WELCOME
Understanding and Using Geometry, Projections, and Spatial Reference Systems in ArcGIS

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Introduction

We want to give you a basic understanding of geometry and spatial references

• We won’t show you code
  - Our libraries are low level
  - Many APIs built on top

• We will talk about
  - Geometry types
  - Spatial references and their properties
  - How geometries and spatial references interact
Geometry
What is a geometry?

- Defines the shape of a feature

- Points, lines, and polygons represent real-world objects
Points

Building blocks for all geometries

(20, 20, 30)
Multipoints

Each multipoint feature is a collection of points

- (20, 20, 30)
- (5, 5, 10)
Polyline
A collection of paths

- Polyline
  - Paths
    - Segments
      - Line
      - Elliptical Arc
      - Bézier Curve
      - Circular Arc
  - Points
    - Composed of paths
    - Composed of segments
    - Segments can be four types
    - Points are used to build segments
Polyline

Single part

Multipart
Polygons

A collection of rings

- Polygon
  - Rings
    - Segments
      - Line
      - Elliptical Arc
      - Bézier Curve
      - Circular Arc
  - Points
    - Points are used to build segments
    - Segments can be four types
    - Composed of closed segments
    - Composed of rings
Polygons

Outer ring

Inner ring
We want “valid” geometries

• What?
  - Adhere to a specified set of topological rules
  - Known as “simple”

• Why?
  - Storage in a database
  - Cannot rely on results from operations using non-simple geometries
    - Get an error
    - Get incorrect results

• How?
  - ArcGIS Pro and ArcMap
    - Check Geometry and Repair Geometry GeoProcessing tools
  - ArcGIS Server
    - IsSimple and Simplify operations
  - All Esri APIs have similar functionality
Non-simple Polygons
Simple Polygons

Simplifying may add or remove vertices
Why do we care if geometries are simple?

Demo
Spatial References

Id_Mercator
CS_WGS_1984
_WGS_1984
[ "WGS_1984", 6378137.0, 298.257223563, "Greenwich", 0.0],
[ "WGS_1984 Free", 0.0174532925199433] ,
[ "Mercator " ],
[ "Central_Meridian", 0.0],
[ "Standard_Parallel_1", 0.0],
[ "False_Easting", 0.0],
[ "False_Northing", 0.0],
[ 1.0] ]
Key properties of spatial references

• Coordinate system
  - Geographic
  - Projected

• XY Resolution

• XY Tolerance
Coordinate Systems

- Geographic (GCS)
- Projected (PCS)
What is a coordinate system?

• An agreed upon way to describe locations

• Represents locations
  - Geographic features
  - Imagery
  - Observations such as GPS locations

• Common geographic framework
  Used to integrate geographic locations from different datasets
Geographic Coordinate System (GCS)

- Global – 3D spherical surface
- Point referenced by longitude and latitude values
Projected Coordinate System (PCS)

- Flat – 2D surface based on a GCS
- Point referenced by x, y coordinates on a grid
Coordinate System

Projected Coordinate System

- Projection
  - Projection Parameters

- Linear Unit

Geographic Coordinate System

- Datum
  - Spheroid

- Prime Meridian
  - Angular Unit
Geographic Coordinate System
Well-Known Text (WKT)

GEOGCS[ "GCS_WGS_1984",
  DATUM[ "D_WGS_1984",
    SPHEROID[ "WGS_1984", 6378137.0, 298.257223563] ],
  PRIMEM[ "Greenwich", 0.0],
  UNIT[ "Degree", 0.0174532925199433] ]
What is a datum?
Projected Coordinate System
Well-Known Text (WKT)

PROJCS[ "World_Mercator",
    GEOGCS[ "GCS_WGS_1984",
        DATUM[ "D_WGS_1984",
            SPHEROID[ "WGS_1984", 6378137.0, 298.257223563] ],
            PRIMEM[ "Greenwich", 0.0],
        UNIT[ "Degree", 0.0174532925199433 ] ],
    PROJECTION[ "Mercator " ],
    PARAMETER[ "Central_Meridian", 0.0],
    PARAMETER[ "Standard_Parallel_1", 0.0],
    PARAMETER[ "False_Easting", 0.0],
    PARAMETER[ "False_Northing", 0.0],
    UNIT[ "Meter", 1.0 ] ]
Well-Known ID (WKID)

- Every predefined coordinate system has a WKID
  - For example, GCS_WGS_1984, WKID = 4326

- WKID < 32767 is EPSG assigned

- WKID > 32767 is Esri assigned
  - Esri WKID may change
  - Esri → EPSG
  - Old WKID will still work
  - Example, Web Mercator 102100 → 3857
All projections have some distortion

Web Mercator Projection
What is happening when we project data?

