INTELLIGENT TRANSPORTATION SYSTEMS

Lecture 2:
Geographic Information Systems
GIS
(5 Oct 2022)

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Reference: Introduction to GIS mapping, University of Waterloo (Don Boyes)
The first law of Geography:
Everything is related to everything else, but near things are more related than distant things
(Waldo Tobler).
What is a map? Real picture?
What is a map? Real picture?
What do we include? Interesting places?
What is a map?

A simplifies version of the real picture?
What is a map?
What do we include? Traffic status?
What is a map?
What do we include? Bike trails?
What is a map?
What do we include? Different layers of information.
Where is the place? Where am I? How do I get there?
Where is the place? Where am I? How do I get there? What is there? A campfire? Walking trail?
**Geographic Information Technologies**


- **Remote Sensing (RS):** Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites. Ex. European Space Agency's (ESA) Sentinel-1a.
Geographic Information Technologies


- **Geographical Information System (GIS)**: A framework that provides the ability to capture and analyze spatial and geographic data.

- **Remote Sensing (RS)**: Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites. Ex. European Space Agency's (ESA) Sentinel-1a.
Geographic Information System; a bit of history

Canadian Geographic Information System (CGIS)

- In the late 1950s and early 1960s, the Canadian government began to realize the need to manage the use of land and resources better for economic and political reasons.
- In 1962, the government decided to map the entire country and started the Canada Land Inventory.
- The plan was to create about 1,500 (paper) maps to cover the entire country.
- Roger Tomlinson was involved in creating this Canada Land Inventory.
- He realized the limitations of doing things the old-fashioned way with paper maps.

"Data for Decision" produced by the National Film Board of Canada describes the development of the Canada Geographic Information System (CGIS).
Geographic Information System; a bit of history

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- He realized the limitations of doing things the old-fashioned way with paper maps.

**limitation:**

1. The amount of information one can pack into one map on paper
2. How to interpret and analyze the map (measures, features, combine )
It is about connecting a database to a map.
Not easy to interpret
### 2015 USA Population Density - Tract (0 selected)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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*Not easy to interpret*
Not easy to interpret
Not easy to interpret

Picture = 1,000 words
Geographic Information System (GIS)

A computer system for:

- capturing,
- storing,
- filtering,
- analyzing,
- visualizing

Geospatial data.

That is data that's been geographically referenced.

Not easy to interpret
GIS Components

- Hardware
- Software
- Geospatial data
- Procedures (data managements, analysis)
- People
Software

Provides the functions and tools needed to store, analyze, and display geographic information:

- A database management system
- Tools for the input and manipulation of geographic information
- Tools that support geographic query, analysis, and visualization
- A graphical user interface (GUI) for easy access to tools
### Data

#### Locations

- Where is it?

#### Attributes

- What is it?

#### Relationships

- How things are related?

<table>
<thead>
<tr>
<th>Year</th>
<th>Population Density (Pop per Square Mile)</th>
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<tbody>
<tr>
<td>2010</td>
<td>2015</td>
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<tr>
<td>505</td>
<td>481</td>
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<tr>
<td>1,682</td>
<td>1,663</td>
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<td>1,633</td>
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<td>2,446</td>
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<td>52</td>
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<tr>
<td>19</td>
<td>20</td>
</tr>
</tbody>
</table>
Procedure

For successful GIS operation, a well-designed plan and business operation rules are essential. Methods can vary with different organizations. Any organization has documented its process plan for GIS operation. Standardized process models to build a system are still in a transition phase.
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People

People are an essential catalyst in doing a GIS Components setup. GIS projects require a strong workforce and inventory management; hence project development requires GIS Analysts, Developers, Database Administrators, ML/AI Engineers, Data Scientists, ...
Mapping the Real World

The objective is to map the real world.

Q: How much details are enough?
The objective is to map the real world. Q: How much details are enough?
The objective is to map the real world.
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Mapping the Real World

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Mapping the Real World

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Q: How much details are enough?
Real world features exist as...

Continuous phenomena: Elevation, temperature...
Real world features exist as...

Continuous phenomena: Elevation, temperature...

Discrete objects: Buildings, roads...
Real world features exist as...

