SuperMap Objects Java 6R Technology Document

——Map Projection

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Legal Statement

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Content

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Summary

GIS is the academic technology to process the information about geographic space distribution. The common foundations of GIS science or technology includes how to build earth model, how to identify or represent locations on the earth, the theoretic and approaches to transform spatial curved surface into plane. It provides a unified locating framework on input, output, and matching information, serving a common geographic foundation for various geographic information and data. Map projection is the foundation of transforming geographic information from spatial curved surface to plane displaying. The vast majority of GIS software offers rich map projection functionality.

The following contents are introduced in this section:

1） Aims of Map Projection

2） Spatial Coordinates System

3） Map Projection

4） How to Choose a Suitable Map Projection

5） Map Projections of SuperMap Objects Java

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Map Projection

The real earth spheroid is a curved surface which became a problem when we want to unfold it onto a flat piece of paper. Since our earth surface is a spherical surface that cannot be unfolded without cracks, we have to use special method to unfold it to a flat and complete piece of paper. Consequently, the map projection theory is applied. The basic principles of the map projection is drawing the crossed points of the latitude and longitude lines on a plane first, as the position of any point on the earth could be found by its latitude and longitude degree; and then connecting all the points with the same latitude degree as latitude lines and all the points with the same longitude degree as longitude lines, which constructed a net. On the basis of this net, points on the spherical surface could be drawn on the correct places as the diagram below shows:

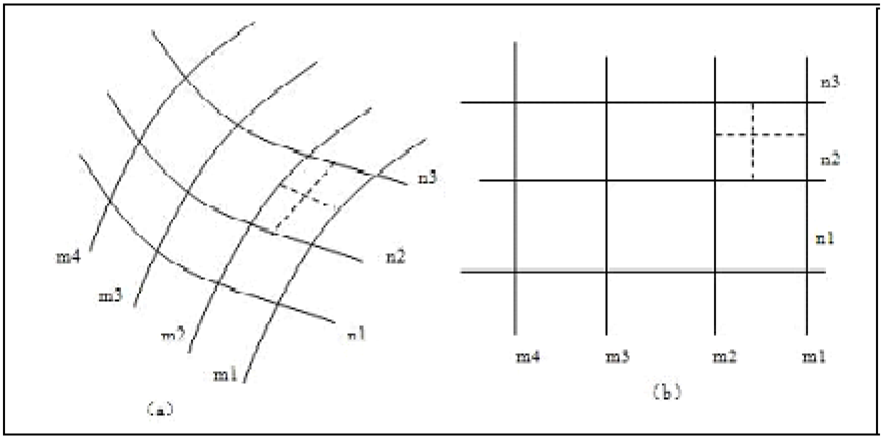

Diagram 1 Drawing the points on the spherical surface to a plane

Many analyzing techniques we currently have are on the basis of two-dimensional coordinates or plane coordinates. Therefore, we have to employ the map projection to project the three-dimensional coordinates to a plane coordinates; however, there are distortions during this procedure. The so-called Map Projection transforms the latitude-longitude coordinates (λ, ϕ) into plane coordinates (X, Y) to solve this problem by using specific mathematic formulas.

In conclusion, map projection plays a very important role in GIS to make sure the spatial information can be completely transformed from geographic coordinates system to plane coordinates system with continuous regions, which is the basic requirement in mapping, spatial operation, and spatial analysis.

3

Spatial Coordinates System

3.1 The Earth Spheroid

It is well known that we usually use the spheroid to describe the shape of the earth. Sometimes, it is considered as a sphere for convenient calculation. However, in most time it is taken as a spheroid. Usually, when the scale is smaller than 1:1,000,000, the earth is considered as a sphere, as the difference between a sphere and a spheroid cannot be told in this case. However, when the scale is larger than 1:1,000,000, we use the spheroid as the earth shape. The spheroid is on the basis of the ellipse, which displays the earth by two axes, the major axis (equatorial radius) and the minor axis (polar radius). In many cases, people use the major axis and the flattening to describe the degree of the earth's roundness and flatness. The flattening is the ratio between the remainder of the major axis minus the minor axis and the major axis. The bigger flattening indicates a more flat earth; while the smaller one indicates a more round earth.

