Floating Ring:
A New Tool for Visualizing Distortion in Map Projections

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We present a new method for interactive visualization of distortion in map projections. The central idea is a floating ring on the spheroid (globe) that can be interactively positioned and scaled. As the ring is manipulated on the globe, the corresponding projection of the ring is distorted using the same map projection parameters. We apply this method to study areal and angular distortion. This method is particularly useful when analyzing large geographical extents (such as in global climate studies) where distortions are significant, as well as visualizations for which information is geo-referenced and perhaps scaled to the underlying map. It serves as a reminder that distortions exist in maps and provides information about the degree, location, and type of distortion.

Key Words and Phrases: Map projections, distortion, visualization, cartography.

1 Introduction

The use of computers in the creation, storage, and display of maps has increased rapidly for many years now. The computational and display power of even the most modest desktop systems today make computers an obvious and attractive alternative or complement to traditional hand-drawn maps. Even the way we view maps has changed. For centuries, maps have been displayed on paper. Geographic Information Systems (GIS) allow us to store and display geographic information with speed and flexibility. We are in a position to fundamentally change the way we view maps. Instead of limiting ourselves to viewing static images, we can take more of an interactive role.

In this paper, we discuss a method of interactively visualizing distortion in map projections. We use a floating ring that rests on the surface of the spheroid. Like a contact lens, this ring can move freely on the surface. The ring also scales. This floating ring gives a fascinating range of distortion patterns depending on the map projection. Unlike other methods of representing distortion that produce static images, the user is able to interactively manipulate the floating ring to allow real-time viewing of shape deformations caused by the scaling or repositioning of the ring. The use of color enhances the visual cues of the ring shape deformations.

The floating ring tool is useful to people who use maps in a wide variety of applications and disciplines. Students can use the ring as an educational tool to gain insights into the subject of map projections. Map users can use the system as a guide in interpreting the visual information contained in maps. Finally, professional cartographers may find additional insights in an already well known projection, or a new projection. The floating ring tool is implemented in a system that performs real-time interactive map projections (Section 4.4). The system allows users to view a representation of the Earth simultaneously as a spheroid and as a projection with the ability to interact with both images. It is available on the World Wide Web through http://www.cse.ucsc.edu/research/slvg/map.html for non-profit use. We foresee the system as an integral part of Geographic Information Systems to provide additional flexibility for its users.

The motivation for this paper grew out of our work in visualizing uncertainty [10] in a number of applications. One of these applications is data assimilation [4, 13] where model forecasts are correlated with readings from in-situ weather instruments such as meteorological stations, wind profilers, and radiosondes as well as remote instruments such as satellite images, CODAR and NEXRAD moment data. The 3D weather models usually output their forecasts using a particular projection (e.g. Lambert Conformal). One of the key issues in fusing the forecasts with the actual data is the different coordinate systems in use and the need to account for the distortions in different map projections. This paper also seeks to answer some of the challenges presented in [1] and re-iterated in [6] on issues regarding visualization of data quality.

2 Background

2.1 Glossary of Cartographic Terms

We have included a list of cartographic terms and their definitions for readers outside of the geosciences. This is by no means an exhaustive list, and some definitions may omit extraneous information that was deemed irrelevant given the scope of this document.

- **Map:** For our purposes, a graphical representation of geographic information on the Earth's surface.
- **Map projection:** A mathematical system for transforming points on a spheroid to a developable surface. Also, the representation of points on a planar surface resulting from a mathematical projection from corresponding points on a spheroid or geoid.
- **Developable surface:** A surface that can be projected onto a planar surface without distortion. Examples include cylindrical, conic and planar surfaces.
- **Distortion:** In the context of map projections, changes in the direction scales of points on a projected map with respect to corresponding points on the globe. It can be thought of as the "stretching" and "squashing" of points on a map introduced by the system of projection.
- **Geoid:** A description of the exact shape of the Earth.
- **Spheroid:** A regular geometric figure closely approximating the shape of the Earth. Used in mapping as a simple alternative to the complex shape of the geoid. Its form is an ellipsoid or slightly "flattened" sphere.
- **Geographic Information System (GIS):** A computer-based system that processes geographical information [7]. Generally, the system is a database that outputs geographic information based on user queries. The output is commonly in the form of a map, but may also be textual and/or numerical.
- **Cartographic Information System (CIS):** A computer-based system designed specifically to produce maps. Can be stand-alone (such that it can also be considered a GIS) or a subsystem of a GIS [7].

- **Latitude:** Angular distance in the North-South extent, measured in degrees, minutes and seconds from the Equator.
- **Longitude:** Angular distance in the East-West extent, measured in degrees, minutes and seconds from the Central Meridian.
- **Meridian:** A line of constant longitude, extending from pole to pole.
- **Parallel:** A circle connecting points of equal latitude, extending around the globe.
- **Great circle:** Any circle on the globe whose plane passes through the center of the globe. The equator and pairs of opposite meridians are examples of great circles.
- **Graticule:** A network of latitude and longitude lines on a map.
- **Graticule spacing:** Distance between parallels or meridians on a graticule.
- **Rhumb line:** Also called a **loxodrome**. A line of constant compass bearing.
- **Conformality:** The characteristic of preserving the angular relationships in a map.

2.2 Map Projections and Distortion

The problem of projecting a spherical object to a flat surface has intrigued cartographers, mathematicians and navigators for over 2500 years[14]. A spheroid is not a developable surface, thus any system of conversion to a planar surface must include some "stretching" or "squashing" of some or all of the areas on the original surface. More precisely, distortion is based on the concept of scale at a point in a direction on a map. On a globe, scale can be considered unity everywhere and in every direction, except at the poles. The process of projection introduces changes in the scale at homologous (corresponding) points on the spheroid and projection, referred to as distortion. The knowledge of the types, magnitudes and distribution of distortion on a projection is of paramount importance in understanding the relationships between information on a map and the "real world" objects being represented.

