Lecture 3: Cartography and Map Projections in GIS

GE 118: INTRODUCTION TO GIS
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Maps -- Definition

- Fundamental language of geography, and therefore automated/digital geography
- Model of spatial phenomena
- An *abstraction* of reality → real world is simplified and reduced in size
- Most efficient shorthand to show locations of objects with attributes and their spatial distributions
- Graphical representation of the spatial structure of the physical and cultural environments
The Paper Map

- Has long been a powerful and effective means of communicating geographic information
- An analog and scaled representation of the real world
Types of Maps

- General-purpose or Reference maps
- Special purpose or Thematic maps
Reference maps

- Not designed for any specific application
- Focus on locations and physical and cultural features
- Supply the locational information of the spatial database for GIS
- Example: topographic maps
Reference Map
Thematic map

- Designed to depict a particular type of feature or measurement
- Depict geographic phenomena and processes for GIS
- Examples: population distribution maps, rainfall maps, soil maps, land cover maps
Thematic Map

New England 2000 - Population Density

Population Density
- From 0 to 1
- From 1 to 10
- From 10 to 50
- From 50 to 100
- From 100 to 200
- From 200 to 400
- From 400 to 158,016

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Map Scale

- Amount of reduction
- Ratio of distance on the map to the corresponding distance on the Earth’s surface
- One of the principal factors that govern the design, production and use of maps
- Scale is determined by the purpose of the map
- May be expressed in the following forms:
  - Representative fraction (RF)
  - Statement scale
  - Bar scale or graphical scale
Importance of Maps in GIS

- A map can be both a source of data for geographic databases and an analog product from a GIS
- Many of the ideas associated with GIS are inherited from paper maps
  - Example: The concept of scale
Analog vs. Digital

- Digital representations can include information that would be very difficult to show on analog maps
  - Example: curved surfaces, topography/3-D, changes in land cover
- Maps are static whereas digital representation in GIS can represent changes over time
- Easier to edit digitally
Map Projections

- A systematic projection of all or part of the surface of a round body, especially Earth, on a plane (Snyder, 1987)
- Function is to define how positions on the Earth’s curved surface are transformed into a flat map surface
  - Geographic coordinates (Φ,λ) to Cartesian coordinates (x,y).
- Required because of the need to produce a map of the Earth on a flat, 2-dimensional surface
Properties of Map Projections

- **Conformal/Orthomorphic** – shapes of small features on the Earth are preserved; scale and direction of Earth and map are equal for small areas
  - Useful for navigation and topographic mapping
- **Equal Area/Equivalent/Authalic** – areas on the map are always proportional to areas on the Earth’s surface
  - Useful for area computation applications
- **Equidistant** – preserves distances between points; constant scale
- **Azimuthal** – true directions are preserved; direction measurements on the map are the same as those made on the ground
  - Useful for air and sea navigation

Note: Any map projection can only satisfy *some* of these properties
Classification of map projections

1. **Cylindrical** – features/positions on the Earth are projected to a cylinder
2. **Conic** -- features/positions on the Earth are projected to a cone
3. **Planar or Azimuthal** – features/positions on the Earth are projected to a plane
Classification of Map Projections
Variants of map projections

- **Aspect** – the orientation of the projection surface; may be normal, transverse, or oblique
- **Viewpoint** – projection (light source location) may be from the center (*Gnomonic projection*), from infinity (*Orthographic projection*), or from the opposite side (*Stereographic projection*)
- **Intersection with the Earth** – location or locations that a projection surface touches or cuts through the globe; may be tangent or secant
Aspect
Viewpoint

GNOMONIC

STEREOGRAHPIC

ORTHOGRAHPIC

INFINITY
Intersection

Tangent Case

Pattern of Distortion
- Low
- Medium
- High

Secant Case

Graticule
Intersection

Tangent Case

Secant Case

Pattern of Distortion

Graticule

Low
Medium
High
Some commonly used map projections in GIS

*Plate Carrée or Cylindrical Equidistant Projection ("Unprojected Projection")*

- Simplest projection
- Just maps longitude as x and latitude as y
- Heavily distorted image
- Non-conformal and not equal area
- Correct distance between every point and the equator
- Problematic when used in GIS for analysis such as distance and area related analyses
- Commonly used to map the entire Earth
Cylindrical Equidistant Projection
Some commonly used map projections in GIS

**Universal Transverse Mercator (UTM)**

- Based on the Mercator projection but the cylinder is transverse rather than normal
- A secant projection
- Scale at each zone’s central meridian is 0.99996 and at most 1.0004 at the edge of the zone
- Parallels and meridians are curved, except for the central meridians and equator
- Map is divided into 60 zones, each 6° wide
- Problematic for areas at high latitudes and places that are located in two zones
- Commonly used for military applications and for mapping at a global or national coverage
Universal Transverse Mercator
Some commonly used map projections in GIS

