The many ways of GIS for digital humanities

Summer School on Digital Humanities

Web site: `https://bit.ly/dt4h-gis`

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Plan of the Tutorial

- The tutorial is divided into seven sessions.
- The first session is lecture-style, introducing basic concepts, terminology, and background.
- Each of the following six sessions focuses on a specific tool or concept and includes hands-on exercises:
  - QGIS, OpenStreetMap, UMap, GaiaGPS, Georeferencing with QGIS, and Leaflet.
- Only minimal prior experience is expected, so everyone can participate.
- All learning materials are available online, so you can revisit and try exercises at home if needed.
- You can keep the slides on your phone and practice on your PC

What is digital cartography (aka GIS)

- Digital cartography shares fundamental principles with classical cartography:
  - It records the geographical position of objects or reference points
  - It represents the morphological features of the landscape
  - It maps travel routes and pathways
  - It associates specific attributes and characteristics with mapped objects
  - It can depict imaginary landscapes or reconstruct past and future territorial scenarios

Why do we use digital cartography?

- Digital and conventional cartography share similar purposes
- Both serve as essential tools for:
  - Measuring geometric dimensions of objects and areas
  - Defining and recording state and property boundaries
  - Planning and navigating routes to specific destinations
  - Documenting journeys and various forms of travel
  - Geographically situating human or natural events to analyze relationships
  - Depicting and teaching about distant or inaccessible places
- These applications can relate to the present, as well as to past or future scenarios

The advantages of digital cartography

- Digital and traditional cartography differ primarily in the medium used to store maps
  - Digital maps are recorded on various types of digital media and accessed via suitable devices
- This distinction brings several key advantages:
  - Easy sharing due to the dematerialization of maps
  - Automatic acquisition of positions and movements
  - Ability to merge data from multiple maps
  - Integration of multimedia information
  - Simplified creation and reuse of maps

Cartography and public history

- History and cartography are deeply interconnected
  - History records events in relation to places
- The way we represent the world reflects our perspectives and values
- Was a medieval geographer creating maps for his king a public historian?
  - Engaging the public with the past
  - Applying history to practical use
  - Encouraging critical reflection
- Can the T-and-O map be considered a public history document?
- Will today's maps become public history documents in the future?
- Who has the capability to create such historical records?
  - Digital cartography opens new perspectives on this sense
  - The answer depends on accessibility and widespread use

Diffusion of digital cartography

- Digital cartography relies on:
  - Powerful graphics processors
  - High-definition displays
- In the Pentium era, these were largely inaccessible to PCs
  - ...limiting the advantages previously mentioned
- Digital cartography became widely affordable around 2005
- Today, nearly everyone carries a pocket-sized GIS engine
- Despite advancements, multiple representation standards still exist (standardization is ongoing)
- Cartography is now technically accessible to anyone
- Current challenges:
  - Simplifying access to cartographic tools
  - Harmonizing representation to enable data integration
- Future directions:
  - Developing autonomous devices to continuously record environmental features
  - Enhancing the communication of historical narratives

Web Mapping

- The Web is a powerful medium for sharing resources
- Web mapping technology emerged a few years after the creation of the WWW in 1989
- The evolution of the Web paralleled the advancement of Web mapping
- In the early '90s, maps were primarily static, offering limited interaction or layering
- By the late '90s, users gained the ability to manipulate maps and create new ones
  - ...with computationally intensive tasks handled on the server side
- Between 2000 and 2005, advancements in Web technologies facilitated the rise of Web mapping services
  - ...enabling seamless integration with other services via standardized interfaces
  - ...making the definition of standard representations and protocols increasingly important

Web Mapping in Web 2.0

- More powerful personal computing devices enable real-time interaction with Web mapping servers
  - ...allowing maps to be generated as mashups from multiple databases
- The advent of Web 2.0 (2005) introduces crowd-sourced geospatial data
- Increased computing power enables client-side manipulation of map features
  - ...with cloud storage and servers facilitating authentication and data sharing

Access: open vs closed digital cartography

- A fundamental choice in online content:
  - Data can be publicly accessible or restricted to private use
- The same distinction applies to digital cartography

Examples:

- **Open-source cartography**: OpenStreetMap
  - Maps are freely available in the public domain
  - Anyone can contribute by adding features
  - Maps can be reused without restrictions
- **Freely accessible but proprietary cartography**: Google Maps
  - Access is provided through a private service
  - Users can create and overlay their own maps
- **Commercial/private cartography**: Mapbox
  - Maps are provided as a paid service
  - Costs scale with usage (e.g., number of views)

