Spatial Databases as Models of Reality

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Introduction

- The real world is too complex for our immediate and direct understanding
- We create “models” of reality that are intended to have some similarity with selected aspects of the real world
- Databases are created from these “models” as a fundamental step in coming to know the nature and status of that reality

Definition

- Spatial Database: a collection of spatially referenced data that acts as a model of reality
  - A database is a model of reality in the sense that the database represents a selected set or approximation of phenomena
  - These selected phenomena are deemed important enough to represent in digital form
  - The digital representation might be for some past, present or future time period (or contain some combination of several time periods in an organized fashion)

Standards

- Many of the definitions in this presentation have been standardized by the proposed US National Digital Cartographic Standard (DCDSTF, 1998)
  - These standards have been developed to provide a nationally uniform means for portraying and exchanging digital cartographic data
  - These cartographic standards will form part of a larger standard being developed for the digital representation of all earth science information

Database Content & an Organization's Mission
ORGANIZATION MANDATES

- Organizations have mandates to perform certain tasks that carry out their missions
  - Mandates are the reasons they exist as organizations
- Organizations have different needs for data depending on their mandates and the activities required to carry out these mandates
  - Mandates often help identify & define entities of interest, requiring a certain view of the world
  - What might seem at first glance to be the same data need in two different organizations can actually be quite different when looked at in more detail
    - example: wildlife and forestry departments both need info on vegetation, but the detail needed is different

Database Content & an Organization's Mission
DATABASE CONTENTS

Example: Transportation

- Highway data from the different points of view:

A natural resource organization might only need logging roads and the connecting access to state highways.

A transportation organization's main interest is in identifying highways used by the public. (The database might also be used to store detailed highway condition and maintenance information.)

- We would expect transportation's need for highway data to be more detailed than would the natural resource organization's

Database Content & an Organization's Mission
DATABASE CONTENTS

Example: Wetlands

- Wetland data from the different points of view:

An ecological organization might define wetlands as a natural resource to be preserved and restricted from developed. (That perspective might require considerable detail for describing the area's biology & physical resources.)

A taxing authority might define a wetland to be a "wasteland" and of very little value to society. (That description might require only the boundary of the "wasteland" in the database.)

Database Content & an Organization's Mission
DATABASE DESIGN

- In each organization only certain phenomena are important enough to collect and represent in a database
  - The data collection process involves a sampling of geographic reality to determine the status of that reality(whether past, present or future)
- Identifying the phenomena and then choosing an appropriate data representation for them is part of a process called database design.

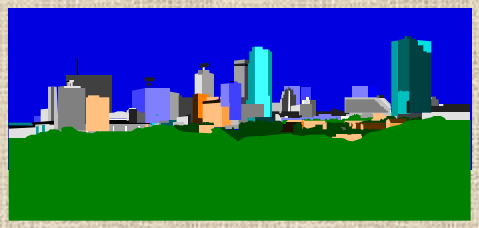
Fundamental Database Elements

- Elements of reality modeled in a GIS database have two identities:
  - **Entity:** the element in reality
  - **Object:** the element as it is represented in the database
- A third identity that is important in cartographic applications is the **symbol** that is used to depict the object/entity as a feature on a map or other graphic display

These definitions are based on those defined by the DCDSTF, 1998

Entity

- A phenomenon of interest in reality that is not further subdivided into phenomena of the same kind
  - Example: a city could be considered an entity and subdivided into component parts, but these parts would NOT be called cities, they would be districts, neighborhoods or the like



  - Example: a forest could be subdivided into smaller forests

Object

- A digital representation of all or part of an entity
- The method of digital representation of a phenomenon varies according to scale, purpose and other factors
  - Example: a city could be represented geographically as a point if the area under consideration were continental in scale
  - the same city could be geographically represented as an area if dealing with a geographic database for a state or a county

Entity Types

- Similar phenomena to be stored in a database are identified as entity types
- An entity type is any grouping of similar phenomena that should eventually get represented and stored in a uniform way (i.e., roads, rivers, elevations, vegetation)
  - Provides convenient conceptual framework for describing phenomena at a general level
  - Organizational perspective influences this interpretation to a large degree

Entity Types ~ Continued

- Precise definitions should be generated for each entity type
  - Helps with identifying overlapping categories of information
  - Aids in clarifying the content of the database
  - The US National Standard for Digital Cartographic Data, Vol. 2, includes a large number of definitions for entity types.
    - Examples:

Entity Types ~ Continued

- First step in database design: Selection and definition of entity types to be included
  - This is guided by the organization's mandate and purpose of the database
  - This framework can be as important as the actual database because it guides the development
- Second step in database design: Choose an appropriate method of spatial representation for each of the entity types

Spatial Object Type

- The digital representation of entity types in a spatial database requires the selection of appropriate spatial object types
- The National Standard for Digital Cartographic Databases specifies a basic list of spatial objects and their characteristics
- This classification is based on the following definition of spatial dimensions (next slide).