There are hundreds of projections in standard use, and often the most important consideration in map use is the type of projection to use for a particular purpose. For instance, the popular Mercator projection has been used heavily in navigation because true compass bearings are represented as straight lines on the map, a valuable characteristic. Other projections may be used to minimize the effects of distortion in a particular area of interest.

2.3 Classification of Map Projections

There are several classification systems for map projections. We briefly describe two that are relevant to this paper – one based on the type of developable surface used in the projection, and the other based on the type of distortion introduced in the map projection.

Map projections can be classified by the shape of the intermediate developable surface used for projection. Figure 1 shows several spheroids inscribed in three such shapes. A **cylindrical** projection is created by projecting every point on the spheroid onto the surface of the cylinder. The cylinder is then "cut" along the length its body and laid flat to produce the map. Likewise for a cone and a plane, producing **conic** and **planar** projections, respectively. The point or loci of points of the developable shape tangent to the spheroid define a region of constant scale. Note that not every projection can be associated

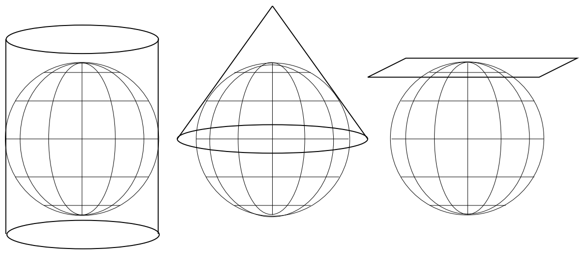


Figure 1. Three different types of developable surfaces used in map projections. (A) Cylindrical. (B) Conic. (C) Planar.

with a geometric object. The user interface of the MapViz program described in Section 4.4 uses this classification to aid users in selecting a map projection.

Another common system for classifying map projections is by the type(s) of distortion present on the projection. Angular distortion occurs if the *ratio* of the scale factors in at least one pair of perpendicular directions at a point is not unity. A **conformal** or orthomorphic projection is one that preserves the ratio of scale factors of every perpendicular direction at every point, and therefore contains no angular distortion. It must be stressed that this quality only applies to points and not areas of any extent. A conformal projection tends to preserve reasonable shape across small geographic extents but deforms the area. The Mercator projection, in Figure 5, provides a clear example of the effects of the distortion of a conformal projection, especially in the higher latitudes. Notice that Greenland appears larger than the South American continent, which is grossly inaccurate.[1]

Area distortion occurs if the *product* of the scale factors in perpendicular directions at a point is not unity. An **equivalent** or equal-area projection preserves unity of the products of the scale factors at every point and in every direction on a map, except at the poles. Equivalent maps therefore represent geographic areas in relative proportion, i.e. two objects of identical size on the sphere will retain that property on the projection. The tradeoff is that angular relationships will change because the ratios of perpendicular scale factors are not preserved. Thus equivalent maps tend to distort the shapes of land masses, but retain areal relationships. Conformality and equivalence require contradictory scale relationships so that no map projection can retain both characteristics, and in fact most retain neither.

Equidistant projections maintain correct distances either between all points along one direction or from one or two points in all directions. Correct distance between points implies uniform scaling along the direction between the points.

Finally, **azimuthal** projections show some "true directions" as straight lines. True direction in the cartographic sense is the path along any great circle and is the shortest distance between two points on a sphere. [2] Usually azimuthal maps represent true directions as straight lines only from one or two points or within a very limited area.

[1] Area of Greenland: 2,175,600 sq.km. Area of South America: 18,291,928 sq.km.

[2] In general, true direction is not equivalent to true compass bearing. A line of constant bearing (rhumb line) will coincide with a great circle if you are traveling north or south along a meridian, or east or west along the equator.

3 Related Work

3.1 Tissot's Indicatrix

Formal methods for graphically representing distortion in map projections date back at least 100 years. The most notable is the use of Tissot's indicatrix. The indicatrix is simply an ellipse whose shape and size represent the scale factors at an intersection of any pair of perpendicular directions on the spheroid. Figure 2 is a representation of the basic idea of the indicatrix. The circle centered at O of radius $OA = OB$ represents an infinitesimal circle on the surface of the sphere. The radius is considered unity. The values a and b represent the scale factors of point O in the directions of OA and OB, respectively. It is important to keep in mind that the lengths shown in the diagram are only representative of scale factors at a point and do not correspond to any actual distance. Once projected, the circle will be deformed. If the projection is conformal, the shape will remain circular since the scale factors must be equal. The area, however, is not constrained and therefore will vary from point to point. An equivalent or equal-area projection, on the other hand, must retain relative areas, so the product of a and b must be equal to unity, but $a = b$ does not hold, so the shape of the indicatrix becomes elliptical and angular distortion is introduced. The point M on the circle and the corresponding point M' on the ellipse are points subject to the maximum angular deflection. The amount of angular distortion in a quadrant ω, is given by the relation $\omega = U - U'$ where $U = \angle MOA$ and $U' = \angle M'OA$. The maximum angular distortion at a point is given as 2ω, which represents the maximum angle deflection in two quadrants adjoining the major axis of the ellipse.