*State Plane Coordinates and other local systems*

- Although distortions in the UTM system are small, they are still significant for accurate surveying.
- Problems regarding zone boundaries also arise in the UTM since the zones are not tailored according to jurisdictions (states or countries).
- Therefore, states in the US adopted a projection and coordinate system of their own (known as the State Plane Coordinate Systems).
- Many countries have adopted projections and coordinate systems of their own, specifically customized for their country.
Philippine Transverse Mercator

Figure 4. UTM Zones and the Philippines

Figure 5. PTM Zones with Central Meridians
Importance of Map Projections in GIS

- Necessary for combining data with different projections into a single GIS by means of transformations
- Consideration of the effect of the Earth’s curvature is necessary for GIS projects at a global or regional scale
- Transforming features on a curved surface to a plane is necessary for displaying data
Coordinate Systems

- Constructed on the basis of map projections
- Superimposed on the surface, resulting from the map projection, to provide the referencing framework by which positions are measured and computed
Coordinate Systems

Coordinates

- Set of numbers that determines the location of a point in a space of a given dimension
- Simplifies and standardizes the computational methods, making the use of computers possible
- Facilitates the transformation of geographic space to conform to other frameworks of entities and relationships, which is often required in mapping and GIS operations
Types of Coordinate Reference Systems

1. Plane Rectangular Coordinate System
2. Plane Polar Coordinate System
Plane Rectangular Coordinate System

- Cartesian Coordinate System
- Simplest coordinate system
- Position of a point is fixed by two distances measured perpendicularly from the point to the axes

Axes of the coordinate system – two straight lines intersecting at right angles
- used to define the geographic space

Origin – intersection of the axes

X-axis (Easting) – horizontal axis

Y-axis (Northing) – vertical axis

Quadrants – partitioning of the coordinate system; four quadrants in a coordinate system
Plane Rectangular Coordinate System

- **X-axis**
- **Y-axis**
- Quadrant I
- Quadrant II
- Quadrant III
- Quadrant IV

**Point P (x, y)**
Plane Polar Coordinate System

- Position of a point is fixed using an angular measurement and a linear measurement
- Position of a point is determined by its direct distance from the pole and the angle it forms with respect to the polar axis

*Pole* – origin

*Polar axis* – single line passing through the pole
Plane Polar Coordinate System

P \((r, \theta)\)

\(r\)

\(\theta\)
Geographic Coordinate System

- Three-dimensional spherical coordinate system of the Earth
- Takes into account the shape of the Earth
- Uses a network of latitudes and longitude (called *graticules*) to fix the position of a point on the Earth
North and South Geographic Poles – primary reference points on the Earth
– points of intersection of the axis of rotation and the Earth
Equator – an imaginary line halfway between the poles; great circle perpendicular to the axis of rotation
Meridian – great circle which contains the poles
Latitude \((\Phi)\) – vertical angle measured from the equatorial plane to the point
Longitude \((\lambda)\) – horizontal distance from the prime meridian (zero meridian) to the point
Geographic Coordinate System
Spatial Reference Framework of the Philippines
Components of a Reference Framework

- **Projection**
  - There is not a 'best projection,' the one most commonly used in the Philippines, is the Transverse Mercator because the country stretches primarily in N-S direction

- **Model representing the shape of the Earth**
  - Earth is not a perfect sphere due to rotational forces created which causes flattening at the north and south poles and bulging along the equator.
Components of a Reference Framework

- Model representing the shape of the Earth (cont'n)
  - Points of elevation are identified through a vertical network based upon another sphere known as geoid

- Datum
  - Using the ellipsoid the horizontal datum is developed
  - In the Philippines, there are two basic datums
Datums used in the Philippines

- **WGS 84**
  - commonly used worldwide datum from satellite measurements of the earth.
  - The origin is the center of the earth

- **Luzon 1911**
  - Most commonly used datum for the Philippines
  - Uses Clark 1866 ellipsoid and its origin is located just south of Luzon at Balanacan.
    - **PRS 92**
      - Created by NAMRIA, not a new datum but an adjustment of the Luzon datum
    - Luzon Datum
      - Not a separate datum, it is the Luzon Datum with different WGS 84 transformation parameters
Components of a Reference Framework

- Coordinate Systems and Projections
  - Geographic Coordinate System
    - Also known as latitude and longitude
    - Comprised of angular measurements
  - Projected Coordinate System
    - UTM
    - PTM
Thank you!