PDHonline Course L155 (5 PDH)

Data Models and Data processing in GIS

Instructor: Steve Ramroop, Ph.D.

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PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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Slide 1

Lecture 2 Content

- **Geographic Information Systems (GIS)**

Data Models,

Data Structures and Data Management

(Continued)

This lecture is the continuation of the GIS topic identified in the course description which is Data Models, Data Structure and Data Management.

Slide 2

- **Spatial Data Models**
  - **Hierarchical data model**
  - **Network data model**
  - **Relational data model**
  - **Object oriented data model**
  - **Temporal data model**

This is the contents of this lecture. Details into each of the data model are presented in this lecture. The structure of this lecture is that each data model is presented with a description of its common characteristics. The first type of spatial data model adopted when GIS was first introduced was the Hierarchical data model.

Slide 3

1) Hierarchical Data Model

- data sets are organized in a hierarchical tree structure
- relationships among the data sets entities are defined by the organization of the hierarchy
- that is the hierarchy is encoded in the records for each entity

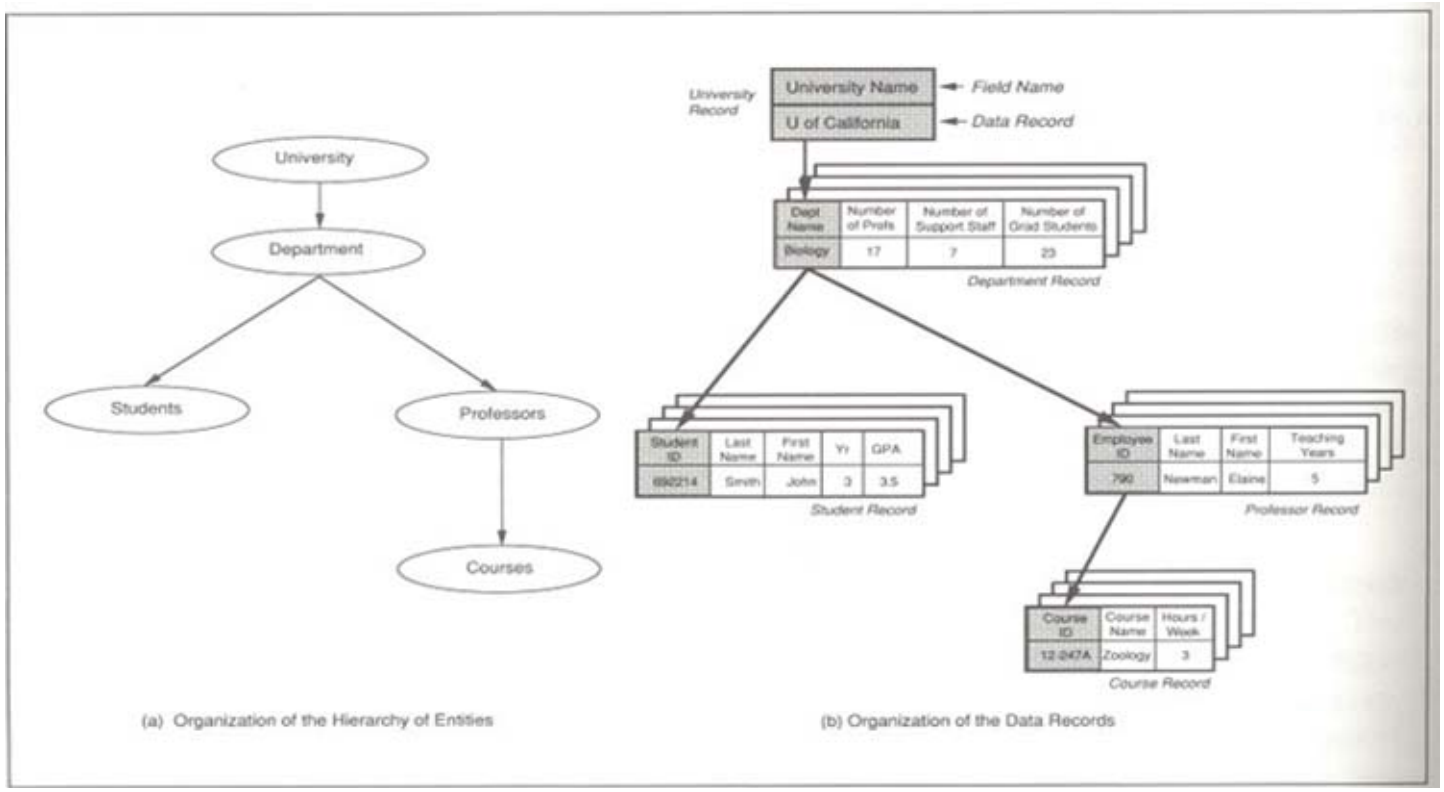
This slide gives some characteristics of the Hierarchical Data Model. In this model the organization's structure is explicitly defined in the model. The hierarchy had to be encoded into the records of each entity presented on the map. The following slide gives a graphic example.