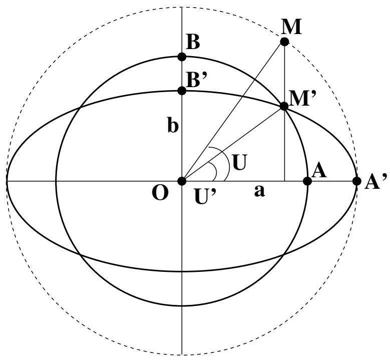


Figure 2. Tissot's indicatrix: The smaller circle represents an infinitesimal small circle on the globe of unit radius. The ellipse represents the same circle on the projected image. The values $\mathrm{a} = \mathrm{OA}'$ and $\mathrm{b} = \mathrm{OB}'$ represent the scale factors used to define the angular and areal deformation at a point in a projection.

Conceived in 1881, Tissot's indicatrix is still considered the standard method for representing map projection distortion. It is simple, elegant, easy to comprehend and very effective in conveying the distortion characteristics of a projection. It is, however, limited in its usage. Since each ellipse is representative of the scale factors at an infinitesimal point, distortion over areal extents of a projection is generally achieved by placing multiple indicatrices on convenient intersections of the graticule, such as every 10 or 15 degrees latitude and longitude, as in Figure 3. The distortion scale therefore cannot be known at arbitrary points on the projection, and the presence of many such ellipses on a static projection image may obscure geographic data.

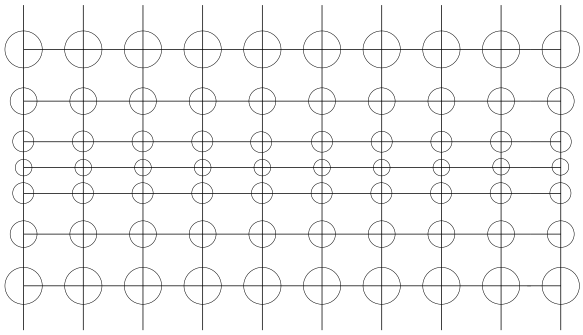


Figure 3. Mercator projection graticule shown with Tissot's Indicatrices placed on line intersections. Notice each indicatrix is a circle, indicating conformality. The area of each indicatrix is proportional to the areal distortion at that point, and increases toward the poles.

3.2 Other Distortion Visualization Methods

A common method of representing distortion on map projections is the use of isarithms (isolines) to show regions of equal angular or areal distortion. This method is useful because it gives the user an idea of the overall pattern of distortion on the projection, but the lines can interfere with the geographic information being represented, and is in practice limited to show discrete values.

Cartographers may use what Robinson and Sale refer to as Visual-Logical Analysis [12] to determine overall distortion characteristics of an unfamiliar projection by examining graticule patterns. For instance, the intersection of parallels and meridians will always be at right angles in a conformal map, so angles other than 90 indicate a non-conformal map. This method is useful only for those with considerable knowledge of map projections, and may not make apparent some of the subtleties of the projection.

Another common and useful device is the general method of "familiar shapes". As the name implies, the distortion characteristics of a projection can be demonstrated by the deformation of a projected image of a familiar shape. Examples of this method employ single shapes, such as a human's head [12], or a circle and compass rose [9], or multiple shapes, such as a network of equilateral triangles covering the extent of the globe [5]. In general, these methods obscure underlying geographic information and are limited by the static nature of the projected image. Of course, the deformation of familiar coastlines and other geospatial characteristics can often provide sufficient visual cues to allow a user to gain an overall sense of the distortion of a projection.

Clarke and Mulcahy introduced the concept of color differentiation, mapping three color scales to the x range, y range and angular convergence at a point on the projection [2]. The distortion pattern of the entire projection is visualized without obscuring underlying uncolored geographic data. Projecting a checkerboard pattern or grid square pattern has been used by Steinwand, Hutchinson and Snyder [15] to study the effects of distortion introduced by re-projecting raster data sets.

Each of these methods is effective in different circumstances. The primary benefits of the floating ring include its flexibility through interactivity and ability to convey distortion information effectively across varying areal extents. Color information is used to enhance the user's ability to gauge the rate of change of distortion over the extent of the ring and the magnitude of distortion at a point. The shape of the ring is circular, a shape that has many beneficial qualities for use in this capacity, notably that small deformations of the shape are easily recognizable as such, and do not depend on the user's geographic or cartographic knowledge. The ring is transformable through user interaction, which overcomes the shortcomings of static images. The use of the ring does not obscure the geographic data, and can be easily hidden. Finally, the floating ring tool is implemented in a system that provides interactive visualization of map projections, so that the effects of different projections on the ring and the underlying data can be easily compared.

4 Interactive Distortion Visualization

4.1 Floating Ring Tool

The floating ring tool is simple to comprehend and use, yet provides powerful visual cues of the types and amounts of distortion in a projection. The ring floats on top of the spheroid, and can be easily manipulated by the user with simple mouse interaction. Figure 4 shows a simplified schematic demonstrating the concept of the floating ring. Both the position and scale of the ring can be changed, and the results of those changes are shown in both the globe and the projection images in real time. The ability to see immediately the changes made to both images is one of the key strengths of this system.

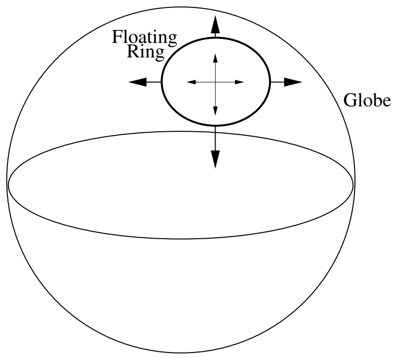


Figure 4. Schematic of floating ring on a globe. The ring can be moved in any direction and scaled with simple mouse interaction. The ring is projected in real time.

