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

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Introduction

We present fundamental concepts necessary for the correct and efficient use of geometry and spatial reference APIs

• Spatial references and their properties
• Geometry types
• How spatial references and geometries interact
Spatial References
Spatial references

Key properties

- 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
    - For example, GPS locations

- Common geographic framework
  - Used to integrate geographic locations from different datasets
Two common types of coordinate systems

- **Geographic (GCS)**
  - Global – 3D spherical surface
  - Point referenced by longitude and latitude values
Two common types of coordinate systems

- Projected (PCS)
  - Flat – 2D surface based on a GCS
  - Point referenced by x, y coordinates on a grid

```plaintext
<table>
<thead>
<tr>
<th>X &lt; 0</th>
<th>X &gt; 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y &gt; 0</td>
<td>Y &gt; 0</td>
</tr>
</tbody>
</table>

(0,0)
```
Coordinate System

Projected Coordinate System
- Projection
- Linear Unit
- Projection Parameters

Geographic Coordinate System
- Datum
- Spheroid
- Prime Meridian
- Angular Unit

Angular Unit

Linear Unit

Datum

Spheroid

Prime Meridian

Projection Parameters

Linear Unit

Datum

Spheroid

Prime Meridian

Angular Unit

Projection Parameters

Linear Unit

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] ]
Datum

Local datum coordinate system

Earth-centered datum coordinate system

- Earth’s Surface
- Earth-centered datum (WGS84)
- Local datum (NAD27)
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
Projection data flow

PROJCS A1

PROJCS A2

GEOGCS A

Projection

(lon, lat)

(x, y)

(λ, φ)
Projection with a common GCS
Projection with transformation data flow

Projection

Geographic Transformation

PROJCS A1

GEOGCS A

GEOGCS B

PROJCS B1

(λ, φ)

(x, y)
Geographic transformations

- 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
  - We present a list in order of most to least suitable
  - You must pick which GT to use
  - Normally, you want to use the top entry
Projection between different GCSs
There are 38 transformations between GCS_North_American_1927 and GCS_WGS_1984

Which is best?
Depends on the region covered by your data
Why do we need to transform our data?

European Datum 1950 vs. World Geodetic System 1984
A few words about Web Mercator

- WGS_1984/Web-Mercator_Auxiliary_Sphere
  WKID 102100 or 3857

- Online mapping services use a sphere-based Mercator
- Easy, quick to calculate
- Preserves shapes and angles?
  - Original Mercator YES
  - Web Mercator NO
- Distorts distances and areas
- Display YES, Analysis NO
Web Mercator Projection
Tolerance and Resolution
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
XY Tolerance

- Minimum distance between coordinates when processing features
  - Simple geometry validation
  - Topology operations such as Buffer
  - Relational operations
  - Editing operations
XY Tolerance
Merge polygons
Tolerance vs. Resolution

- Resolution: refers to number of decimal places used to store x, y coordinate values
- Tolerance: minimum separation between features used by some operations
  - Should never be less than 10 times resolution

- Default resolution = 0.0001 meter or equivalent
- Default tolerance = 0.001 meter or equivalent

Highly recommended to use default values!
Geometry
Overview of Geometry

• What is a geometry?
  - Defines the shape of a feature
  - Vector representation for top level types
    In other words, vertices have x, y coordinates
  - Optional z- (height) and m- (measure)

• Working with and analyzing geometries
  - Simple geometry verification
    - Adheres to a set of rules
  - Topological operations
    - For example, Buffer, Symmetric Difference, Union, Intersection
  - Relational operations
    - For example, Disjoint, Touches, Overlaps, Crosses, Within
What does geometry have to do with spatial references?

- Geometry is a collection of points

- Spatial reference determines
  - where the coordinates are placed
  - how the coordinates interact with each other
Points

Always simple

(20, 20, 30)
Multipoints

- Each multipoint feature is a collection of points
- Simple if each point is unique
Polyline
A collection of paths

Polyline
- Composed of paths

Paths
- Composed of segments

Segments
- Segments can be four types

- Line
- Elliptical Arc
- Bézier Curve
- Circular Arc

Points
- Points are used to build segments
Polylines

Simple

Non-simple
Polygons
A collection of rings

Polygons are composed of rings, which are composed of segments. Segments can be four types: Line, Elliptical Arc, Bézier Curve, and Circular Arc. Points are used to build segments.
Polygons

Simple polygon

Outer ring

Inner ring
Non-simple Polygons
How does a spatial reference affect a geometry?

1. A geometry that is simple in one spatial reference may not be so in another spatial reference

2. So what? Why do we care if a geometry is simple? Garbage in, garbage out

3. An operation on features may give different results depending on the spatial reference
1. What is simple here may not be simple there
2. So what? Why do we care if geometries are simple?

- Cannot rely on results from operations using non-simple geometries
  - Get an error
  - Get incorrect results
2. Why do we care if geometries are simple?
3. How does a spatial reference affect a geometry?

- An operation on features may give different results depending on the spatial reference.

- For example, Buffer operation.
3. Buffer and Spatial Reference
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
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- Quick Link from www.esri.com/devsummit
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Enter Offering ID: 263
That’s all folks!
Understanding our world.