Slide 4

Organization of a database using the Hierarchical Data Model

> Courses are taught by Professors

> Students are in a Department



This slide shows and example of a hierarchical data model adopted in the context of University that has professors who teach courses. As shown in the figure there is a relationship between University and Department; Department and Students; Department and Professors; and Professors and courses.

In this model a **“child”** can have only one **“parent”**. That is, in this data model, lower levels of the hierarchy cannot have multiple higher level relationships. For example “Courses” are taught by “Professors”, and “Students” are in a “Department”.

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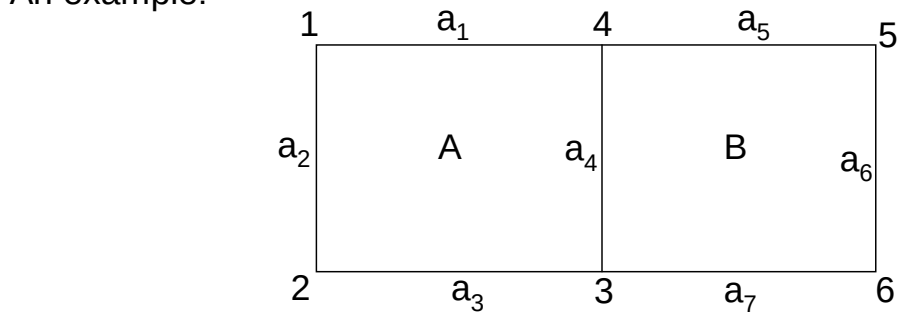
Notes on the previous figure:

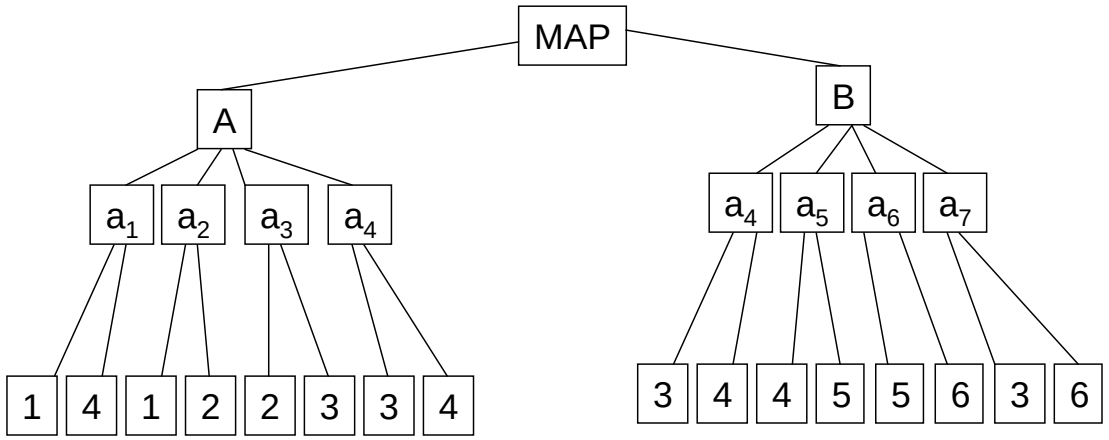
- **The highest level of the hierarchy is called the *"root"* which consists of one entity**
- **Except for the root, every element has one higher level element related to it, that is called its *"parent"* and one or more subordinate elements is called the *"children"***
  - **an element can have only one parent but can have multiple children**
- **All relations are many-to-one relation or one-to-one relation**
  - **e.g. many departments belong to one university and many students are in each department**
- **Information is retrieved by traversing the hierarchy structure starting from the root of the hierarchy**