Fundamental Core Concepts

- Concepts that **simplify access** to geographic data
- **Coordinates**: Latitude and Longitude
- **Geographic Features**:
  - Point – Defined by a single coordinate pair
  - Segment – A straight line connecting two points
  - Line – A sequence of connected segments
  - Area – A closed shape formed by a continuous line
- **Data Models**:
  - Vector Model – A collection of features with attributes
  - Raster Model – A grid of cells storing attributes
    - Often derived from graphic formats like JPEG
- **Additional Core Elements**:
  - Attributes – Data linked to features and cells
  - Layers – Organized sets of maps for structured visualization
- A suite of tools supports the manipulation and visualization of these concepts

Geographic Coordinate Systems

- **Harmonizing representation** requires the existence of standards for data models
- A Geographic Coordinate System (GCS) defines how a point is represented on the Earth's surface
- A standard GCS plays a crucial role in sharing meaningful information about positions, paths, and distances
- The standard evolves over time to accommodate changing needs and advances in technology
  - Originally, latitude was computed based on the maximum duration of daylight

World Geodetic System of 1984

- A widely adopted Geographic Coordinate System (GCS) today is `WGS84` (World Geodetic System 1984)
- The label `EPSG:4326` refers to its "non-projected" version
  - For example, `EPSG:3856` represents its Pseudo-Mercator projection on a square surface
- `WGS84 EPSG4326` is used by the Global Positioning System (GPS) and for data storage formats such as GeoJSON
- `WGS84 EPSG3856` is used by Google Maps and computer visualization tools
- Key features of `WGS84 EPSG4326`:
  - Coordinates are expressed in latitude (north) and longitude (east) (in this order)
  - Coordinates are expressed in degrees (decimal format)

Storing a digital map

- A digital map usually includes:
  - raster tiles as a visual background
  - a collection of vector features
- **Raster tiles** are available from various providers like OpenStreetMap (free) or Mapbox (paid)
- Tiles are accessed by specifying the zoom level and the tile's position in a grid
  - e.g.: `http://tile.openstreetmap.org/<zoom>/<x>/<y>.png`
  - try `https://tile.openstreetmap.org/7/67/46.png`
- **Vector features** are stored in a database, with tools for searching and updating similar to those in conventional databases
- As with traditional databases, you can choose between relational and non-relational models

PostGIS: a relational GIS database

- A sample query that creates a new feature:

```
INSERT INTO places (name, coord)
    VALUES ('Pisa', ST_GeographyFromText('SRID=4326;POINT(10.41 43.72)'));
```

- Legend:
  - places is a table created beforehand
  - It contains two columns: one for the name of a place and one for its coordinates
  - The INSERT command adds a new row to the table
  - The new point is named *Pisa*
  - Coordinates are provided using the ST_GeographyFromText function from PostGIS
  - The input string includes an SRID to define the coordinate system
  - `4326` refers to the `WGS 84` standard (EPSG:4326)
  - Coordinates follow the format: longitude first, then latitude — note the order is reversed from `WGS 84` standard

GeoJSON: maps as JavaScript objects

- GeoJSON is a GIS extension of the JSON object description language
- A `map_layer` variable hosting a collection of features is initialized as

```
map_layer = { "type": "FeatureCollection",
              "features": [] }
```

- A new point feature is defined with

```
new_feature = { "type": "Feature",
                "properties": {"name":"Pisa"},
                "geometry": {"type": "Point", "coordinates": [ 10.41, 43.72 ] } }
```

- And the JavaScript statement to insert the new feature in the empty collection is:

```
map_layer["features"].append(new_feature)
```

GeoJSON and noSQL databases

- The previous example refers to variables in the scope of a Javascript program
- Using a noSQL database service, the service provides an API based on JavaScript objects
- The following snippet connects to a MongoDB server, selects a collection and inserts a new feature

```
client = MongoClient("mongodb://localhost:27017") # Connect to DB
db = client["gis_database"] # Select a database
collection = db["map_layer"] # Select a collection
# insert the feature
collection.insert_one(
  { "type": "Feature",
    "properties": {"name":"Pisa"},
    "geometry": {"type": "Point", "coordinates": [ 10.41, 43.72 ] } } )
```

- Note: the `insert_one` call corresponds to the SQL `INSERT` query seen above

Going deeper

The rest of this tutorial is divided into six introductory hands-on sessions:

- Fundamentals of QGIS
- Working with OpenStreetMap
- Creating Maps with uMap
- Using GaiaGPS for Field Data
- Georeferencing in QGIS
- Introduction to the Leaflet Library