Since our earth has this special shape, it has been measured by many countries countless times across the history. As a result, today, we've got many ellipsoids, but none of them can accurately describe the overall shape of the earth. Therefore, in practice, which ellipsoid is a suitable one for the country depends on its specific zones and conditions. The North American mainland usually apply Clark ellipsoid of 1866 (major axis: 6,378,206.4m, flattening: 1/294, 98). In China, we used Krasovsky ellipsoid of 1940 (major axis: 6378245.0m, flattening: 1/298.3). The second one used was IAG1975 ellipsoid of 1975 (major axis: 6,378,140, flattening 1/298.257) on the basis of Xi'an 80 coordinate system, which is recommended by International Union of Geodesy and Geophysics. In 2008, State Bureau of Surveying and Mapping declared to use a new national datum on the basis of geocenter, and the new ellipsoid has major axis 6,378,137, flattening 1/298.257222101.

3.2 Datum

The earth ellipsoid only illustrates us the size and shape of the earth. In order to accurately describe the specific position of features on the earth, we need to introduce the concept of datum. The datum determines the relative position of the earth ellipsoid to the earth core, providing a reference frame for measuring and positioning. Meanwhile, the zero point and the direction of the latitude-longitude net are settled down, which are the position and direction of the ellipses.

Datum takes the spherical center of the earth ellipsoid as the origin. The ellipsoid of a datum for a district cannot take the true geocenter as its geocenter. In order to display the surface situation of the district, the coordinates system of the earth surface is created referring to the spherical center of the ellipsoid. The current widely used datum is WGS84, which is taken as the basic framework of the datum. Every country or district has different datum, as one datum cannot applied to all the places. For instance, NAD27 is suitable for the North American, while ED50 is used in Europe.

3.3 Geographic Coordinate System

Geographic coordinate system describes the position of three-dimensional land objects. The position of land object is decided by its latitude-longitude coordinates, whose unit is degree, minute, and second. Latitude degree and longitude degree is measured by the angle degree centered to geocenter. The latitude is represented by the horizontal lines, the longitude by the vertical lines, both of which contribute to the latitude-longitude net embracing the earth.

The middle latitude line between polar is equator, also named zero degree latitude line. The zero degree longitude line is also named the prime meridian. In most of the coordinate systems, the prime meridian is the longitude line crossing the meridian of Greenwich in London. In some countries, they use Bem, Bogota, and Paris as their prime meridians. The coordinate of crossed point by the prime meridian and equator is taken as (0, 0), i.e. the start point. The start point and the two crossed lines give us four quadrants, the semi-ellipsoids divided by the prime meridian are eastern semi-ellipsoid and western semi-ellipsoid; while the ones divided by the equator are southern semi-ellipsoid and northern semi-ellipsoid.

Usually, the geographic coordinate system consists of a datum, prime meridian, and angular units.

Geographic coordinate system is a static coordinates system to the earth. There are two kinds of the datum, the geocentric coordinate system and the ellipse-centered coordinate system. The origin point of the geocentric coordinate system is the same with earth centroid; while the origin point of ellipse-centered coordinate system is the same with the center of the referred spheroid used by the country or district, which is not corresponding to the geocenter. In history, there are three ellipse-centered coordinate system used in China, Beijing Coordinate System of 1954, Xi'an Coordinate System of 1980, and New Beijing Coordinate System of 1954. All of them contributed significantly to China's economic and social development and national defense establishment. However, with the development of the modern science and technology, especially the development and application of the satellite positioning techniques, many developed countries and moderately developed countries have been employed geodetic coordinate systems for many years. From 1st July of 2008, the China Geodetic Coordinate System 2000, i.e. CGCS2000, was applied, which is a three-dimensional coordinate system with geocenter as the origin.