The choice to use a circular shape was based on several factors. Every point on a circle is in contact with the sphere. A planar rectangular or triangular object does not have this property, unless the shape is deformed to match the curvature of the spherical surface using spherical geometry. Part of the effectiveness of the floating ring is that the circular shape remains constant and undeformed on the globe regardless of its position or scale. This gives the ring a simplicity and symmetry that greatly enhances the user's ability to comprehend the deformation of the projected ring caused by the projection. The visual cues offered by the deformed ring provide a link to understanding the distortion characteristics of a projection, in both localized extents or over large regions of the map.

4.2 Map Distortion and Shape Deformation

For this document, we will refer to two projections for illustrative purposes, the standard Mercator and the American polyconic, shown in Figure 5. The Mercator is a conformal, cylindrical [3] projection used in navigation and conformal

[3] The Mercator projection is almost universally classified as cylindrical, although technically it is not a direct geometric projection [3]. For our purposes we need not be concerned with this detail.

mapping of equatorial regions [14]. Angular relationships are preserved at every point but area is distorted as one moves toward the poles. The polyconic projection is a conical projection, but is neither conformal nor equivalent. It shows increasing angular and areal distortion from the central meridian (yellow-green line running north-south through Africa in Figure 5). It has been historically used to map regions of primarily north-south extent and limited east-west extent [11]. These projections were chosen partly because they have very different distortion characteristics, and thus together provide a clear medium to demonstrate the floating ring tool. A detailed analysis of the projections is beyond the scope of this work, but interested readers can find plenty of detailed information on both projections, especially in [3] and [8].

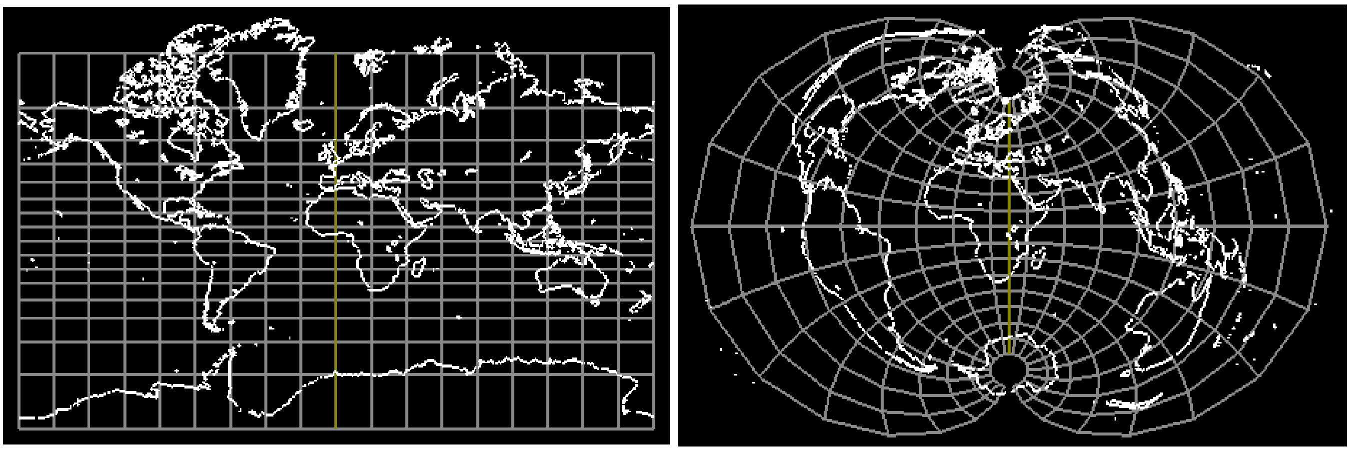


Figure 5. Mercator and Polyconic projections. The central meridian is represented by the yellow-green longitude line. The Mercator projection preserves angles but not areas, while the polyconic projection preserves neither angles nor areas.

The floating ring is effective in representing both angular and areal distortion. Areal distortion in a projection is accompanied by an enlarging or shrinking of the projected ring shape. In the Mercator projection, this is best seen as an enlargement of the ring as it is moved into higher *latitudes*, as illustrated in Figure 6. In the polyconic case, the area of the ring changes with *longitude*, becoming enlarged as it is moved away from the central meridian. Also effective is a scaling of the stationary disk, which allows the user to see the effect of distortion over a large area of the projection.

Angular distortion is accompanied by a deformation of the ring in the polyconic projection away from the central meridian, as in Figure 7 [4]. The ring becomes unsymmetrically elongated and rotated with respect to its orthogonal axes based on its position and scale.

The point at the center of the ring is also displayed. This serves as a reference point, and provides an additional visual cue of the effects of the distortion on the ring. In Figure 6, for example, the ring's center point on the projection sits low in the ring, reinforcing the visual perception of increased distortion toward the poles.

The use of multiple rings in a single projection can greatly enhance the ability of the user to gain an understanding of the distortion characteristics of the projection through simple visual comparison. Comparing multiple rings in different positions or with different scales provides many interesting scenarios in addition to the single ring configuration. Adding or deleting rings from the display is accomplished with GUI controls (see Figure 12). Managing multiple rings on the display adds very

[4] This graphic representation is a simplification of the polyconic projection. The construction of the polyconic projection includes an infinite number of cones tangent at infinitesimally spaced latitudinal steps.

