A Prototype of a Web Mapping System Architecture for the Arctic Region

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Abstract

Web mapping is widely used in applications ranging from professional researches (e.g., environmental sensor data visualization) to daily location-based services (e.g., shortest route planning). Google provides services using the *web Mercator projection*, which has become the most popular map projection among existing web mapping systems. However, one of the critical problems of web Mercator projection is the large systematic distortion at the high latitude regions. While the distortion increases as latitude increases, polar regions have the largest distortions. In northern hemisphere, the Arctic region has abundant natural resources and unique environmental characteristics; therefore Arctic research is attracting more and more attentions. Since the Arctic region is surrounded by multiple nations, Arctic research usually requires cooperation between research groups. In order to facilitate Arctic data sharing and research collaborations, a web mapping system suitable for Arctic region is necessary. Hence, the objective of this research is to develop a web mapping system for Arctic region as a coherent online platform for researchers to intuitively visualize Arctic data. We propose new solutions in both client and server components to support multiple map projections while attaining very short response time. In addition, we found that polar projections sometimes are difficult to interpret, as users are used to the convention (including in the web Mercator projection) that maps are presented with north facing upwards on the map. We propose a new module allowing users to rotate maps for better visualization experience. The prototype demonstrates an efficient and intuitive multi-projection web mapping system for the Arctic region.

Background and Relevance

As the Mercator projection forms the parallels and meridians in regular grids where the North is always facing up, this regular grid allows web mapping systems to divide the entire map into regular map pieces (i.e., map tiles). Hence, instead of transmitting huge maps, web mapping systems are able to transmit small map tiles efficiently (Wei *et al.* 1999), which is the main idea of web Mercator projection.

In 2005, Google published their web mapping system derived from the Mercator projection, which is called the web Mercator projection. The web Mercator projection first maps ellipsoidal latitude and longitude coordinates onto WGS84 datum with the spherical Mercator equations; and then with the regular grid form of the Mercator projection, the map is cut into small and regular map tiles that can be pre-processed and easily transmitted through the Internet. As Google Maps very quickly attracted a very large number of users, most modern web mapping systems directly followed the web Mercator projection to deliver their maps (e.g. Microsoft Bing Maps , OpenStreetMaps).

However, although the web Mercator projection is one of the most common projections for mapping global data, the major issue is that the projection distorts several properties of the map, especially in Polar Regions (Jenny 2012). For instance, "the Greenland problem" is a famous example for this distortion issue. Although Greenland appears to be the same size as Africa in the Mercator projection, Africa's land mass is actually fourteen times larger than Greenland. Therefore, the web Mercator projection does not satisfy the needs of professional users, especially for the Polar Regions.

Fig. 1. Greenland takes as much area as Africa on the Mercator map, but is 14 times smaller in reality. Latitudes beyond ±85° are clipped. (Jenny 2012)

As web Mercator projection-based web mapping systems are not suitable for sharing and visualizing Arctic data over the Web, some applications have been developed for Arctic region visualization (Johnson *et al.* 2011). However, the common weakness of these systems is that they render maps on-the-fly, which means that every view-change on the map (e.g., through pan and zoom) requires a server-side processing to provide a corresponding view, thus the response time is usually slow (i.e., from seconds to minutes to load a new view). In order to address this issue, this paper proposes a system architecture, which generates map tiles in advance and hosts them as tile cache to prevent on-the-fly processing.

However, unlike the Mercator projection for most global regions, there is no specific projection for polar region datasets as different projections preserve different properties, such as shape, area, and distance. Therefore, instead of providing maps in only one projection, a web mapping system that supports multiple projections and allows users to switch projections is needed.

To sum up, this paper proposes a system architecture of a multi-projection web mapping system for the Arctic region that allows users to visualize maps on different projections. As the proposed system is simply based on JavaScript and is lightweight enough to be run on not only desktop computers but also mobile devices, we argue that this easy-to-access multi-projection web mapping system is able to facilitate the cooperation and geospatial data exchange between multinational polar research teams.

Methods and Data

In order to construct a multi-projection web mapping system, we propose new solutions in both client-side and server-side components. The high-level system requirements include: (1) easy accessibility by most web browsers, (2) ability to switch between different projections, (3) ability to rotate the map, and (4) short response time.

The system architecture is shown in Fig. 2. In order to meet the system requirements and provide a high-performance system, map tiles are pre-generated in advance and stored in a cache database, where the web service can directly retrieve pre-generated tiles and return them to the web client without extra processing.