3.4 Projected Coordinate System

Projected coordinate system projects the points on the spherical surface on a plane (map). There are two kinds of projected coordinate systems, the plane polar coordinate, and the plane rectangular coordinate. The latter one consists of an origin and two vertical intersected axes. In the latter coordinate, the plane position of a point is fixed by the rectangular coordinate principle. It is also named Cartesian coordinate or rectangular coordinate. In surveying, the rectangular coordinate has opposite X axis and Y axis.

Usually, a projected coordinate system includes the following parts: the name, unit, project type, geographic coordinate system, and project parameters of the projected coordinate system. The following parameters are frequently used in many cases:

False Easting & False Northing

FalseEasting, FalseNorthing This parameter makes sure that there are no negative coordinate values. For instance, in the GK6 zoning projection, the abscissa is 500 kilometer by east to secure all abscissa values are positive.

Azimuth

Azimuth is used to define the azimuth angle of the projection face, calculating from north to east by clockwise. If it is orthoaix, the value is zero; if it is abscissa, 90 degree; if it is inclined axis, x degree.

Central meridian / Longitude of origin

Defines the centre meridian, i.e. the abscissa's starting point.

Central parallel / Latitude of origin

Defines the centre latitude, the ordinate's starting point. In some cases, with the origin and ordinate, the False Northing is not necessary.

Standard parallel 1& standard parallel 2

Defines the parallels with the same length: Lambert equivalent projection defines one parallel, and the ordinate with origin.

Longitude of first point & Latitude of first point, Longitude of second point & Latitude of second point

It is used in the two-point equidistant azimuthally projection. The four parameters define the latitude and longitude coordinates of two points. For instance, Two-Point Equidistant and Hotine Oblique Mercator projections.

Scale factor

The Scale factor of the center meridian or projection center, for instance, in UTM, it is 0.9996.

4

Map Projection

Map projection is a subject researches the methods, and how to draw the latitude and longitude net on a plane according to certain mathematic calculation.

4.1 How to Conduct Map Projection

Geometric Perspective: drawing the curved surface (the earth spherical surface) on the plane, cylinder surface, or cone surface. This method has a long history.

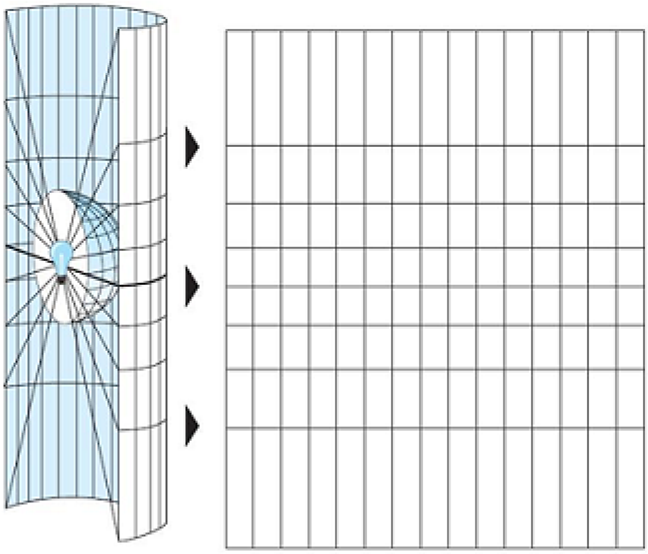

Diagram 2 Illustration of Perspective (quoting from internet)

4.2 The Distortion of Map Projection

Since our earth surface is a spherical surface that cannot be unfolded without cracks, we have to use special method to unfold it to become a map. In order to display the features completely, the crack or overlapped part should be stretched or compressed evenly to avoid the cracks and wrinkles. However, this procedure will cause the stretched place on the map lost connection with its real geographic place. This is the projection distortion.

The map projection distortion includes length distortion, angle distortion, region distortion, and shape distortion.

1) Length Distortion

The minus between length ratio and 1 is length distortion. The length ratio is a micro section length on the projection surface and its correspondent micro section length on the spherical surface. The length distortion is a basic distortion that causes the square dimension and angles distortions.