This slide gives some notes of the hierarchical data model. Note that in this model searches are done by traversing the entire hierarchy starting from the root.

Slide 6

An example:





This is another graphic representation of how the hierarchy data model is applied to a map representation.

The Map is the root, A and B are the sections of the Map. Each section is defined by a set of arcs labeled by a lower case (a) with a sequential numbering as its subscript. An arc is defined by a start node and an end node. Nodes are labeled at the intersection of arcs and the nodes are numbered sequentially starting from 1 and ending at 6. Notice that arc a_4 is repeated under sections A and B.

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Notes on the previous figure (hierarchy model example):

- The root is “Map” while its children is “A” and “B”
- “A” and “B” are parents themselves who have children
  - “A” has children → a_1 …. a_4
  - “B” has children → a_4 …. a_7
- a_4 is repeated

This slide gives some notes on the hierarchy model example from the previous slide and the notes.

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- **Advantages of the hierarchy structure :**
  - **easy to understand**
  - **easy to update but cumbersome because the relationships need to be maintained**
  - **easy access to large amounts of data sets**

- **Disadvantages of the hierarchy structure :**
  - **retrieval of data is slow because the entire hierarchy need to be traversed**
  - **duplication of data because some relationships need to be replicated**
  - **updating is cumbersome because relationships need to be maintained**
  - **data relationships are difficult to modify and queries are restricted to traversing the existing hierarchy**
  - **multiple parents are not allowed (especially necessary where an element needs to be represented as a member of multiple groups)**

This slide identifies the advantages and disadvantages of the hierarchy data model. The disadvantages identify the drawbacks of the hierarchical data model.

