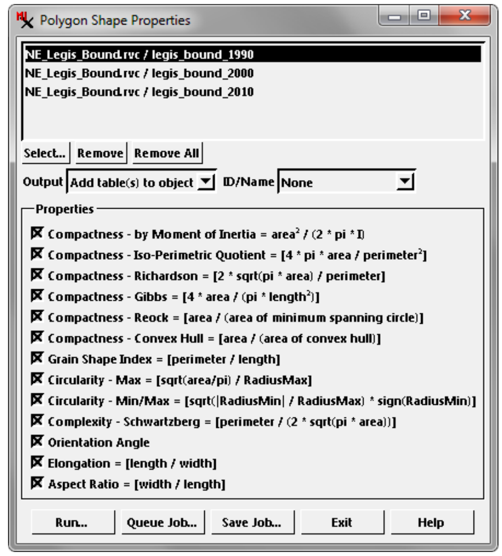
Polygon Shape Properties

The Polygon Shape Properties process (Geometric / Attributes / Polygon Shape Properties) computes shape metrics for individual polygons in one or more geometric objects (vector, CAD, or shape). The results can be saved in tables added to the input objects or to CSV-formatted text files.



Compactness

The process provides a number of measures of *compactness*, which is the most widely-used polygon shape property. A compact polygon has a relatively simple boundary with vertices that are relatively equidistant from the centroid. A circle is the shape with maximum compactness. Compactness measures have applications in analyses of ecological habitats, hydrological properties of drainage basins, and in assessing legislative redistricting plans.

Compactness can be quantified in several ways: 1) from physics, the moment of inertia of the polygon; 2) computations using polygon area and perimeter (or maximum length); 3) area comparison with an ideal shape such as a circle or the polygon's convex hull. Compactness values for the measures described below range from 0 to 1.0. Numbers in square brackets refer to the numbered references on the next page.

By Moment of Inertia [3]: area² / 2 * pi * moment of inertia

The physical measure of an object's resistance to changes in its rotation is called moment of inertia. It depends on the object's mass, the distribution of mass (shape), and the point of rotation. For 2D polygons, moment of inertia is measured relative to rotation about an axis at the polygon centroid and perpendicular to the mapping plane. Moment of inertia increases with area and complexity of the shape, so compactness is calculated as the ratio of the moment of inertia of a circle of the same area about its center to that of the polygon about its centroid. This measure is less sensitive to polygon vertex positioning errors (noise) and differences in the level of boundary detail than compactness measures computed from perimeter and area, described below.

Definitions

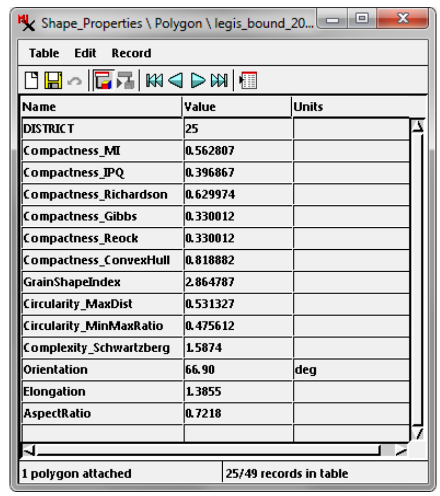
Length: maximum distance between any points on the outer polygon boundary.

Width: maximum distance across polygon in the direction perpendicular to the length direction.

RadiusMax: maximum distance from the polygon centroid to the boundary.

RadiusMin: minimum distance from the polygon centroid to the boundary. Value is negative if the centroid is outside the polygon or inside an island.

Convex hull: the smallest convex region that contains the polygon, constructed by connecting a subset of the polygon vertices.



Name	Value	Units
DISTRICT	25	
Compactness_MI	0.562807	
Compactness_IPQ	0.396867	
Compactness_Richardson	0.629974	
Compactness_Gibbs	0.330012	
Compactness_Reock	0.330012	
Compactness_ConvexHull	0.818882	
GrainShapeIndex	2.864787	
Circularity_MaxDist	0.531327	
Circularity_MinMaxRatio	0.475612	
Complexity_Schwartzberg	1.5874	
Orientation	66.90	deg
Elongation	1.3855	
AspectRatio	0.7218	

Shape measures for a state legislative district polygon.