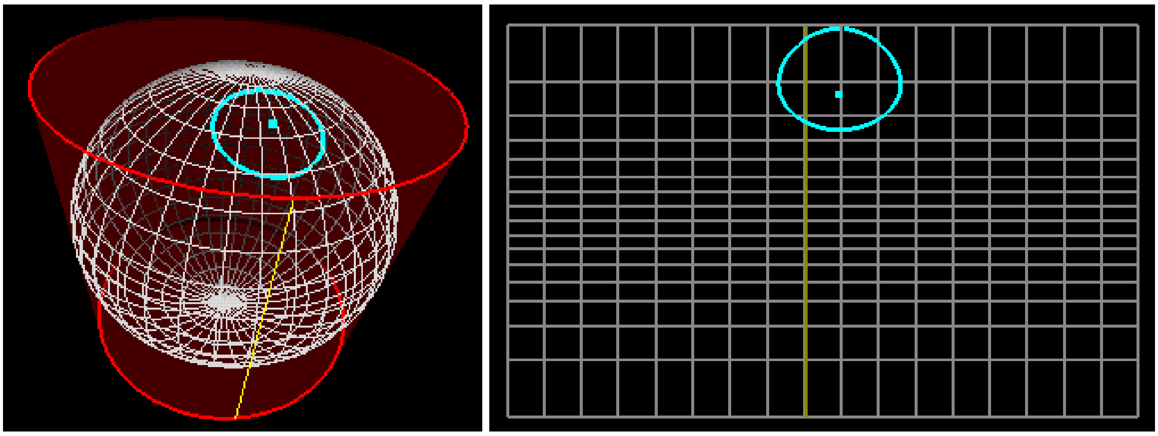


Figure 6. Mercator projection and the floating ring. (A) is a view of the globe inscribed in a cylinder. (B) shows the resulting projection. The image of the floating ring on the globe is shown on the projection with a larger area than a similar ring closer to the equator.

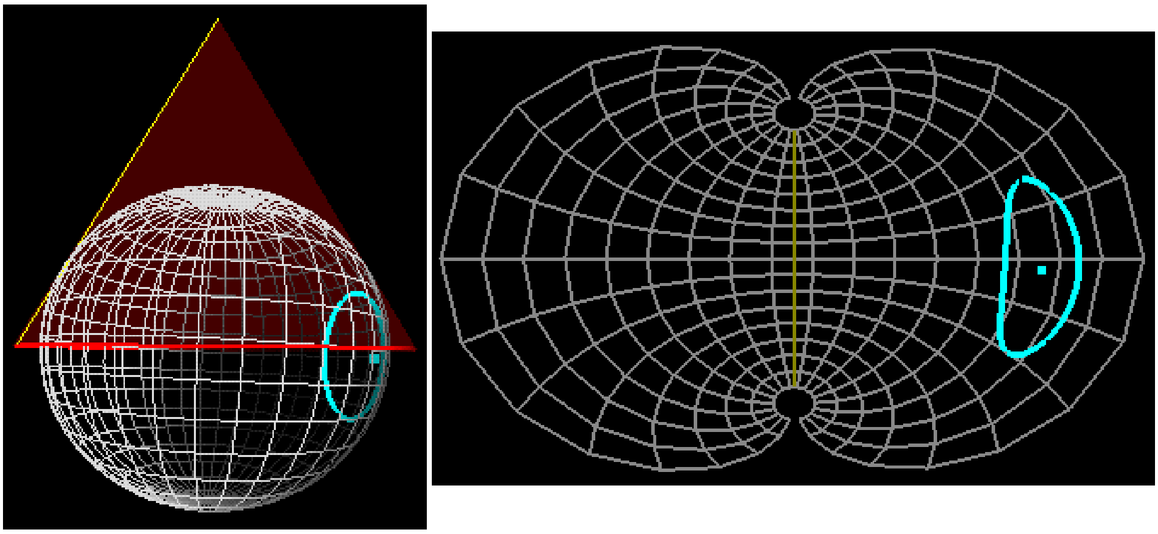
little complexity to the user interaction. Rings can be moved and scaled through mouse picking, so the user controls remain intuitive and uncluttered. In principle there is no limit on the number of rings that can be added, but in practice having two or three is sufficient. Figure 8 shows an example of both the globe and a resulting polyconic projection image with two rings displayed in a partially overlapping configuration.

We restrict the movement and scale of the ring to ensure its most northern or southern extent is within 80° of the equator. In certain projections such as Mercator, the poles cannot be shown correctly because they would be projected at an infinite distance from the equator. So allowing the ring to touch or encompass a pole would result in an unpredictable and inaccurate projection display. We enforce this constraint for each projection to maintain consistency in the behavior and operation of the floating ring tool.

4.3 Color Information

In addition to shape deformation, color is used to represent magnitudes and changes in distortion, both at single points and across areal extents. In the standard mode just the circle outline is presented. This gives an unobstructed view of underlying geographic information and the graticule on the projected image. The ring is colored proportional to the magnitude of distortion at each point, which is discussed in more detail below. The user can also choose to color the entire area within the ring. Coloring the entire area can be useful in determining the magnitude of distortion at various points within the ring, or as an additional aid in understanding how the distortion changes over area. The use of color is in most instances preferable to the use of isarithms because a visual representation of the continual change of the magnitude of distortion provides more complete information than discrete lines representing equal magnitude. In addition, the coloring does not introduce additional lines that might be confused for graticule lines or other geographic information.