2) Angle Distortion

The minus between an angle consisted by any two lines on the projection surface and its correspondent angle on the spherical surface. Angle distortion is the explicit mark of distortion.

3) Region Distortion

The minus between square dimension ratio and 1 is region distortion. The ratio is a micro area on the projection surface and its correspondent micro part on the spherical surface. Region distortion is a factor to measure the distortion degree.

4) Shape Distortion

Shape distortion is the outline shape on the map that seems far away from the real land outline shape.

4.3 Map Projection Types

4.3.1 Classed by the Projection Distortions

According to the nature of distortion, it is divided as conformal projection, equivalent projection, and arbitrary projection (the Equidistant is a special instance)

Conformal or Azimuthal Projection: it keeps the infinitesimal diagram similar and each point has the same length ratio. To the distortion circle, the radiuses are different on different points. In larger scale, the shape between the real and the projected is not totally similar. However, there is no angle distortion, so it is convenient for measuring the directions or angles on the map directly. Therefore, it is widely used on sailing map, ocean current map, and wind-direction map, which require higher accuracy on angle or direction

Equivalent Projection: There is no square dimension distortion, and it is widely used in natural and economic maps which require higher accuracy on square dimension. For instance, geology, soil, land use, and administrative division maps.

Arbitrary Projection: There are distortions in all the stated areas, so it is usually used in teaching map, scientific reference, and the world map we daily use.

4.3.2 Classed by the Projection Methods

There will be two classes: geometric projection and analytic projection.

4.3.2.1 Geometric Projection

First of all, project the latitude-longitude net to a geometric surface directly or with certain conditions, and then unfold the geometric surface to be a plane to get the projection. It includes azimuthal projection, conic projection, and cylindrical projection. With the different relationship of spherical surface, it could be divided into normal projection, transverse projection, and oblique projection. Please see the following diagram:

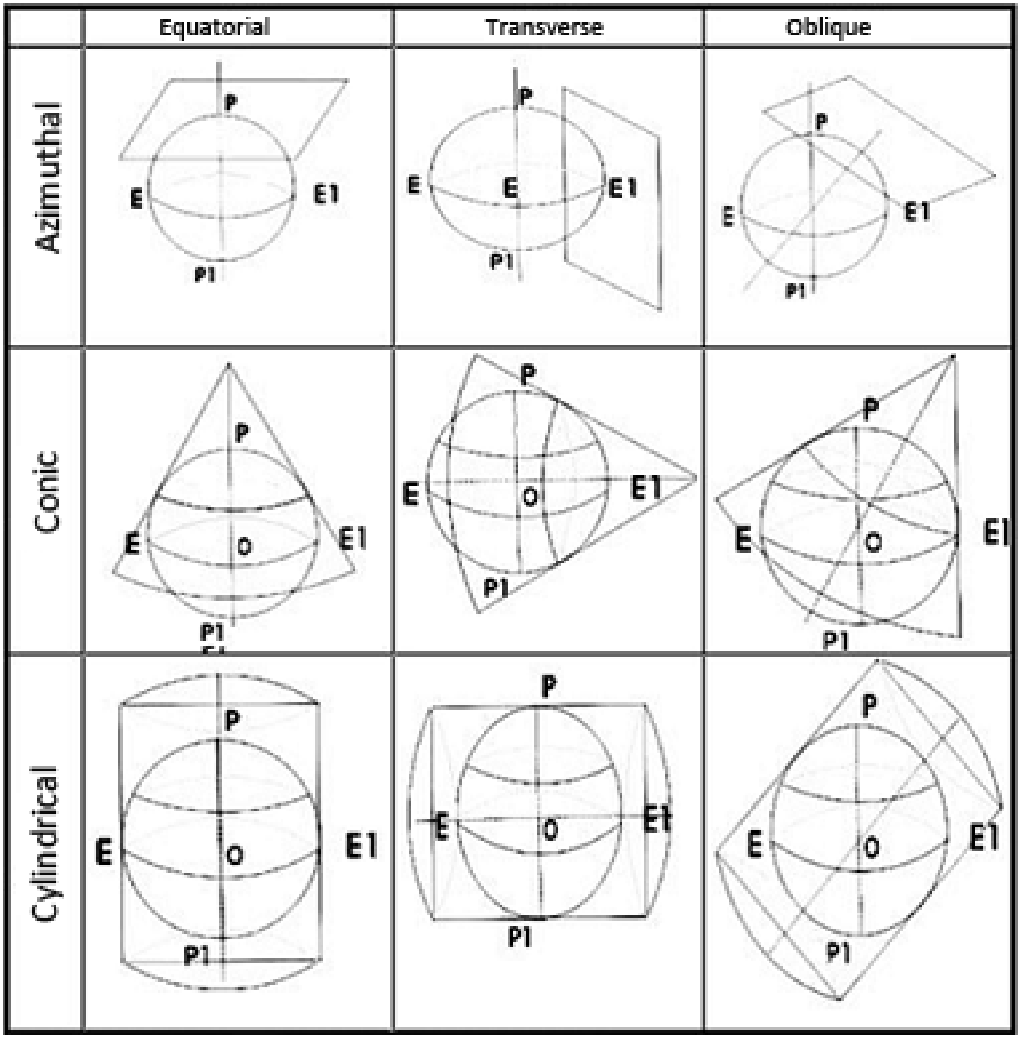

Diagram 3 Geometric Projection Illustration

Azimuthal Projection: first, take a plane as the projected geometric surface that is tangency or secant with the ellipsoid surface, and then project the latitude-longitude net to the plane. There is no distortion on the tangency point or secant line. The farther place away from the tangency point and secant line, the more distortion will be obtained.

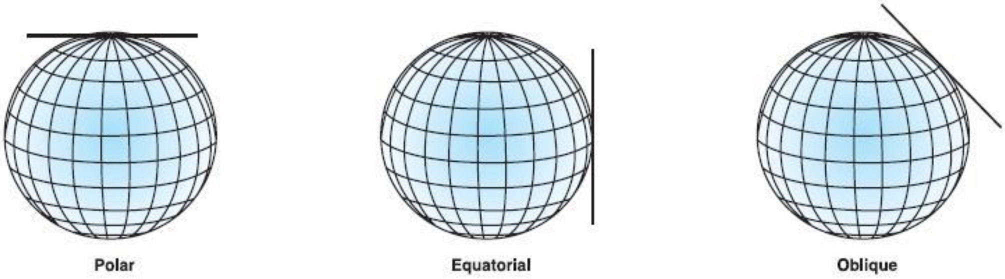

Diagram 4 normal axis, transverse axis, oblique axis (quoting from National Atlas)

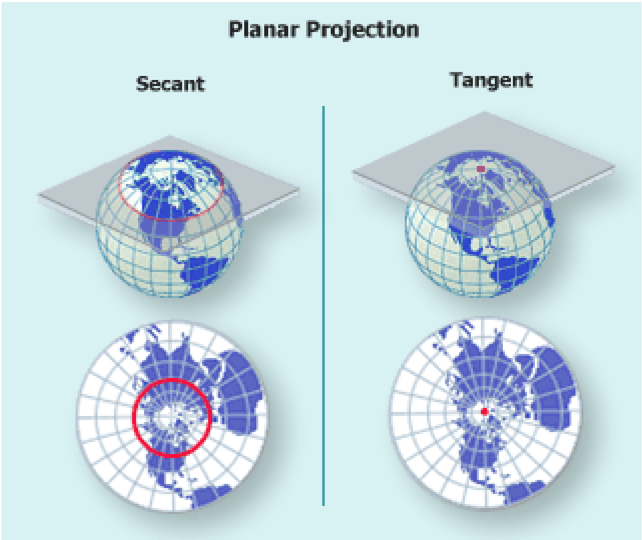

Diagram 5 The tangency or secant between a plane and ellipsoid (quoting from National Atlas)

Conic Projection: take a cone as the projected geometric surface. It is tangency or secant with the ellipsoid surface, projecting the latitude-longitude net to the cone surface. This method is suitable for the middle latitude zones that are extending along the dimensional lines. This method is widely used in China.

