UNIT 22 - THE OBJECT/LAYER DEBATE

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This unit provides background on the debate about "object-oriented databases" currently raging in the GIS community. While this is often seen as complex technical topic, useful insights can be gained from exploring some of the underlying issues.

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A. INTRODUCTION

- if we see the task of building a database as one of representing the contents of maps, then the choice is between:
  - raster - divide the map into a sequence of identical, discrete elements and list the contents of each
  - vector - list the features present on the map and represent each as a point, line or area object
- however the real purpose of the database is to represent the world
- maps are highly efficient ways of showing geographical variation, but representing the contents of maps is not the same as representing the world
  - the objective of a map is visual - to capture geographic information and pass it to the user through the processes of visual perception
  - the objectives of a database - measurement, analysis, modeling - may conflict with the objectives of a map
- the raster/vector debate is only one part of a much larger set of issues concerned with representing the world in spatial databases in meaningful ways
- this unit looks at the debate between layers and objects
- both use databases containing points, lines and areas to describe geographic variation
  - the difference is in how the contents of the database represent the real world

B. THE LAYER VIEW

- the real world is continuous
  - an infinite number of places exist in the world
- locations are specified by some system of coordinates
  - our ability to specify exact location is limited only by the precision of measuring devices
  - in principle, location could be specified using coordinates with any number of digits
- geography can be described using a number of variables, e.g. elevation, soil type, mean January temperature, population density, county
  - each of these variables can be determined at any place given suitable measurement instruments
- each variable can be conceptualized as a layer
  - each layer captures the variation of one variable over the surface of the earth

- the database can be interrogated to determine the value of any variable at any place
  - the result can be checked by visiting the specified place (ground truth)

Data models

- GIS has developed certain data models for representing the layer view of the world, among them:
  - raster - continuous geographic variation is approximated by finite-sized pixels
  - polygon - the world is divided into irregular pieces, and the variable is assumed to be constant within each piece and to change suddenly at each boundary
  - TIN - the world is divided into triangles, and variation is approximated by a plane within each triangle

- each of these models provides a way of capturing the variation of one variable over the earth's surface

- each uses objects of various kinds - points, lines or areas - but the objects exist in the database, for the purpose of describing variation, and not in the real world
  - e.g. contours are line objects, but exist to capture varying elevation

C. THE OBJECT VIEW

- humans see the world as an empty space littered with various types of objects

- objects are used in speaking, writing and thinking about the world

- we find it more convenient to describe places in relation to objects of known location, than using coordinates of any kind
  - e.g. the island of Mauritius is described as "in the Indian Ocean", not by its latitude and longitude

- objects are not simply artificial constructs used in describing variation (the layer view) but fundamental to our understanding of geography

- objects can be points, lines or areas

- any place can be occupied by any number of objects, and can be empty ("there's nothing there")

- the layer view is inefficient when variables are defined only over limited geographic areas or classes of objects
  - e.g. date of last forest fire is defined only over burned areas
  - e.g. name of city is defined only over city points or areas, but name of county is defined everywhere in the US

Scale

- the same object can be represented differently at different scales

- e.g. "San Francisco" can suggest:
    - a city and county with legal geographic limits
    - the entire metropolitan area of San Francisco Bay

Time

- the object view has obvious advantages when well-defined objects move through time, e.g. people
- poorly-defined objects, e.g. clouds, present enormous problems
    - e.g. how to track the movement of an object through time from one image to another when objects are changing form, splitting and merging

Object orientation

- is a set of concepts originating in Computer Science and dealing with the design of both databases and processing algorithms
    - includes programming languages (e.g. Smalltalk) and databases, many of which are still experimental
- argues that it is artificial and confusing to separate the definition of objects from the operations performed on them
    - in GIS, to separate the nature of geographical variation from operations (analysis, modeling) performed on geographical variation
- has very recently stimulated debate within GIS about the nature and role of geographical objects
- contains several key concepts:

Identity

- objects have identity which persists through various kinds of processing
    - e.g. "Indian Ocean" is an identifiable and persistent geographical concept, even though it is not possible to delimit it precisely at any scale
    - in GIS, object identity can persist through scale change and also change of graphic representation (e.g. city as point to city as polygon)

Inheritance

- when new objects are created they can inherit the properties of their parents
    - e.g. when a land parcel is created from survey records, it should inherit properties of those records, including the name of the surveyor and the date of the survey
- in GIS, it is sometimes desirable to deal with complex objects formed as collections of simpler objects, and to have the complex inherit properties of the simple objects, or vice versa
    - e.g. the complex object "airport" might be composed of the simpler objects "runway", "tower", "perimeter" etc. Some of the attributes of "airport" should be

accessible at the level of the simpler objects, such as "airport name"

Encapsulation

- rather than separate the objectives of description and processing, it is desirable to couple objects with the operations performable on them
    - in GIS, a "line" may be part of a county boundary, a river course, a highway or a contour - each has its own set of appropriate operations

D. COUNTER-ARGUMENTS FOR THE LAYER VIEW

Do objects really exist?