Two separate color scales are used, one to represent angular distortion and the other areal distortion. The user simply selects a color scale from the GUI (Figure 12). The color model we use is based on the scale factors at a point in orthogonal directions, represented on Tissot's indicatrix (Figure 2) as $a = OA'$ and $b = OB'$, respectively. These values are simply the



(A) (B)

Figure 7. Polyconic projection and floating ring. (A) is a view of the globe inscribed in a cone. (B) shows the resulting projection. The image of the floating ring on the globe is shown on the projection with both increased angular and areal distortion.

semi-axes of the indicatrix. To determine areal distortion at a point, we multiply a and b. This is proportional to the area of the indicatrix at that point, $2\pi ab$. Since the scale factors are unity at every point on the globe, the product ab of a point on the projection determines the magnitude of the areal distortion. In all cases the lengths of a and b are considered positive, so increases in areal distortion occur when $ab > 1$ and decreases in areal distortion occur when $ab < 1$. A color value is then assigned based on this value. Two colors are specified in the colormap, one for values less than unity and one for values greater than unity, as shown in Figure 9. In a similar way, we use the ratio of scale values, a/b, as the measure of angular distortion. This value can be thought of as the ellipsoidal eccentricity of Tissot's indicatrix. Angular distortion occurs when $a/b \neq 1$. If $a > b$, the ellipse is "squashed", and if $a < b$, the ellipse is "stretched". As in the case for areal distortion, a color value is assigned based on the relationship of the distortion magnitude to unity.

Figure 9 is a graphic representation of two separate colormaps. Either colormap can be specified by the user to represent either the angular or areal color scale. This gives the user flexibility in determining how the map image should look.

In both the Mercator and polyconic projections no scale value falls below unity, so only the color above unity dominates. In the Mercator projection, there is no angular distortion, so the color of the ring is constant (when the angular distortion color scale is chosen). The polyconic projection, however, includes substantial angular distortion. Conceptually, Tissot's ellipses become stretched with longitudinal distance from the central meridian, implying $b \geq a$ or $a/b \leq 1$. Again, one color dominates, but at the minimum end of the colormap, i.e. all values are ≤ 1. Figure 10 shows a filled ring on the Mercator graticule, colored as in Figure 9 (a). Figure 11 shows a filled ring on the Mercator graticule, colored as in Figure 9 (b).

Having two separate color scales representing different types of distortion is an excellent means of comparing distortion information. For instance, the ring in a conformal projection has constant angular distortion, and will be colored uniformly in the angular distortion colormap, but not with the scale magnitude colormap. The polyconic projection, on the other hand, will be colored differently in both scales since it is neither conformal nor equal-area. The user can switch back and forth

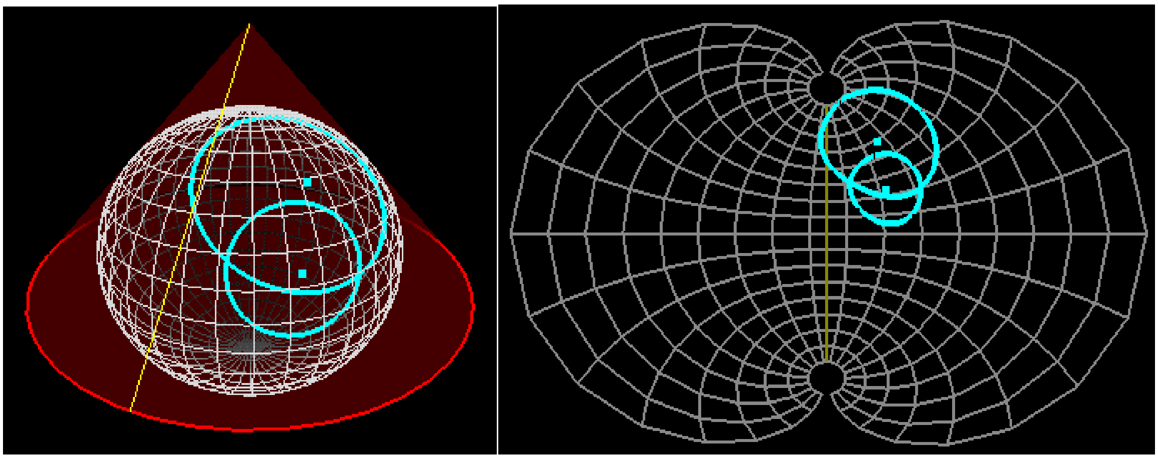


Figure 8. Polyconic projection of a globe and two partially overlapping rings.

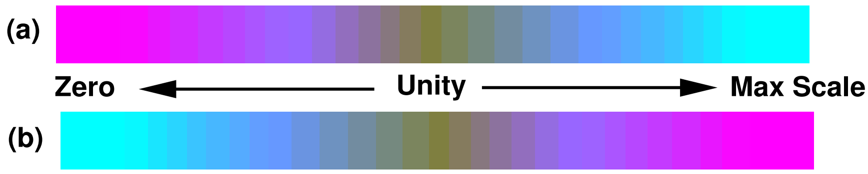


Figure 9. Two possible colormaps used to color the floating ring. (a) $Magenta \rightarrow Cyan$ **and (b)** $Cyan \rightarrow Magenta$**. Unity represents the scale factors on the globe. The difference in angular or areal distortion is expressed with respect to unity. Both colormaps can be used for either angular or areal distortions. Figure 10 uses the colormap in (a) and Figure 11 uses the color map in (b).**

between the two scales to gain nearly instantaneous comparative information on the types and magnitudes of the distortion.

