value to them, to support decisions, and to reveal patterns and anomalies that are not immediately obvious – in other words, spatial analysis is the process by which we turn raw data into useful information, in pursuit of scientific discovery, or more effective decision making. If GIS is a method of communicating information about the Earth's surface from one person to another, then the transformations of spatial analysis are ways in which the sender tries to inform the receiver, by adding greater informative content and value, and by revealing things that the receiver might not otherwise see.

- Some methods of spatial analysis were developed long before the advent of GIS, and carried out by hand, or by the use of measuring devices like the ruler. The term analytical cartography is sometimes used to refer to methods of analysis that can be applied to maps to make them more useful and informative, and spatial analysis using GIS is in many ways its logical successor.

Types of spatial analysis and modeling (Ch. 14)

Spatial analysis using six general headings:

1. Queries استفسارات
2. Measurements قياسات
3. Transformations التحويلات
4. Descriptive التوصيف
5. Optimization التحسين
6. Hypothesis الفرضيات

Queries

- *Queries* are the most basic of analysis operations, in which the GIS is used to answer simple questions posed by the user. No changes occur in the database, and no new data are produced.
- The operations vary from simple and well-defined queries like 'how many houses are found within 1 km of this point', to vaguer questions like 'which is the closest city to Los Angeles going north', where the response may depend on the system's ability to understand what the user means by 'going north.

Measurements

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- *Measurements* are simple numerical values that describe aspects of geographic data.
- They include measurement of simple properties of objects, like length, area, or shape, and of the relationships between pairs of objects, like distance or direction.

Transformations

- *Transformations* are simple methods of spatial analysis that change datasets, combining them or comparing them to obtain new datasets, and eventually new insights.
- Transformations use simple geometric, arithmetic, or logical rules, and they include operations that convert raster data into vector data, or vice versa.
- They may also create fields from collections of objects, or detect collections of objects in fields.

Descriptive

- *Descriptive summaries* attempt to capture the essence of a dataset in one or two numbers.
- They are the spatial equivalent of the descriptive statistics commonly used in statistical analysis, including the mean and standard deviation.

Optimization

- *Optimization* techniques are normative in nature, designed to select ideal locations for objects given certain well-defined criteria.
- They are widely used in market research, in the package delivery industry, and in a host of other applications.