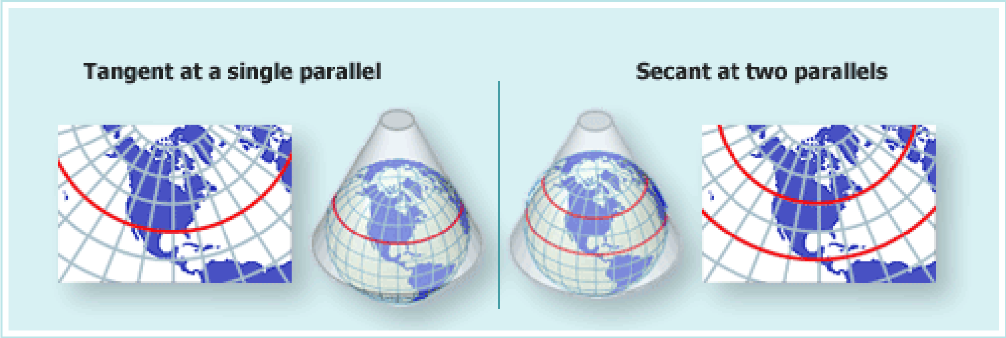

Diagram 6 The Tangency or Secant between orthoaxis and cone (quoting from National Atlas)

Cylindrical Projection: take the cylinder as the projected geometric surface. It is tangency or secant with the ellipsoid surface, projecting the latitude-longitude net to the cylinder surface. Cylindrical projection is suitable for mapping the area around the equator and the world map.

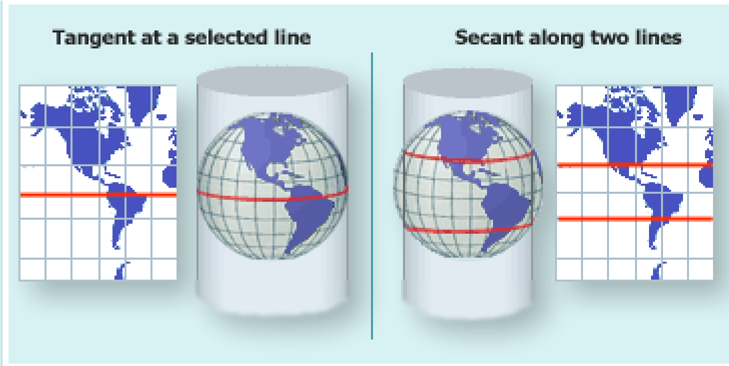

Diagram 7 Tangency or secant between orthoaxis and cylinder (quoting from National Atlas)

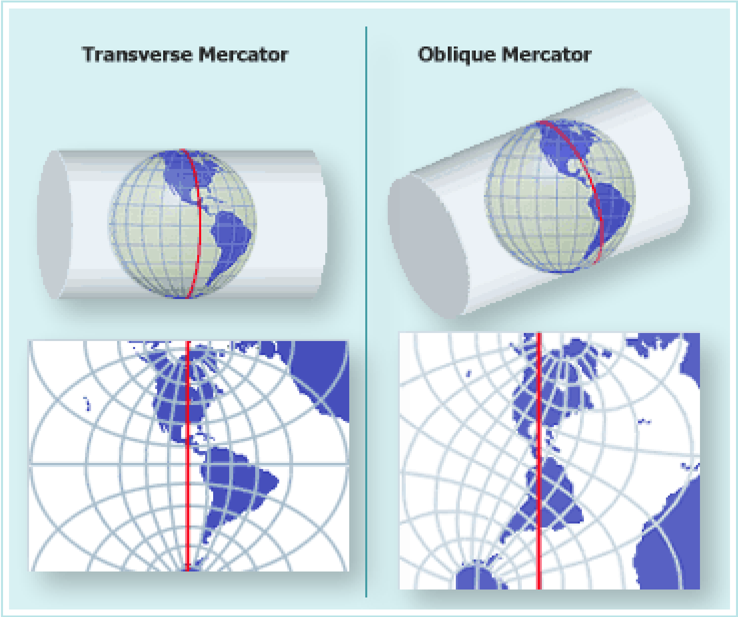

Diagram 8 Tangency between orthoaxis or oblique axis and cylinder (quoting from National Atlas)

4.3.2.2 Analytical Projection

Analytical Projection does not use any geometric surface, but only depends on some analytical methods to obtain the latitude-longitude net, which includes pseudo-conic projection, pseudo-cylindrical projection, pseudo-azimuthal projection, and polyconical projection.