4.4 MapViz: Interactive Map Projection System

The floating ring is implemented in a system that performs interactive map projection visualization, called MapViz (see Figure 12). The user is initially presented with a spheroid consisting of the standard graticule and world coastline data. Through the use of mouse controls, the user is able to rotate the spheroid along the polar axis and an equatorial axis. The user can choose to view one of three developable geometric shapes in this window (Globe Window): a cylinder, cone, or plane. Each of these represents a class of map projections that can be viewed simultaneously in another window (Projection Window). Once a geometric shape has been chosen, a projection is shown in the Projection Window. The projection corresponds to the type and orientation of the geometric shape. The geometric shapes can be independently manipulated through rotation. Rotating the shape or the globe, seen in the Globe Window, changes the projection in the Projection Window appropriately. Currently five different standard projections are supported: Mercator and Transverse Mercator (cylindrical), Polyconic and Lambert Conformal (conic), and Polar Stereographic (planar). Routines from the General Cartographic Transformation Package (GCTP) from the United States Geologic Survey (USGS) are used for the projections. A bounding box tool is included that can be used to define regions of interest for geographic database queries. Like the floating ring tool, the bounding box floats on the surface of the globe and is projected onto the map projection image. The bounding box's rectangular shape

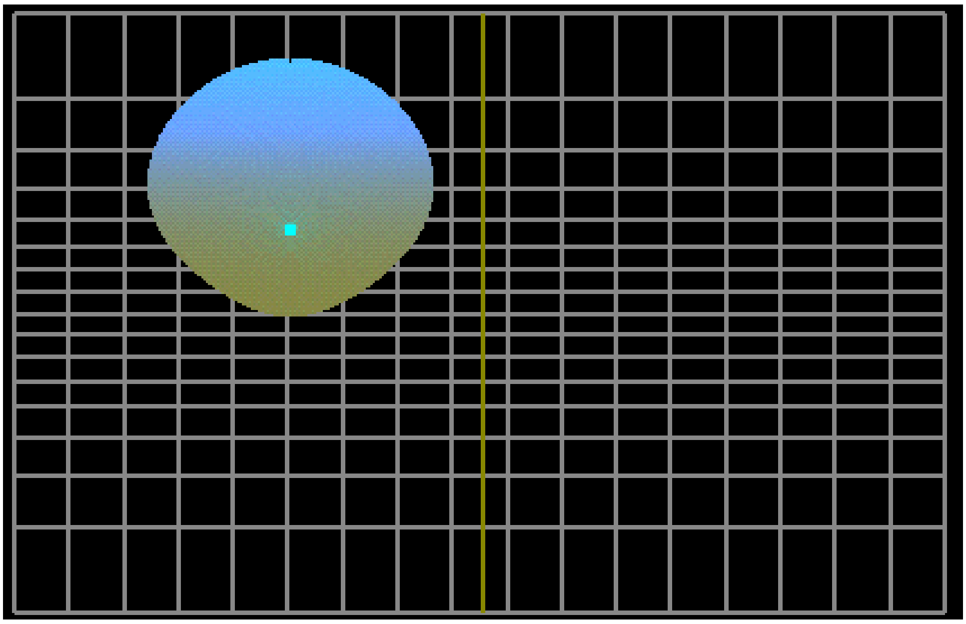


Figure 10. Mercator projection showing a colored disk. The colors inside the ring correspond to amount of areal distortion according to Figure 9 (a). Areal distortion can be noted to increase closer to the poles.

requires that it be deformed to match the curvature of the globe. Each corner of the box is moved separately through mouse picking, and motion is restricted so that every point on a side of the box remains along a meridian or a parallel.

The MapViz system was originally designed as an educational tool, and later converted to a front-end for the visualization component (SLVG) of the Real-Time Environmental Information Network and Analysis System (REINAS) at the University of California, Santa Cruz. REINAS is a system that supports real-time data acquisition, data management, and data visualization of regional scale environmental science [13]. The latest use of the MapViz system is to support the floating ring tool. The system is written in C++, and each object on the screen is represented by a class. This provides a modularity that allows objects to easily be added to or removed from the system. Users can choose the objects to be displayed, allowing for customization. For instance, the user can choose to hide the coastline data, allowing an unobstructed view of the graticule. This might be beneficial in studying graticule patterns in different projections. The modular design also allows the MapViz program to be quickly modified based on the user's desired purpose. The educational version of the MapViz system is available for download via ftp from http://www.cse.ucsc.edu/research/slvg/map.html.

5 Conclusions

We presented a method for visualizing map projection distortion using a "floating ring" on a spheroid. Both angular and areal distortion are visualized based on the size and shape of the deformed ring as well as color mapping. The floating ring tool allows qualitative and quantitative distortion analysis of points as well as arbitrary areal extents. The floating ring overcomes many of the shortcomings of traditional methods of map projection distortion visualization, mostly through the use of powerful, intuitive user interactivity, and the subtle effectiveness of the circular shape in conveying distortion information

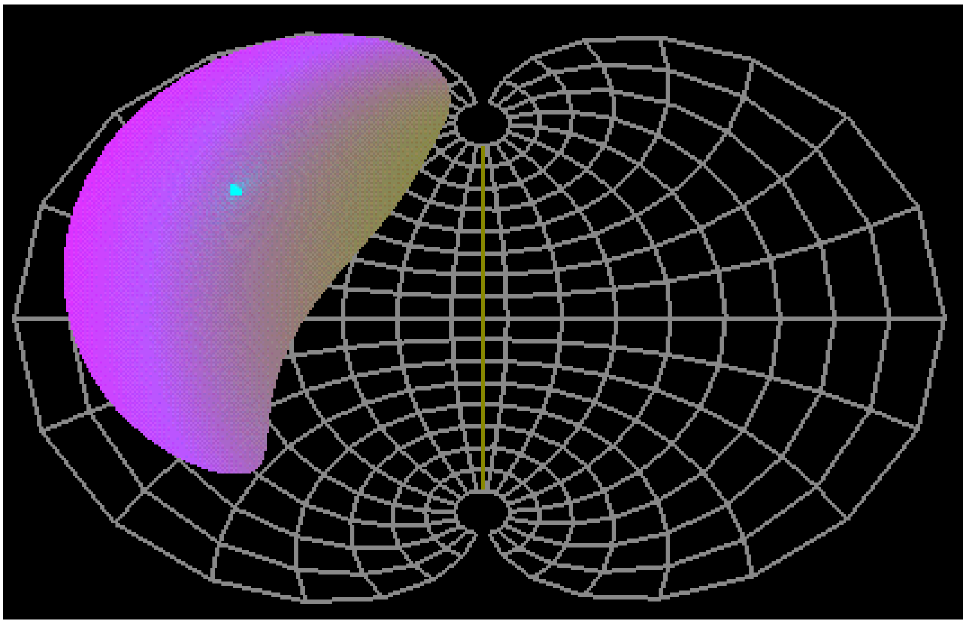


Figure 11. Polyconic projection showing a colored disk. The colors inside the ring correspond to amount of angular distortion according to Figure 9 (b). It can be observed that angular distortion increases the further away from the central meridian (yellow-green longitude line).

through shape deformation and color.