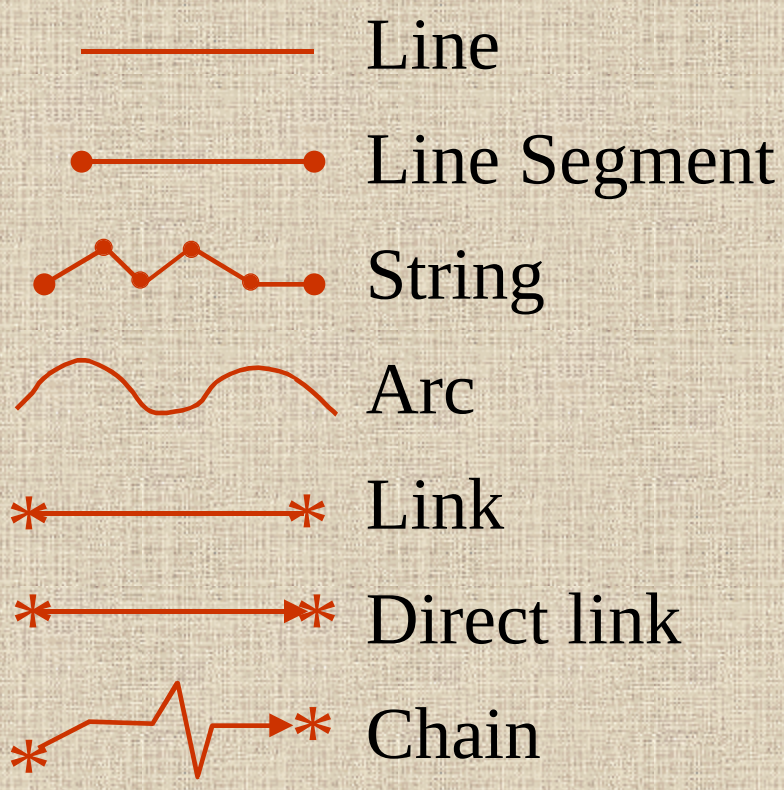
Spatial Dimensions

- O-D: an object that has a position in space, but no length
  - A point
- 1-D: an object having a length
  - Composed of 2 or more 0-D objects
  - A line
- 2-D: an object having a length and width
  - Bounded by at least three 1-D line segment objects
  - An area
- 3-D: an object having a length, width, and height/depth
  - Bounded by at least four 2-D objects
  - A volume

Basic 0-Dimensional Object Types

- Point
- Node

Basic 1-Dimensional Object Types



Basic 1-Dimensional Object Types (Continued)

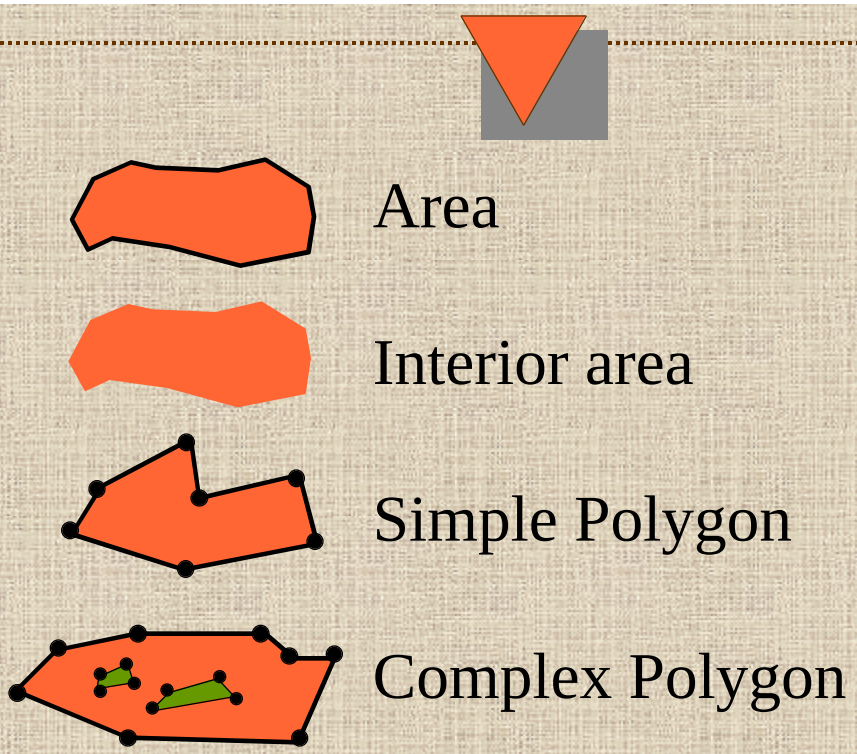
Ring created from string(s)