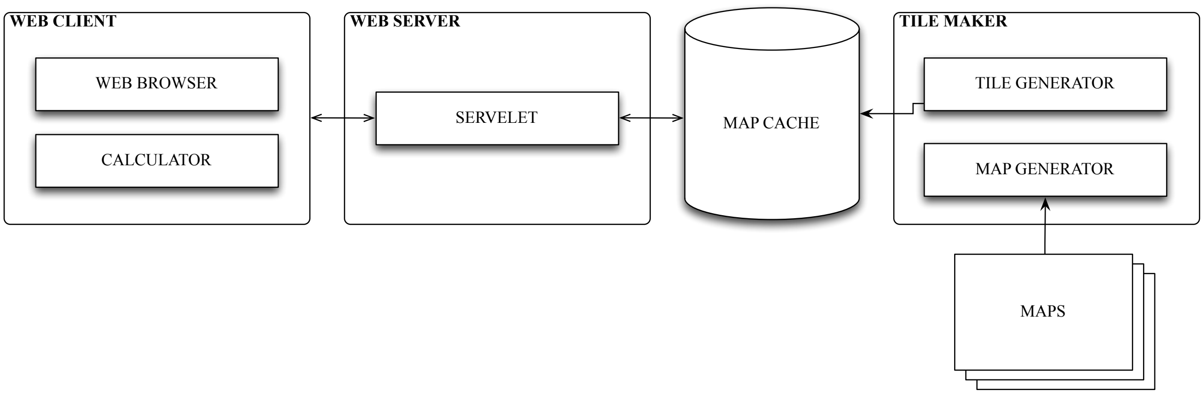


Fig. 2. System Architecture

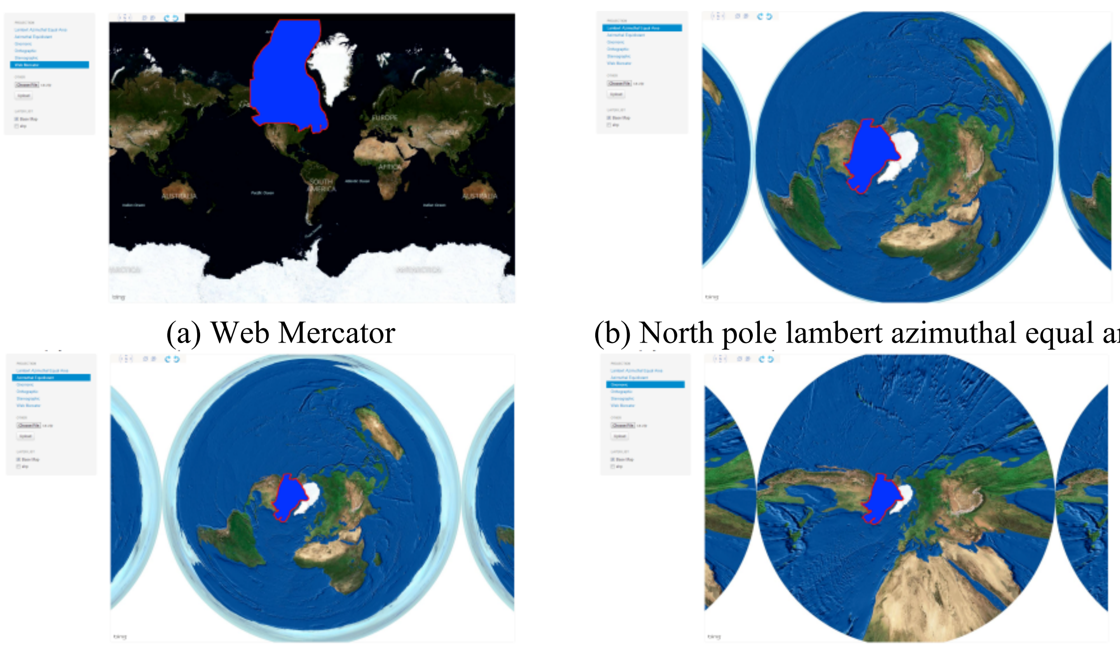
The web client is a web browser with a coordinate calculator, which handles mandatory calculations for coordinates transformations between different map projections. The web server is a middleware between the web client and the map tile cache. The web client retrieves map tiles from the web server with the name of map, projection name, and map tile indices. In addition, the tile maker is constructed to generate map tiles in multiple projections. Moreover, the system also supports overlaying features in a Shapfile. By using the web service to parse user's uploaded Shapefile into a GeoJSON string, the web client can use the GeoJSON string to overlay features on maps in different projections.