Case 1: Both PCSs contain the same GCS

PCS A1 \[\rightarrow\] Projection \[\rightarrow\] PCS A2

GCS A

(x, y)

(lon, lat)

(λ, φ)
What is happening when we project data?

Case 2: Each PCS contains a different GCS

Projection

GCS A

Geographic Transformation

GCS B

PCS A1

PCS B1

(x, y)

(lon, lat)

(λ, φ)
Geographic Transformations (GT)

• Convert from one GCS to another GCS

• Suitable for a particular area

• Defined in a particular direction
  - For example, NAD27 to WGS84
  - All are reversible

• May be more than one applicable GT
Why do we need to transform our data?

European Datum 1950 vs. World Geodetic System 1984
There are 38 transformations between GCS_North_American_1927 and GCS_WGS_1984

Which is best?
Depends on the region covered by your data
How do I find transformations?

Demo
Tolerance and Resolution
XY Tolerance

- Minimum distance between coordinates
- Comes into play when we are working with geometries
  - Make sure our geometries are simple
  - Topological operations
    - For example, Buffer, Symmetric Difference, Union, Intersection
  - Relational operations
    - For example, Disjoint, Touches, Overlaps, Crosses, Within
  - Editing operations
XY Tolerance

Default value = 0.001 meters or equivalent

Do these two points intersect?
Yes, since the distance between them is less than the tolerance.

XY tolerance = 0.001 m
XY Tolerance

Editing Merge operation
Merge Polygons

Demo
XY Resolution

- Numeric precision used to store x, y coordinate values
- All coordinates lie on coordinate grid
- Default value is 0.0001 meters or equivalent
  - $x_1 = 5.1234, x_2 = 5.1235$ stored as unique coordinate values
  - $x_1 = 5.12344, x_2 = 5.12345$ both stored as 5.1234
  - Each square in grid is 0.0001 x 0.0001
## Tolerance vs. Resolution

<table>
<thead>
<tr>
<th>Tolerance</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default = 0.001 meter or equivalent</td>
<td>Default = 0.0001 meter or equivalent</td>
</tr>
<tr>
<td>Used when doing something with geometry</td>
<td>Used to store geometry in database</td>
</tr>
<tr>
<td>Determines if points are considered equal</td>
<td>Determines number of decimal places to store</td>
</tr>
</tbody>
</table>

Resolution should be no greater than 1/10 of the tolerance

Highly recommended to use default values!
What do spatial references have to do with geometries?

- Geometry is a collection of points

- Spatial reference determines
  - where the coordinates are placed
  - how the coordinates interact with each other
How does a spatial reference affect a geometry?

- We need to know where to put the geometry on the map
- Could change the geometry visually or structurally
- An operation on features may give different results
Where is my data?

Demo
Spatial reference can change the geometry

Here we have the same geometry in 4 different spatial references

- WGS 84
- Azimuthal Equidistant
- South Pole Gnomonic
- Cube
An operation on features may give different results depending on the spatial reference.

For example, Buffer operation.
Buffer and Spatial Reference

Demo
That’s all folks!

Don’t forget to fill out the survey

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Resources

http://resources.arcgis.com/en/help

*Desktop → Guide Books → Map projections*

Developer Help

*List of ArcGIS APIs*

*Lining Up Data in ArcGIS, Margaret Maher*

ESRI Technical paper: *Understanding Coordinate Management in the Geodatabase*

ESRI Technical paper: *Understanding Geometric Processing in ArcGIS*
Demos

All the demos are on GitHub at https://github.com/alocke/DevSummit2015

• ArcMap Demos
  - DevSummit2015.gdb
    - How do I find transformations? (Project.mxd)
    - Merge polygons (MergePolygons.mxd)
  - QM.gdb
    - Where is my data? (QM.mxd)

• JavaScript Demos
  - Why do we care if geometries are simple? (SimplifyPolygon.html)
  - Buffer and Spatial Reference (GeodesicBufferWebMercator.html and GeodesicBufferOther.html)