Pseudo-azimuthal Projection is based on azimuthal projection. With the orthoaxis, latitude lines are concentric circles. However, all the longitudes are curves symmetric to the central meridian which is the only straight line, and intersected at the common circle center of the latitudes.

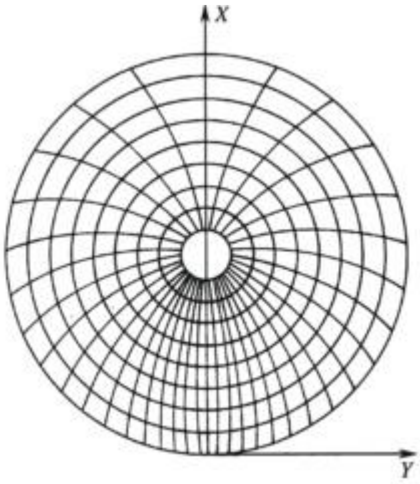

Diagram 9 The latitude-longitude net of the pseudo-azimuthal projection (quoting from internet)

Pseudo-cylindrical projection is on the basis of cylindrical projection. On the normal cylindrical projection basis, the latitude lines are parallel to each other. Except the central meridian keeps as a straight line, other longitude lines should be symmetric to the central meridian.

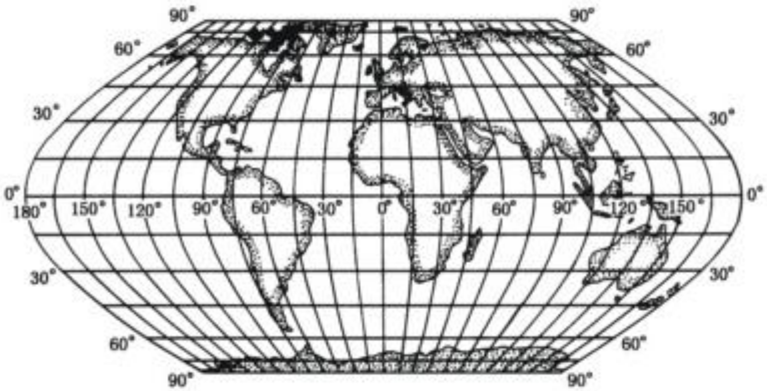

Diagram 10 The latitude-longitude net of the pseudo--cylindrical projection

Pseudo-conical projection is on the basis of conic projection. Like the normal conic projection, the latitude lines should be the concentric arcs. Except the central meridian keeps as a straight line, other longitude lines are symmetric curves to the central meridian.