2) Network Data Model

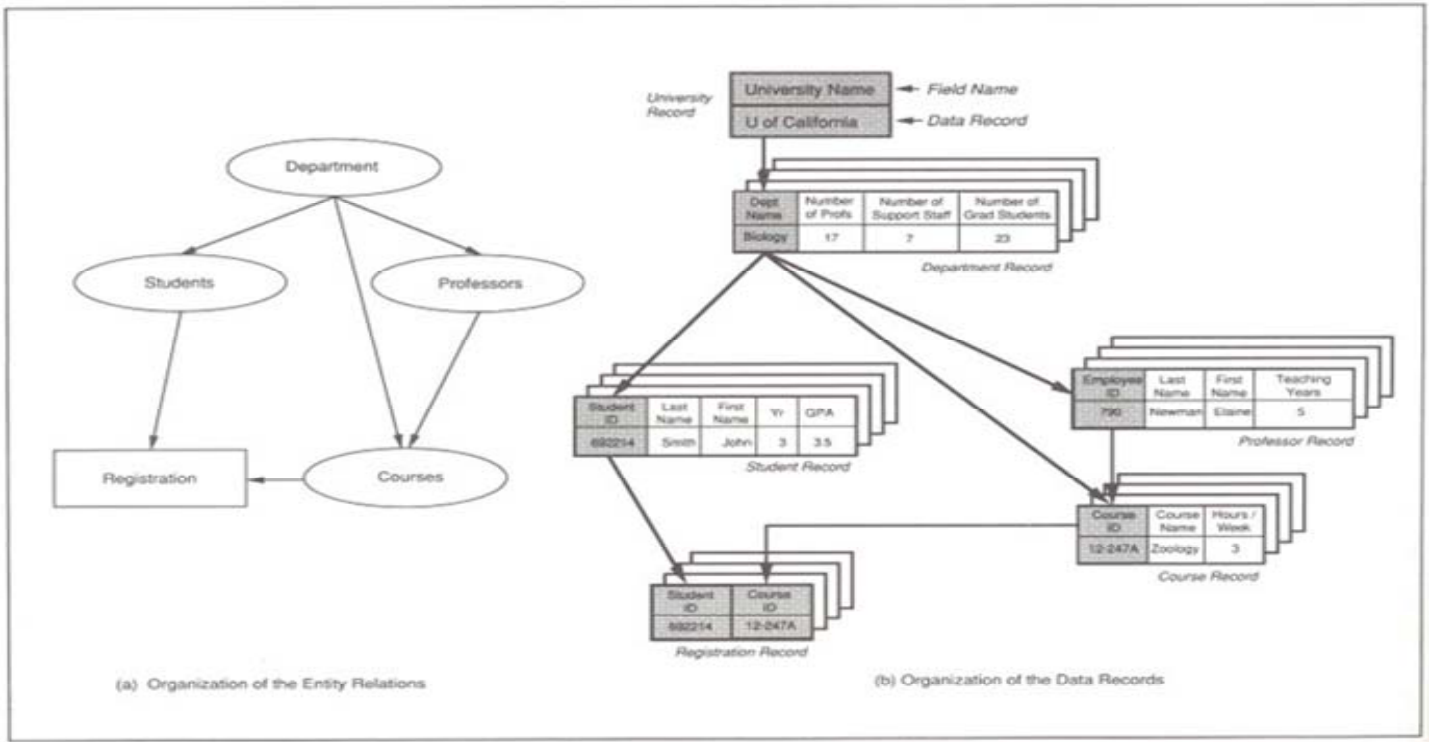
- overcomes some of the inflexibility and disadvantages of the hierarchical model
- an entity can have multiple parent as well as multiple “child” relations
- roots are not necessarily required
- data records can be directly searched without traversing the entire hierarchy

This slide shows the second data model which is called Network Data Model. This model improved on the drawbacks of the Hierarchical Data Model. The common characteristics of the Network Data Model are shown in this slide.

Slide 10

> Courses are related to the Department and the Professors

> Registration are related to the Courses and Students



Organization of a database using the Network Data Model

This slide show the same example adopted in the context of University that has professors who teach courses. As shown in the figure there is a relationship between University and Department; Department and Students; Professors and courses; and Students and Registration. There are multiple relationships between Courses and Registration. That is, Courses have a relationship with Professors and also a relationship with Department. Registration has multiple relationships as well. There is a relation between Registration and Courses; as well as a relationship with Registration and Students. This entire example is applied using a Network Data Model as shown in the figure.

In the Network Data Model a “child” can have more than one “parent”. That is, in this data model lower levels of the hierarchy can have multiple higher level relationships. For example “courses” are related to the ‘department’ and “professors”, and “registration” has a relationship to the “courses” and the “students”.

