Rendering Vector Geometry with Adaptive Composite Map Projections

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Abstract. An adaptive composite map projection combines multiple projections as the user changes scale or the area shown on a map. Different projections are combined, depending on the height-to-width ratio of the map, the map's scale, and the central latitude of the visible area. This paper documents various issues and solutions that are specific to the projection and rendering pipeline for web maps using adaptive composite map projections. It outlines required processing steps to create web maps from vector data with adaptive composite map projections.

Keywords: Adaptive composite map projections, vector web maps, map rendering.

1. Real-time projection and rendering of vector data

Adaptive composite map projections are an alternative to the static web Mercator projection used by current web mapping services (Jenny, 2012). An adaptive composite map projection seamlessly combines multiple projections as the user changes the area shown on the map. Different projections are combined, depending on the height-to-width aspect ratio of the map, the map's scale, and the central latitude of the visible area (Snyder, 1987). The user can rotate poles to the center of the map, and the central meridian can be arbitrarily selected.

Vector data are first streamed to the Web client in geographic coordinates. They are then projected to Cartesian plane coordinates, and finally rasterized by the Web browser. The projection and rasterization of vector data are real-time operations, with data projected and rasterized each time the user changes the map scale or the extent of the visible geographic area. These operations are computationally expensive and must be optimized for achieving interactive frame rates.

2. Vector Geometry Rendering in Four Steps

Whenever the user adjusts the area displayed in the map by a panning or zooming interaction, the map projection is adapted. Depending on the visible geographic area, projection parameters are adjusted, or projections are exchanged. These continuous adjustments require vector geometry to be repeatedly projected and rasterized on screen. The underlying vector projection and rendering pipeline has four conceptual steps. The first three steps deal with spherical coordinates. The fourth step creates projected Cartesian coordinates, which are then rasterized to create the map image.

In the first step, circumferential polygons are detected. Circumferential polygons, such as the landmass of Antarctica, require special consideration as they share two borders with the antimeridian. For the majority of data stored in the equirectangular projection (*Plate Carrée*), the antimeridian is at +/-180 degrees longitude. This first step removes line segments along the antimeridian, thereby transforming vector geometry from the Cartesian equirectangular projection (*Plate Carrée*) to spherical coordinates. This is a preparatory step that is executed only once, after vector data is loaded into the web browser.

The second step rotates coordinates on the sphere to create oblique aspects, such that an arbitrary location appears at the center of the final map. A rotation involving spherical geometry, as described by Snyder (1987), is used.

The creation of a map with an oblique aspect changes the antimeridian. The antimeridian is no longer at +/-180 degrees longitude, but is the semi-great circle opposite the central point of the map. The third step therefore intersects the rotated geometry with the rotated antimeridian. This intersection takes nested topological relations (i.e. nested islands and holes) and circumferential polygons into account. Hence, step 3 is the opposite of step 1. Step 1 removed the seam along the original antimeridian, whereas step 3 again adds a seam along the rotated antimeridian.

The fourth step transforms vector geometry from spherical coordinates to Cartesian coordinates. A map projection and a point densification are applied to the vector geometry. The densification is required to avoid lines with an edgy appearance at locations where the graticule is considerably curved. Line segments are densified based on their deviation in Cartesian map coordinates, but intermediate points are added along great circles computed on the sphere.

3. Vector Geometry with Azimuthal Projections

Azimuthal projections require an additional treatment for polygons lying along the rim of the graticule. If the antipode of the projection center is inside a polygon, an additional circular outline has to be added to the polygon to construct a closed ring. The added circular outline has the diameter of the graticule of the azimuthal projection. The resulting doughnut-shaped polygon has a regular circular outer border and an irregular inner border. Point-in-polygon tests are added to the projecting pipeline to detect these cases. The point-in-polygon tests area applied to geometry in spherical coordinates, before geometry is projected to Cartesian coordinates.

References

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