Ring created from arc(s)

Ring created from link(s)

Ring created from Chain(s)

Basic 2-Dimensional Spatial Object Types



Attributes

- An attribute is a characteristic of an entity selected for representation
- Usually non-spatial
  - Though some may be related to the spatial character of the phenomena under study
    - Examples: area, perimeter

Attribute Value

- The actual value of the attribute that has been measured (sampled) and stored in the database
- An entity type is almost always labeled and known by attributes
  - Example: a road usually has a name and is identified according to its class (i.e., alley, freeway)
- Attributes values often are conceptually organized in attribute tables which list individual entities in the rows and attributes in the column
  - Entries in each cell of the table represent the attribute value of a specific attribute for a specific entity
    - Note: attribute table is not an official DCDSTF term

Database Model

- Is a conceptual description of a database defining entity type and associated attributes
  - Each entity type is represented by specific spatial objects
- Examples of database models can be grouped by application area
  - Example: transportation applications require different database models than to natural resource applications

Database Model ~ Continued

- After the database is constructed, the database mode is a view of the database which the system can present to the user
  - Other views can be presented, but this one is likely useful because it was important in the conceptual design
    - Example: the system can model the data in vector form but generate a raster for purpose of display to the user
  - Need not be related directly to the way the data are actually stored in the database
    - Example: census zones may be defined as being represented by polygons, but the program may actually represent the polygon as a series of line segments

Layers

- Spatial objects can be grouped into layers, also called overlays, coverages or themes
- One layer may represent a single entity type or a group of conceptually related entity types
  - Example: a layer may have only stream segments or may have streams, lakes, coastline and swamps
  - Options depend on the system as well as the database model
  - Some spatial databases have been built by combining all entities into one layer

Steps in Database Design

- Conceptual
  - Software and hardware independent
  - Describes and defines included entities
  - Identifies how entities will be represented in the database
    - i.e., selection of spatial objects - points, lines, areas, raster cells
  - Requires decisions about how real-world dimensionality and relationships will be represented
    - These can be based on the processing that will be done on these objects
    - i.e., should a building be represented as an area or a point?
    - i.e., should highway segments be explicitly linked in the database?

Steps in Database Design ~ Continued

- Logical
  - Software specific but hardware independent
  - Sets out the logical structure of the database elements, determin3ed by the database management system used by the software
- Physical
  - Both hardware and software specific
  - Requires consideration of how files will be structured for access from the disk

Desirable Database Characteristics

Database should be:

- **Contemporaneous:** should contain information of the same vintage for all its measured variables
- **As detailed as necessary** for the intended applications
  - The categories of information & subcategories within them should contain all of the data needed to analyze or model the behavior of the resource using conventional methods & models
- **Positionally accurate**

Desirable Database Characteristics ~ Continued

Database should be:

- **Exactly compatible** with other information that may be overlain with it
- **Internally accurate**, portraying the nature of phenomena without error: requires clear definitions of phenomena that are included
- **Readily updated** on a regular schedule
- **Accessible** to whoever needs it

Issues in Database Design

- Almost all entities of geographic reality have at least 3-dimensional spatial character, but not all dimensions may be needed
  - *Example:* highway pavement has a depth which might be important, but is not as important as the width, which is not as important as the length

- Representation should be based on types of manipulations that might be undertaken
- Map-scale of the source document is important in constraining the level of detail represented in a database
  - *Example:* on a 1:100,000 map individual houses or fields are not visible