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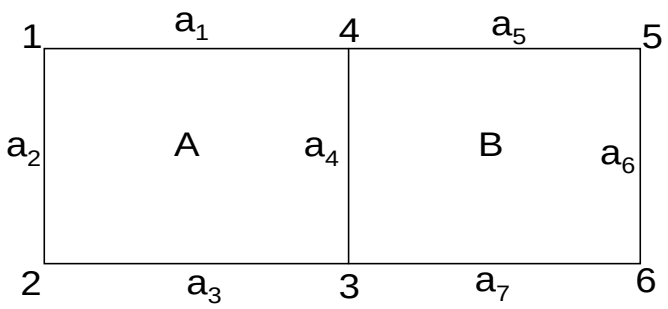
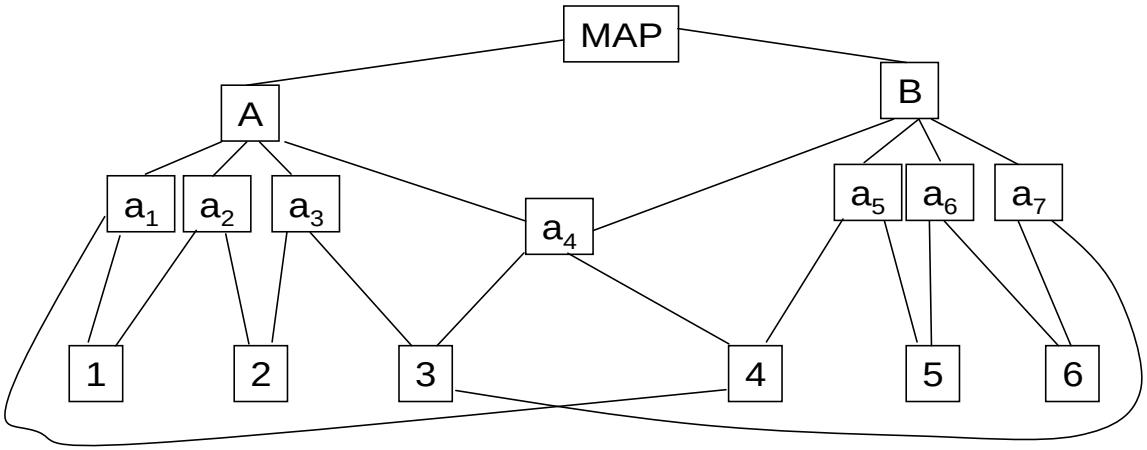
An example:





This is another graphic representation of how the network data model is applied to a map representation.

The entire Map is shown. The letters A and B are the sections of the Map. Each section is defined by a set of arcs labeled by a lower case (a) with a sequential numbering as its subscript. An arc is defined by a start node and an end node. Nodes are labeled at the intersection of arcs and the nodes are numbered sequentially starting from 1 and ending at 6. Notice that arc a_4 is **not** repeated under sections A and B.

Notes on the previous figure (network model example):

- no hierarchy of data fields within a record
- "A" and "B" are parents themselves who have children
  - "A" has children → a_1 …. a_4
  - "B" has children → a_4 …. a_7
- a_4 is NOT repeated

This slide gives some details into the previous slide of the Network Data model.

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Pros and Cons of the network model

Advantages	Disadvantages
Less redundancy	More extensive linkage information must be stored
Ability to be very complex	Data files are complex
Fast query	Updating time is time consuming (due to numerous links)

This slide identifies some of the pros and cons of the network model. Because of the disadvantages there was need to adopt another data model.

3) Relational Data Model

- more popular data models used in GIS
- no hierarchy of data fields within a record
- every data field can be used as a key
- the table as a whole represents the relationship among all the attributes it contains in a single table and is often called a ***"relation"***
- relations are also defined between tables using unique ID numbers
- Data integrity is managed by having many tables with their relations explicitly defined. This is the process called ***"normalization"***

The third data model is presented here -- Relational Data Model. Put simply, it is the ability to define the relationships between entities using tables that defined the entities. This model maintains data integrity through a process called normalization. This is the process in which smaller tables are defined to explicitly define the relationships between tables. This is done in order to maintain data integrity and also facilitate easy updating. Note that every data field in a table can be used as a key which can be linked to other tables that has the same key definition.