The use of computers and Geographic Information Systems to manage, store and visualize geographic information opens up many new avenues, not only for what we view but how we view the information. Interactively viewing and manipulating map projections and map distortion tools represents just one of those avenues, and is an attempt to use visualization methods to allow cartographers, students and others in the geosciences communities to enhance their understanding of spatial geographic information and hopefully stimulate creative insight from that information.

6 Future Directions

Future work stemming from the floating ring tool and MapViz system will be geared towards correcting for areal distortion in the representation of scalar geographic data such as height fields. In particular, distortion along the vertical dimension is all but ignored and can be significant in some applications such as meteorology. The floating ring tool itself will be enhanced in functionality to provide more distortion information to the user. The study of multiple floating rings merged from different maps and/or different projections can be used in the synthesis of radar or photogrammetric imagery.

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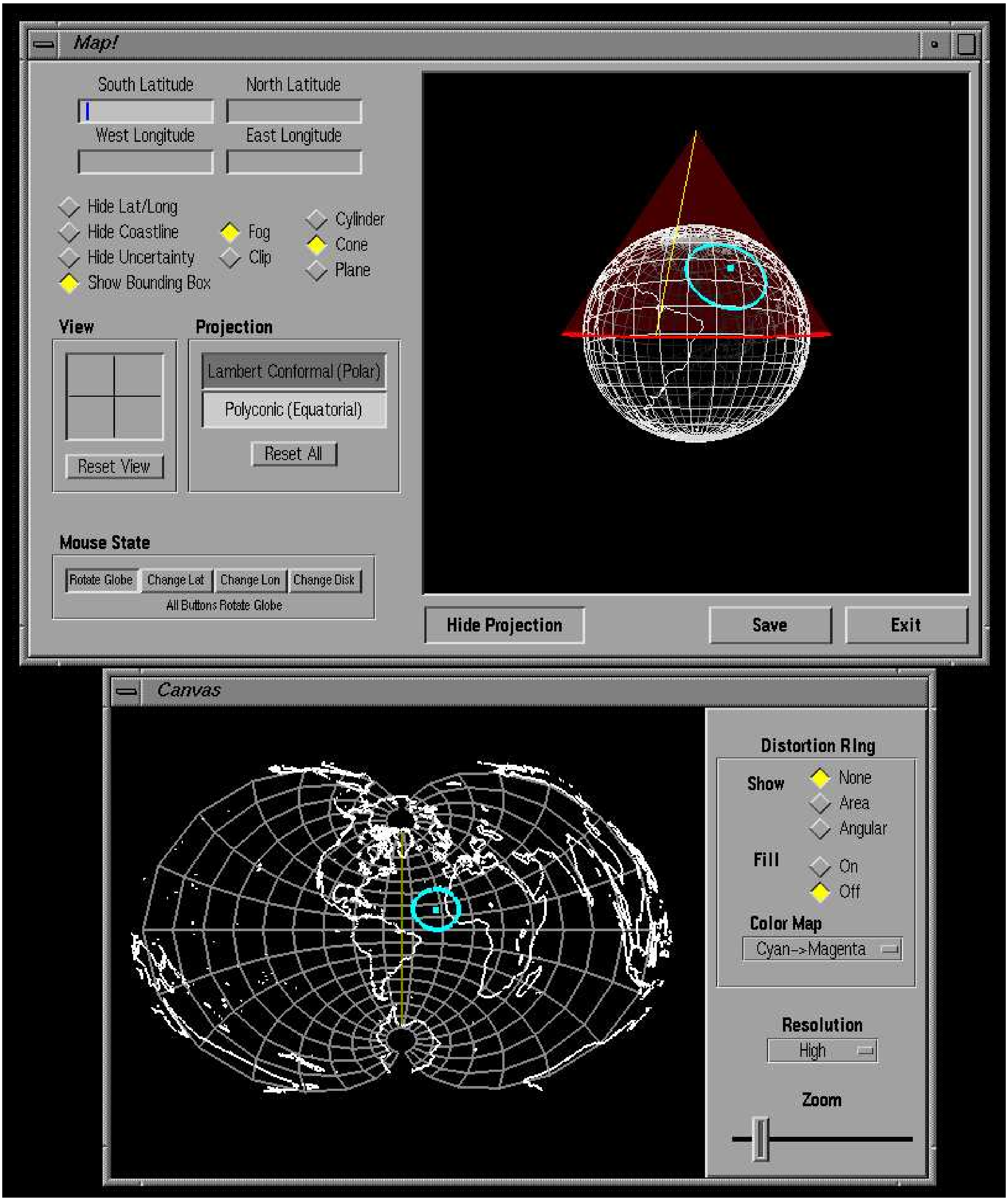

Figure 12. MapViz system for interactively visualizing map projections. It is shown here with the floating ring tool for interactive visualization of map projection distortion.