**Discrete objects:** Buildings, roads...

**Continuous phenomena:** Elevation, temperature...

How can these be shown on a digital map? How can we store data about them?
Data Models

Continuous phenomena: **Raster** data model

Discrete objects: **Vector** data model
Each map layer is a geographic theme
Raster Data Model

- Data is classified as continues
- Frequently changing values
- Elevation, noise pollution, rainfall, heat maps
- Cells are organized in indexed rows and columns
- Aerial photos, Satellite imagery, ...
- Storage format: Esri grid, jpeg, tiff, ...
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- Storage format: Esri grid, jpeg, tiff, ..
Raster Data Model

- Smaller cell size
- Higher resolution
- Higher feature spatial accuracy
- Slower display
- Slower processing
- Larger file size

- Larger cell size
- Lower resolution
- Lower feature spatial accuracy
- Faster display
- Faster processing
- Smaller file size

Vector Data Model

- Representation based on
  - points,
  - lines,
  - polygons.
- Good fit for defining bounding, precision, streets, parcels, roads, ...
Vector Data Model

**Geometry**
- point
- line
- polygon

**Attributes**

<table>
<thead>
<tr>
<th>Name</th>
<th>Speed Limit</th>
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<tbody>
<tr>
<td>Bloor Street West</td>
<td>50</td>
</tr>
<tr>
<td>University Record</td>
<td>Field</td>
</tr>
<tr>
<td>St. George Street</td>
<td>40</td>
</tr>
<tr>
<td>College Street</td>
<td>50</td>
</tr>
</tbody>
</table>
How are things discretized on a map?

Line or area? *(generalization)*

Where is the edge? *(boundary definition)*
Raster or Vector?

Representing elevation
**Raster vs Vector Data Model**

- The most common data format
- Easy to perform mathematically and overlay operations.
- Satellite information is easily incorporated.
- Better represents continuous-type data.
- Accurate positional information that is best for storing discrete thematic features (e.g., roads, shorelines, seabed features).
- Compact data storage requirements
- Can associate unlimited numbers of attributes with specific features.
Latitude and Longitude

I want you to be able to go to that exact location from anywhere on the surface of the Earth.
I want you to be able to go to that exact location from anywhere on the surface of the Earth.
first latitudes: North or South of the equator and then longitude: East or West of the prime meridian.
Latitude and Longitude
Latitude and Longitude

Origin
Equator
Earth’s axis

180° (International Date Line)

North pole

90° W
90° E

0° (Prime Meridian)
Latitude and Longitude

Origin
Equator
Earth's axis

180° (International Date Line)
North pole
90° W
90° E
0° (Prime Meridian)
Latitude and Longitude

latitude and longitude is good for describing locations on the surface of the Earth, but that coordinate system is not very good for measuring distances.
Latitude and Longitude

Degrees, Minutes, Seconds (DMS)

48°51’ 30” N, 2°17’ 40” E

Convert to Decimal Degrees (DD)

Lat: 2.2945272, Long: 48.8582680

+ve latitude

-x, +y  
+x, +y

-ve longitude

-x, -y  
+x, -y

-ve latitude
Earth is not spherical!

It's actually flattened a little bit.
Earth is not spherical!
Earth is not ellipsoidal, neither!

An Earth ellipsoid or Earth spheroid is a mathematical figure approximating the Earth's form, used as a reference frame for computations in geodesy, astronomy, and geosciences. Various different ellipsoids have been used as approximations.

<table>
<thead>
<tr>
<th>Datum Elements</th>
<th>NAD 27</th>
<th>NAD 83</th>
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<tbody>
<tr>
<td>Ellipsoid</td>
<td>Clarke 1866</td>
<td>GRS 80</td>
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<tr>
<td>Semi-major axis</td>
<td>6,378,206.4 m</td>
<td>6,378,137.0 m</td>
</tr>
<tr>
<td>Datum origin</td>
<td>Meades Ranch, Kansas</td>
<td>Center of Earth’s mass</td>
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<tr>
<td>Control points</td>
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<td>250,000</td>
</tr>
<tr>
<td>Best fitting</td>
<td>North America</td>
<td>Worldwide</td>
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