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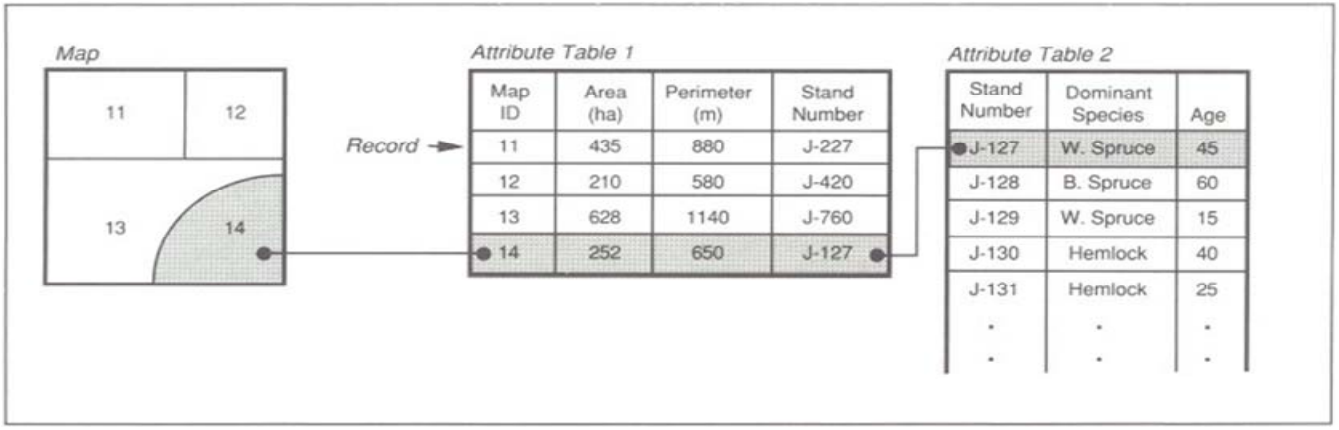
- **table relationships can be :**
  - ***one to one : one table related to another table***
  - ***many to one : many tables related to one table***
  - ***one to many : one table related to many tables***
  - ***many to many : many tables related to many tables***
- **searches can be made of any single table using any of the attribute fields, singly or together**
- **to perform searches on different tables, links between them (using any attribute they share in common) must be established**
  - **→Procedure is termed *"JOIN"***

This slide identifies the various relations that can exist between tables. Before queries can be done, tables can be joined or linked depending upon the existing relationships. GIS software is equipped to represent the relationships between tables, (called attribute data) that are linked to the map phenomena, (called spatial data).

Slide 16



Storage of GIS attribute information in a Relational Database

This is another example of a relational data model that links the spatial data with the attribute data sets. The map is linked to Attribute Table 1 using the Map ID column as the key. Then Attribute Table 1 is linked to Attribute Table 2 using the Stand Number column as the key.

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Notes on the previous figure (relational model):

- need to deal with the "problem" of redundancy of data
- usually there is a trade-off into the amount of redundancy a relational database can have since it affects data storage and the speed at which queries are executed
- note that it takes longer to search the data stored in several tables than to search the same data stored in one table
- However, data stored in one table may also have null entries which is not a good characteristic in databases
- As the number of data tables are reduced, the redundancy of data storage tends to increase
- no restrictions on the type of queries possible (flexible)

This slide gives some self explanatory notes about the relational model. There is the problem of data redundancy in tables. The goal is to get a good balance as to how much redundancy is allowed for a given GIS application.