- if an object is real, it must be possible to visit a place and determine precisely whether the place lies in or on the object
- this is possible for certain mathematically defined objects, e.g. the Northern Hemisphere, the Equator
- for the object "house" to be real, every place on the earth's surface must be either inside or outside
    - we would need to define the precise footprint of the house
    - we would need to be able to measure a place's location exactly, and this is not possible because of limitations in geodesy and surveying technologies
- objects like "woodlot", "Indian Ocean" are not precisely defined
- in the layer view, very few geographical objects exist in any precise sense

Environmental modeling

- theories of atmospheric, oceanic, geophysical processes are compatible with the layer view
    - e.g. meteorology models fields, a field being a variable defined everywhere in two or three dimensions
    - examples of such fields are temperature, wind speed and direction, atmospheric pressure
- environmental scientists use layers to describe soil and vegetation types, biodiversity, species ranges etc.
- much data for environmental modeling comes from remote sensing, which implies a layer view, at least until the data is analyzed and interpreted

Gradients

- the object view of the world as populated by discrete objects is less compatible with notions of continuous geographical change:

e.g. gradients, transition zones, zones of uncertainty, fuzziness, slopes, ecotones, clines

Enlightenment

- people see the world, learn and talk about it and navigate using objects
- scientific understanding often requires a new perspective
    - e.g. understanding electromagnetic radiation requires the concept of continuous, invisible fields
    - e.g. atmospheric science requires continuous fields of temperature, pressure
- the scientist's view of the world may have to be radically different from more traditional modes of human thought
    - the layer view may be the scientist's way of imposing a more enlightened perspective on the world

E. AREAS OF APPLICATION

- some areas of GIS application are more likely to take the object view, some the layer view

Resource management (layer view)

- geographic variation can be described by a relatively small number of variables
    - there are measurement problems in many areas, e.g. biodiversity
- conceptualization does not change radically from one scale to another
- difficulties occur in handling information on moving individuals, e.g. tracking grizzly bear, using the layer view

Utilities (object view)

- the notion of empty space littered with well-defined objects fits the problems of managing large numbers of pipes, valves, meters etc.
- two objects may occupy the same location, but be separated vertically
- the notion of a variable measurable everywhere on the earth's surface has little relevance

Transportation, hydrology (mixed)

- roads, railways and streams are mostly well-defined line objects
- area objects are sometimes needed for analysis
    - e.g. lake, noise buffer around highway
- some types of hydrologic modeling require a layer view
    - e.g. overland, subsurface flows are not often confined to objects, better modeled

as fields using layers

F. EXCEPTIONS

- some information is not well suited to either view

Transport networks

- often modeled as line and point objects (links and nodes) lying in the plane
- the DIME and TIGER databases of the US Census use a layer view to model street networks
  - street intersections are nodes (0-cells)
  - streets between intersections are links (1-cells) bounded by 0-cells
  - blocks are areas (2-cells) bounded by 1-cells
  - all places are in exactly one 2-cell or on a 1-cell
  - as a consequence of this planar enforcement, all crossings of streets are also intersections - both overpasses and grade intersections are 0-cells
  - this makes it difficult to use the model for routing
- in transportation, all information is limited to links and nodes - places that are not on links or nodes cannot have attributes of any kind
- the links and nodes form a 1-dimensional space embedded in the geographical 2-dimensional space
- objects are restricted to points on the network, or line segments of the network - there is no equivalent of the area object
- positions on the network can be specified in terms of link number and distance from the link's beginning node
- in the object view, it would be necessary to create links and nodes wherever attributes change, thus fragmenting the network unnecessarily

G. CONVERSION

- it is possible to convert from one view of the world to the other
- this is commonly done in the construction of a layer database from digitized "spaghetti", e.g. in digitizing a soil map
  - the lines on the map (boundaries between soil classes) are digitized as separate objects
  - objects may cross, one place may be empty or occupied by any number of objects
- the "building of topology" or process of planar enforcement essentially converts this object view of the world into a layer
  - after conversion, every place either lies on a boundary, or has exactly one soil type

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EXAM AND DISCUSSION QUESTIONS

1. It has been said that geographical data is special because it is inherently infinite - the world contains an infinite number of variables defined at an infinite number of places. Do you agree? Are there any other examples?

2. Consider a set of driving directions from your house to your supermarket. Do they imply a layer or an object view of the world, or is neither appropriate?

3. Which layers would you identify as most important in describing the natural environment?

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