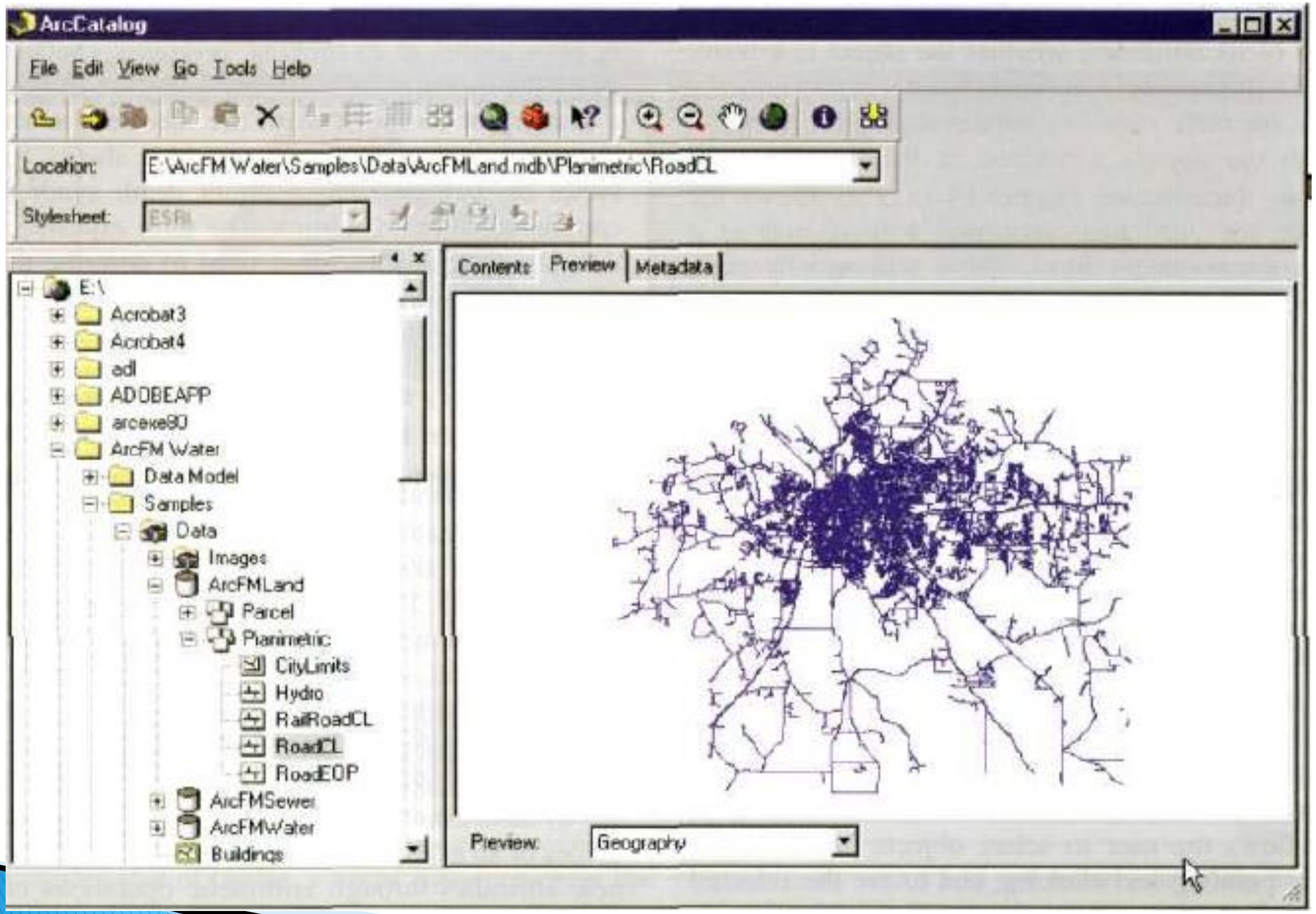
Hypothesis

- *Hypothesis testing* focuses on the process of reasoning from the results of a limited sample to make generalizations about an entire population.
- It allows us, for example, to determine whether a pattern of points could have arisen by chance, based on the information from a sample.
- Hypothesis testing is the basis of inferential statistics and lies at the core of statistical analysis, but its use with spatial data is much more problematic.

1- Queries

- In the ideal GIS it should be possible for the user to interrogate the system about any aspect of its contents, and obtain an immediate answer.
- Interrogation might involve pointing at a map, or typing a question, or pulling down a menu and clicking on some buttons, or sending a formal SQL request to a database
- Today's user interfaces are very versatile, and have very nearly reached the point where it will be possible to interrogate the system by speaking to it – this would be extremely valuable in vehicles, where the use of more conventional ways of interrogating the system through keyboards or pointing devices can be too distracting for the driver.

- The map view of a dataset shows its contents in visual form, and opens many more possibilities for querying. When the user points to any location on the screen the GIS should display the pointer's coordinates, using the units appropriate to the dataset's projection and coordinate system.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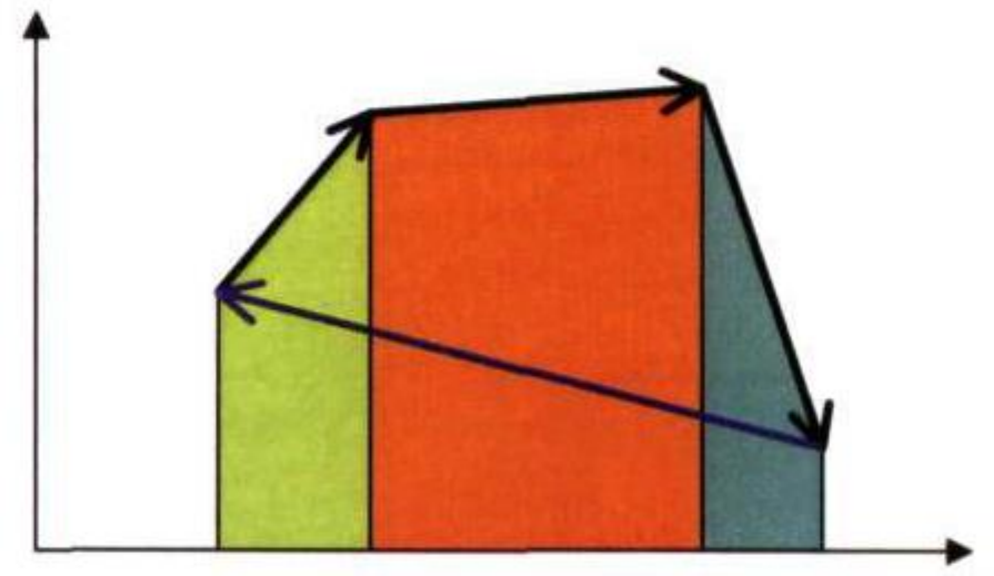
Preview: Geography

2- Measurements

- Many types of interrogation ask for measurements - we might want to know the total area of a parcel of land, or the distance between two points, or the length of a stretch of road - and in principle all of these measurements are obtainable by simple calculations inside a GIS.
- Comparable measurements by hand from maps can be very tedious and error-prone. In fact it was the ability of the computer to make accurate evaluations of area quickly that led the Canadian government to fund the development of the world's first GIS, the Canada Geographic Information System, in the mid-1960s , despite the primitive state and high costs of computing at that time. Evaluation of area by hand is a messy and soul-destroying business. The dot-counting method uses transparent sheets on which randomly located dots have been printed - an area on the map is estimated by counting the number of dots falling within it. In the planimeter method a mechanical device is used to trace the area's boundary, and the required measure accumulates on a dial on the machine.