In general, the system consists of three tiers: data tier, business logic tier (middle tier), and presentation tier. In the data tier, test data are maps in different projections that are cut into map tiles in advance and stored in the map tile cache. This system uses the following projections to prove the concept: WGS84 reference system Mercator projection, polar azimuthal equal area projection, polar azimuthal equidistant projection, polar stereographic projection, polar gnomonic projection, and polar orthographic projection. ESRI ArcGIS was used to perform map re-projection. A Matlab application was developed to generate map tiles and the tiling scheme follows the Bing Maps tile structure.

The business logic tier is a web server, which was developed as a Java Servlet hosted in Apache Tomcat. The presentation tier consists of three components: a HTML page with the coordinate calculator written in JavaScript, a web mapping framework using Microsoft Bing Maps AJAX Control version 7.0, and Twitter Bootstrap for responsive HTML styling. Three main functions are included in this system: (1) rotation, (2) switching between different projections, and (3) an upload interface allowing users to upload ESRI Shapefile and present the data on maps in different projections.

Results

We proposed a new system architecture for a multi-projection web mapping system, which serves as a high-performance and easy-to-access platform for public or any organizations that have a need to share or visualize their arctic data. Our prototype is publicly accessible online since early 2012. As demonstrated in the Fig. 3, we are able to upload a Shapefile with Canada's national boundary and display it over the base maps in different projections. While Fig. 3(a) clearly shows that the boundary is distorted significantly in the web Mercator projection when the feature is near the polar region, the feature in other polar projections is much less distorted. In addition, our system is able to rotate map while using polar projections for users to rotate the map to let the North facing up. This rotation functionality is missing in any other existing arctic web mapping systems. For the performance, compared to other on-the-fly processing solutions, as our system uses a map cache mechanism, users can switch base maps to different projection and rotation with a very short response time.

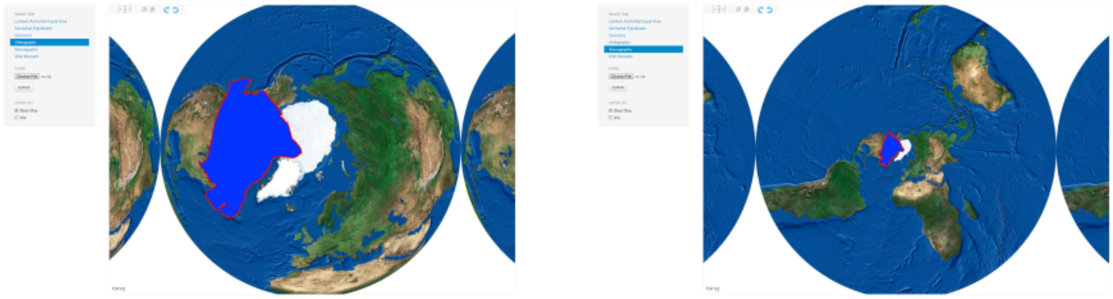


(a) Web Mercator

(b) North pole lambert azimuthal equal area

(c) North pole azimuthal equidistant

(d) North pole gnomonic



(e) North pole orthographic (f) North pole stereographic

Fig. 3. Demonstration of uploading custom data to our web mapping system

Conclusions

One of the major contributions of our proposed system is that although our system supports functionalities like multiple projections and rotation that are very special to the traditional web mapping systems, we can still follow the traditional web mapping tiling scheme. Therefore, our client side component can directly use existing web mapping framework (e.g., Bing Maps) to handle the map loading and display. Hence, the proposed system does not require a powerful client (either is a personal computer or a mobile device) using modern techniques like HTML5.

For future works, as generating map tiles in multiple projections is time- and resource-consuming, to overcome this difficulty, we will try to apply distributed computation technique in map tile generation.

References

Wei, Z., Oh, Y., Lee, J., Kim, J., Park, D., Lee, Y. and Bae, H., 1999, Efficient spatial data transmission in Web-based GIS. In Proceedings of the 2nd WIDM (Kansas, MO: ACM), pp. 38–42

Jenny, B., 2012, Adaptive composite map projections. IEEE Transactions on Visualization and Computer Graphics, vol. 18, no. 12, pp. 2575-2582

Zinn, N., 2010, Web Mercator: Non-Conformal, Non-Mercator, Hydrometronics LLC, GIS in the Rockies, available in: http://goo.gl/jJFKGa

OpenLayers, 2010, Spherical Mercator, available in: http://goo.gl/xbjX

Johnson, G.W., Gaylord, A.G., Franco, J.C., Cody, R.P., Brady, J.J., Manley, W., Dover, M., Garcia-Lavigne, D., Score, R., Tweedie, C.E., 2011 Development of the Arctic Research Mapping Application (ARMAP): Interoperability challenges and solutions Computers & Geosciences, Volume 37, Issue 11, November 2011, Pages 1735 – 1742