Outlines

1. Framework for position
   • Spatial reference systems: Relative vs. Absolute
   • Coordinate systems: Geographic vs. Cartesian

2. Grid coordinate system
   • Universal Transverse Mercator
   • State Plane Coordinate System

3. Spatial object types
   • SDTS definition of spatial objects
1. Framework for Position

• Spatial reference systems
  – Broadly defined term referring to any framework for position
  – Two types of spatial reference systems: relative vs. absolute

• Coordinate systems
  – One of absolute types of spatial reference systems
  – Two types of coordinate systems: geographic vs. Cartesian coordinates
• Think about different ways of referring to position
  – Place name
  – Street address
  – Turn left, turn right
  – South of Seattle
  – The grid of campus map
  – Latitude and longitude
  – etc.

• How are these different frameworks for position organized?
Spatial reference systems

• Relative position referencing
  – Arbitrary grids and relative directions
  – Campus map grid cell reference: row numbers and column letters (works for single sheet)
  – Relative directions: here, there, near, far, to left, to right, relative words

• Absolute position referencing
  – Coordinate systems and cardinal directions
  – Spatial reference system as coordinate system
  – Cardinal directions: North, south, east, NW, SSW, etc
Coordinate systems

• Geographic coordinates (unprojected)
  – Position is described by longitude and latitude
  – The mathematics of geographic coordinates is
    trigonometry: Angle and distance measurements
    using functions like sine, cosine

• Cartesian coordinates (projected, planar)
  – Position is described by X and Y
  – The mathematics of Cartesian coordinates is
    Euclidean geometry: basic algebra
Geographic coordinate system

Cartesian coordinate system

Source: Kimerling et al “Map Use”
What is the relationship between coordinate system and map projection?

Map projection is a mathematical equation that transforms angular location into \((x, y)\) location.

In geographic (unprojected) coordinate system, location is described by angular offset from the center of the earth.

In Cartesian (projected) coordinate system, location is described by distance offset from the origin \((0, 0)\).

Let’s look at predefined planar coordinate systems that are commonly used – State Plane and UTM.
2. Grid Coordinate Systems

- Universal Transverse Mercator (UTM)
  - Developed as a global coordinate system

- State Plane Coordinate (SPC)
  - Developed in order to provide local reference systems that were tied to a national datum in the U.S.

Reading: section 2.3.2 and 2.3.4 at http://courses.washington.edu/geog360/private/GridCoordSys.pdf
Universal Transverse Mercator (UTM)

- UTM is widely used for large-scale mapping all around the world. A USGS topographic map is not an exception.
UTM: how it works

• Divide the world into 6 degree longitudinal strip, and use the strip as a developable surface
• Each strip employs Transverse Mercator

Source: ESRI, “Understanding Map Projections”
UTM: zone numbering

- Zones are numbered for every 6 degree longitude strip from 180 ° W to 180 ° E (international date lines)
UTM: zones in U.S.

Source: Clarke 1999 “Getting Started with GIS”
How to read UTM coordinates

Figure 2.12 The universal transverse Mercator coordinate system.
How to read UTM coordinates

- The grid refers to one zone
- Where will be the true origin (0,0)?
- False northing to ensure positive y value in southern hemisphere
- False easting to ensure positive x value in the area west of central meridian
- Where will be the zone origin after false easting/northing?
- Given the zone origin, x coordinate of A will be larger than 500,000, and y coordinate of A will be larger than 5,000,000
UTM

• ArcGIS demo
  – Check projection parameters for zone number 10 (Seattle area)
  – WGS_1984_UTM_Zone_10N
  – Projection: Transverse_Mercator
  – False_Easting: 500000.000000
  – False_Northing: 0.000000
  – Central_Meridian: -123.000000
  – Scale_Factor: 0.999600
  – Latitude_Of_Origin: 0.000000
State Plane Coordinates (SPC)

- SPC has been used to write legal descriptions of properties and in engineering projects in many states (e.g. land record, utilities)
- When you obtain spatial data of Seattle area for your final project, it is quite likely that your data is stored in SPC (e.g. orthophoto from City of Seattle)
SPC: how it works

- Divide the country into zones, where zone boundaries follow state and county boundaries.
SPC: how it works

• Each zone has its own projection surface
  – Lambert conformal conic for areas with greater east-west extent
  – Transverse Mercator for areas with greater north-south extent
  – Oblique Mercator for areas with greater oblique extent
SPC: two national datum

- SPC 27 is based on NAD27
  - Reference ellipsoid: Clarke 1866
  - Measurement unit: feet

- SPC83 is based on NAD83
  - Reference ellipsoid: GRS 80
  - Measurement unit: meter
SPC

- ArcGIS demo
  - Check parameters of projections when different SPC zones are chosen
    - Washington North Zone
    - Georgia West Zone
    - Alaska Zone 1
3. Spatial Objects

- Defined as the building block of “digital representation of spatial phenomena”

- Typology
  - Dimension: zero, one, two, and three-dimensional object
  - Intended use: geometry vs. topology (display only or operation?)
  - Aggregation: simple vs. composite object

Reading: Section 2 from Electronic reserve SDTS
Motivations

• The same phenomenon is represented differently in the computer. For example,
  – Pixel constitutes aerial photo showing Green Lake
  – Point for labeling the location of Green Lake
  – Line for displaying the trail surrounding Green Lake
  – Polygon for displaying the extent of Green Lake
  – Network for navigating directions to Green Lake

• Spatial object has wide applicability. For example,
  – Representing the terrain of Mars, and human brain, as well as geographic phenomenon (such as traffic volume, traffic accident, road condition, gas emission) – anything that is spatial and anything that can use spatial metaphor (e.g. social network)
Dimensions

- Zero-dimensional spatial objects have
  - Location
- One-dimensional spatial objects have
  - + Length, direction
- Two-dimensional spatial objects have
  - + Extent
- Three-dimensional spatial objects have
  - + Altitude or any other z-value
Intended uses of spatial object

• Most of spatial objects have geometry
  – Spatial position based on coordinates; create shape of spatial data object
  – Used for display only (e.g. visualization)
  – Heavily draw upon Euclidean geometry

• Some spatial objects have topology
  – Spatial relationships between data objects based on connectedness, adjacency, and containment
  – Used for analytical operations (e.g. routing)
  – Heavily draw upon graph theory

From the 2.3 in SDTS, which spatial object has topology?
Aggregation

• Simple spatial object
  – Point, line, polygon
  – Pixel

• Composite objects are constructed from the simple objects by aggregation
  – Layer: an areally distributed set of spatial data representing entity instances within one theme
  – Graph: a set of topologically interrelated objects that conform to a set of defined constraint rules