2.1 Calculation of the area

- The algorithm for calculation of the area of a polygon given the coordinates of the polygon's vertices. The polygon consists of the three black arrows, plus the blue arrow forming the fourth side. Trapezia are dropped from each edge to the x axis and their areas are calculated as (difference in x) times average of y. The trapezia for the first three edges, shown in green, brown, and blue, are summed. When the fourth trapezium is formed from the blue arrow its area is negative because its start point has a larger x than its end point. When this area is subtracted from the total the result is the correct area of the polygon



2.2 Distance and length

- A *metric* is a rule for the determination of distance between points in a space. Several kinds of metrics are used in GIS, depending on the application. The simplest is the rule for determining the shortest distance between two points in a flat plane, called the Pythagorean or straight-line metric. If the two points are defined by the coordinates (x1, y1) and *(x2,, y2),* then the distance *D* between them is the length of the hypotenuse of a rightangled triangle ,and Pythagoras's theorem tells us that the square of this length is equal to the sum of the squares of the lengths of the other two sides. So a simple formula results:

$$D = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

2.3. Shape

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- GIS are also used to characterize the shapes of objects, particularly area objects. In many countries the system of political representation is based on the concept of districts or constituencies, which are used to define who will vote for each place in the legislature. In the USA and the UK, and in many other countries that derived their system of representation from the UK, there is one place in the legislature for each district. It is expected that districts will be compact in shape, and the manipulation of a district's shape to achieve certain overt or covert objectives is termed gerrymandering, after an early governor of Massachusetts, Elbridge Gerry (the shape of one of the state's districts was thought to resemble a salamander, with the implication that it had been manipulated to achieve a certain outcome in the voting; Gerry was a signator both of the Declaration of Independence in 1776, and of the bill that created the offending districts in 1812).

- by law in the USA after every decennial census. An easy way to define shape is by comparing the perimeter length of an area to its area measure. Normally the square root of area is used, to ensure that the numerator and denominator are both measured in the same units. A common measure of shape or compactness is:

$$S = P/3.54\sqrt{A}$$

- where *P* is the perimeter length and *A* is the area. The factor 3.54 (twice the square root of *n)* ensures that the most compact shape, a circle, returns a shape of 1.0, and the most distended and contorted shapes return much higher values.

2.4 Slope and aspect

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- The most versatile and useful representation of terrain in GIS is the digital elevation model, or DEM. This is a raster representation, in which each grid cell records the elevation of the Earth's surface, and reflects a view of terrain as a field of elevation values. The elevation recorded is often the elevation of the cell's central point, but sometimes it is the mean elevation of the cell, and other rules have been used to define the cell's elevation (the rules used to define elevation in each cell of the US Geological Survey's GTOPO30 DEM, which covers the entire Earth's surface, vary depending on the source of data). Because of this variation, it is always advisable to read the available documentation to determine exactly what is meant by the recorded elevation in the cells of any DEM.

3- Transformations

3.1 Buffering

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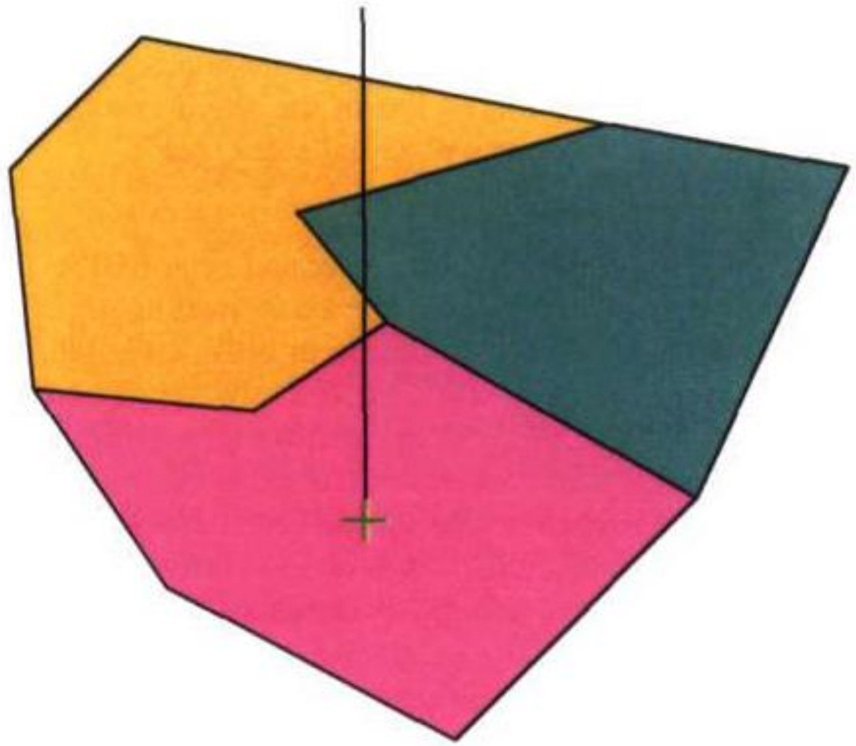
- One of the most important transformations available to the GIS user is the buffer operation . Given any set of objects, which may include points, lines, or areas, a buffer operation builds a new object or objects by identifying all areas that are within a certain specified distance of the original objects. Buffers have many uses, and they are among the most popular of GIS functions:

- The owner of a land parcel has applied for planning permission to rebuild – the local planning authority could build a buffer around the parcel, in order to identify all homeowners who live within the legally mandated distance for notification of proposed redevelopments.
- A logging company wishes to clearcut an area, but is required to avoid cutting in areas within 100 m of streams – the company could build buffers 100 m wide around all streams to identify these protected riparian areas.
- A retailer is considering developing a new store on a site of a type that is able to draw consumers from up to 4 km away from its stores – the retailer could build a buffer around the site to identify the number of consumers living within 4 km of the site, in order to estimate the new store's potential sales

3.2. Point in polygon

- In its simplest form, the point in polygon operation determines whether a given point lies inside or outside a given polygon. In more elaborate forms, there may be many polygons, and many points, and the task is to assign points to polygons. If the polygons overlap, it is possible that a given point lies in one, many, or no polygons, depending on its location.

- The standard algorithm for the point in polygon operation is shown in Figure In essence, it consists of drawing a line from the point to infinity, in this case parallel to the y axis, and determining the number of intersections between the line and the polygon's boundary. If the number is odd the point is inside the polygon and if it is even the point is outside. The algorithm must deal successfully with special cases - for example, if the point lies directly below a vertex (corner point) of the polygon. Some algorithms extend the task to include a third option, when the point lies exactly on the boundary. But others ignore this, on the grounds that it is never possible in practice to determine location with perfect accuracy and so never possible to determine if an infinitely small point lies on or off an infinitely thin boundary line.



3.3. Polygon overlay

- Polygon overlay is similar to point in polygon transformation in the sense that two sets of objects are involved, but in this case both are polygons. It exists in two forms, depending on whether a continuous-field or discrete object perspective is taken. The development of effective algorithms for polygon overlay was one of the most significant challenges of early GIS and the task remains one of the most complex and difficult to program.

4.4 Spatial interpolation

- Spatial interpolation is a pervasive operation in GIS. Although it is often used explicitly in analysis, it is also used implicitly, in various operations such as the preparation of a contour map display, where spatial interpolation is invoked without the user's direct involvement. Spatial interpolation is a process of intelligent guesswork, in which the investigator (and the GIS) attempt to make a reasonable estimate of the value of a continuous field at places where the field has not actually been measured. Spatial interpolation is an operation that makes sense only from the continuous-field perspective.

What role does GIS play in Spatial Analysis?

- GIS is a tool with unique capabilities:
  - Can handle geographically-referenced data
  - Spatial/attribute data entry/update capabilities
  - Data conversion functions
  - Storage and organization of a variety of spatial and attribute data
  - Manipulation of spatial and attribute data (encompasses many different operations)
  - Presentation/display capabilities
  - Spatial analysis tools (many tools may be used in combination)

How can we characterize Spatial Analysis (what skills does it require)?

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- Spatial analysis is an artistic and a scientific endeavor (what does this mean?)
  - It requires knowledge of the problem and/or question to be answered
  - It requires knowledge about the data (how it was collected, organized, coded, etc.)
  - It requires knowledge of GIS capabilities
  - It may require knowledge of statistical techniques
  - It requires envisioning the results of any operation…and the combination of any operations
  - It is not completely objective, in fact some argue that it is completely subjective
  - Many times there is more than one way to derive information that answers a question

Spatial Data Formats

- Spatial data formats are the product of the private sector working to create data files that allow users to:
  - Create maps
  - Manipulate spatial data
  - Perform spatial analysis
- Example ESRI spatial data formats (files): shapefiles, coverages, GRIDs, geodatabases, TINs, Routes