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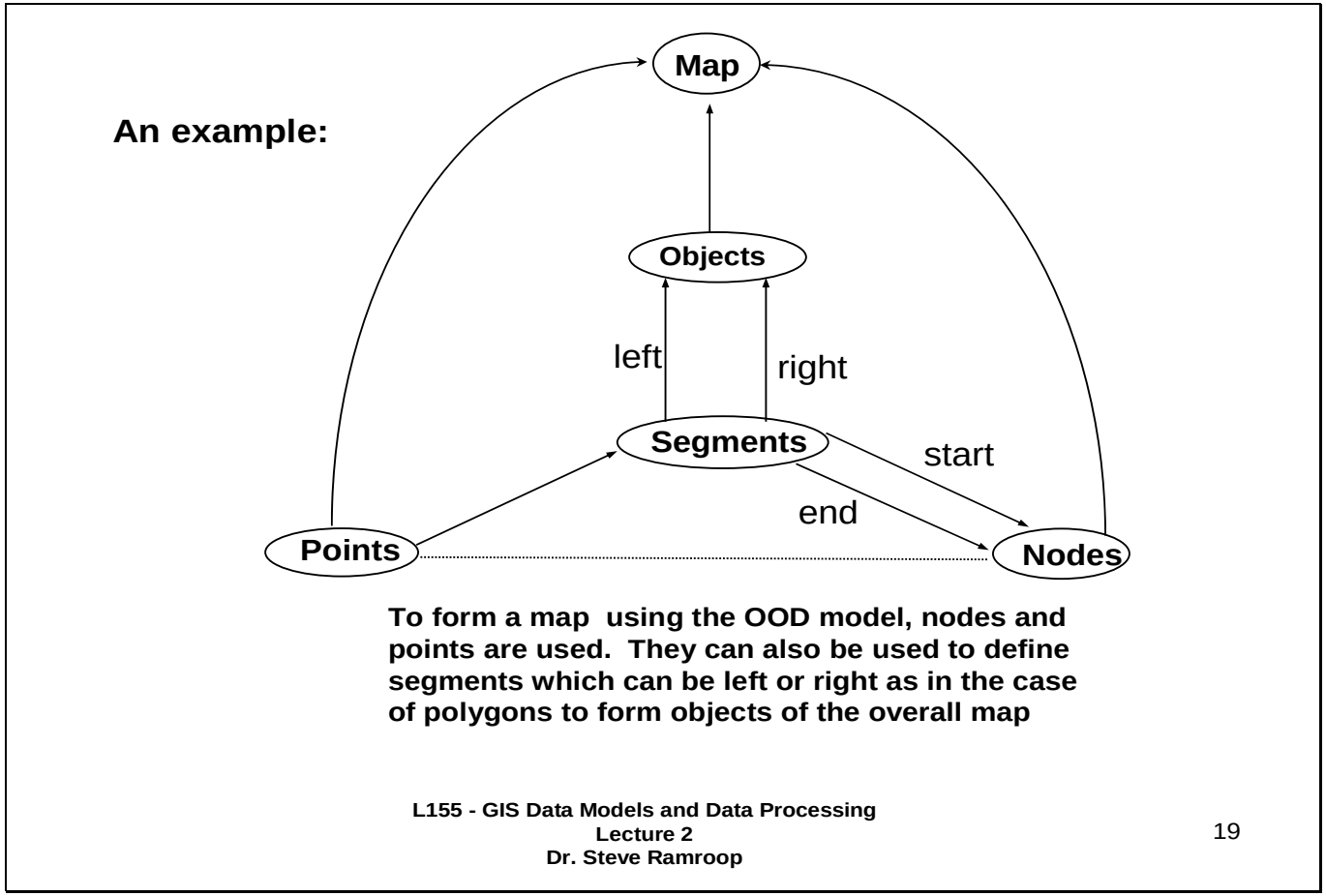
4) Object Oriented Data (OOD) Model

- everything in the real world is considered an object
- each object has its own data plus the program code for accessing or altering the information
- Object Oriented Data Model is based upon the following context (called *abstraction processes)*:

a) Aggregation - transforming relations to a higher level
b) Classification - abstracting common characteristics of objects
c) Generalization - placing classes into a hierarchy of classes

This is the forth data model. This is slowly becoming popular. We are moving towards treating every real world entity as an object, which can have a state, and is capable of being classified.

Slide 19



This is a graphical representation of how OOD model is used to represent map entities. Segments can be aggregated to form objects. Each segments has a start and end node. The collection of segments, nodes, and points are use to represent the map.

5) Temporal Model

- involves the ability to attach time data and its time dimension
- this is one of the recent areas of research and different approaches are being researched to find the ability to maintain / record the time dimension
- particularly useful for cadastral systems where there is a need to register the changes of land ownership and other historical characteristics

This is the fifth data model. It is an area of ongoing research. It is associated with the attachment of time stamps to the data sets.

… The End …