Richardson [3,6]: 2 * sqrt(pi * area) / perimeter

This expression is equivalent to the ratio of the perimeter of a circle with area equal to that of the polygon to the polygon's actual perimeter.

Iso-Perimetric Quotient [3,4]: 4 * pi * area / perimeter²
(also called the Polsby-Popper method and Cox's circularity). This measure is the square of the Richardson compactness.

Gibbs [2]: 4 * area / (pi * length²)

Two measures of compactness are ratios of the polygon area to the area of an ideal shape:

Reock [1,5]: area / (area of minimum spanning circle)

Convex Hull [1]: area / (area of convex hull).

Complexity

Complexity of polygon shape is the opposite of compactness. One measure is provided, with a range from 1 to infinity:

Schwartzberg [1]: perimeter / (2 * sqrt(pi * area));
this is the inverse of the Richardson compactness measure.

Circularity

Circularity is a property similar to compactness, measuring how closely a polygon's shape matches that of a circle. Two circularity measures are provided:

Max: sqrt(area / pi) / RadiusMax
(ratio of the radius of the circle with equivalent area to the maximum radius of the polygon; range is 0 to 1).

Min/Max: sqrt(|RadiusMin| / RadiusMax) * sign(RadiusMin)

The final factor [sign(RadiusMin)] in the expression is 1 for RadiusMin > 0 and -1 for RadiusMin < 0 (for a polygon centroid outside the polygon boundary). The range is -1 to +1.

Miscellaneous Shape Properties

Grain Shape Index: perimeter / length

Orientation Angle: azimuth of the length direction relative to the map projection.

Elongation: length / width

Aspect Ratio: width / length

(continued)

All of the polygon shape measures take island polygons (holes) into account. The presence of islands reduces compactness and circularity and increases complexity.

Objects georeferenced in geographic (latitude / longitude) coordinates are automatically converted to an orthographic projection centered on the object in order to compute the polygon properties. Coordinate reference systems using planar coordinates do not require any conversion.

Process Interface

Press the Select button to select one or more geometric objects with polygons to process. The file and object names of the selected objects are shown in the list at the top of the window. To remove any object, left-click on its list entry to highlight it and press [Remove]. Press the Remove All button to clear the list.

Use the Output menu to choose how to save the computed shape properties: *Add table(s) to object* or *Text file(s)*. You can choose an ID or name to embed in the statistics table(s) to identify each record. The choices from the ID/Name menu are None, Element Number, Polygon_ID.Current (if the polygons have an ID table) and Choose; the latter option prompts you to select a database table and field to provide the ID. When multiple objects are being processed, the field selections presented in the menu refer to the top object in the list. If other objects do not have a field with the selected table and field name, the element number is automatically used as the ID value. For best results with multiple inputs, make sure that they have consistent tables or use element number as the identifier.

The Properties box shows the list of available shape properties with a checkbox allowing you to select or deselect each. Current property selections are saved when you exit the process.

References

1. Azavea, Inc., 2010, Redrawing the Map on Redistricting: A National Study. http://cdn.azavea.com/com.redistrictingthenation/pdfs/Redistricting_The_Nation_White_Paper_2010.pdf.
2. Gibbs, J.P., 1961, *Urban Research Methods*. Princeton, Van Nostrand.
3. Li, Wenwe, Goodchild, Michael F., and Church, Richard, 2013, An efficient measure of compactness for two-dimensional shapes and its application in regionalization problems. *International Journal of Geographical Information Science*, 27(6), p. 1227-1250.
4. Polsby, D.D., and Popper, R.D., 1991, The third criterion: compactness as a procedural safeguard against partisan gerrymandering. Yale Law & Policy Review 9(2), p. 301-353.
5. Reock, E.C., 1961, A note: measuring compactness as a matter of legislative apportionment. *Midwest Journal of Political Science*, 5(1), p. 70-74
6. Richardson, L.F., 1961, The problem of contiguity: an addendum to Statistics of Deadly Quarrels. *General Systems Yearbook* 6, p. 139-187.