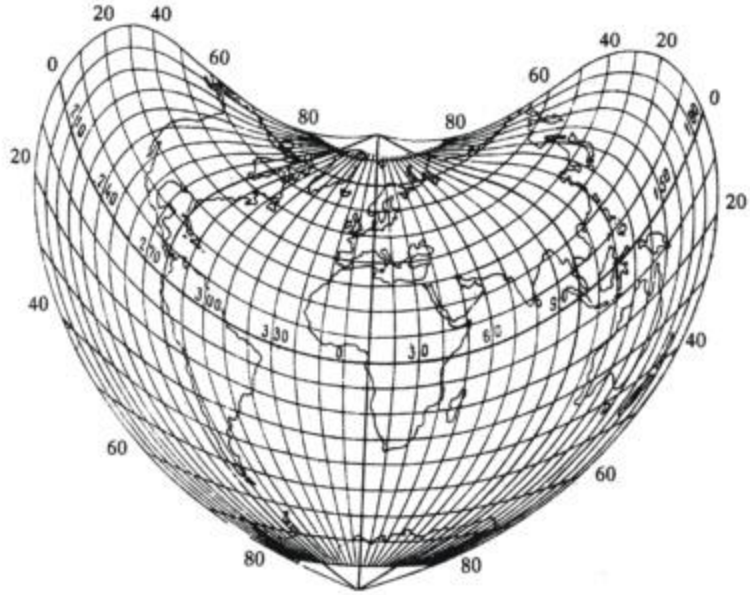

Diagram 11 The latitude-longitude net of the Pseudo-conical projection (quoting from internet)

Polyconical projection depends on an imagination that multiple cones are tangency with the ellipsoid to obtain a projection. All the latitude lines are coaxial arcs, whose circle center is on the central meridian which is a straight line. Other longitude lines are symmetric curves to the central meridian.

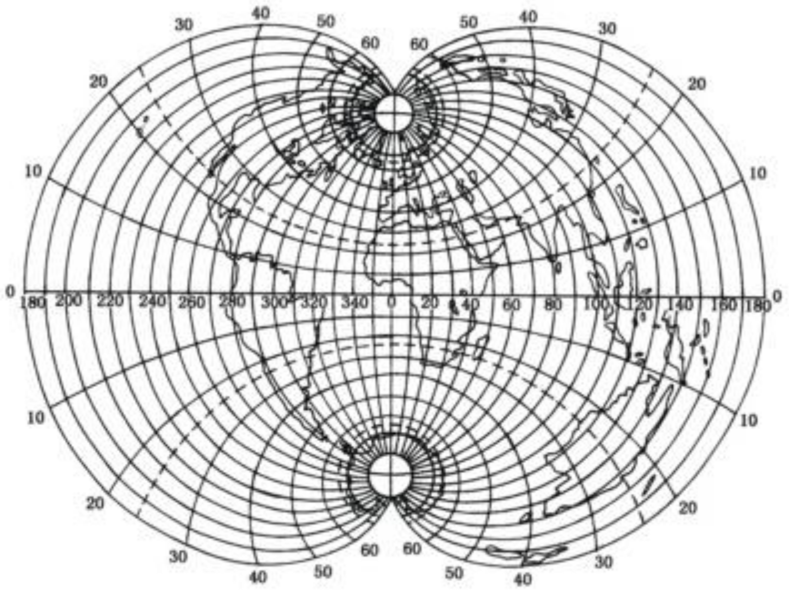

Diagram 12 The latitude-longitude net of the polyconical projection

4.4 Frequently Used Map Projection

There are several projection methods which are currently frequently used, including Mercator projection (Normal cylindrical conformal projection), Gauss-Kruger projection (Transverse tangent cylindrical conformal projection), UTM projection (Transverse secant cylindrical conformal projection), Lambert projection (Secant cone conformal projection).

4.4.1 Mercator Projection

Mercator projection is a "tangent cylindrical conformal projection", created by Chartist Gerhardus Mercator(1512 - 1594) from Netherland in 1569. This method works like there is a light inside the virtual earth which is put inside a cylindrical surface. The inside light projects the maps on the earth onto the cylinder surface. With the projected map, we unfold the cylinder, here is the Mercator projection.

On the map projected by Mercator projection, there is no angle distortion, as the length ratio between lines starting from one point to any direction is the same. The latitude and longitude lines are parallel, and cross each other by right angle. The intervals between the longitude lines are equal. However, the intervals between the latitude lines become more wide one by one from the standard latitude line. The distortion of length and square dimension are obvious, and the distortion degree will gain momentum to the polar direction. The standard latitude line is the only thing has no distortion. Since the distortion is evenly to any direction, the relationship between direction and relative positions are the same with the real phenomena.

Since Mercator correctly offered the angles and direction information, it is widely used in sailing and aviation. If we go along with a straight line between two points on the Mercator projection, it is the desired destination we will arrive. Therefore, it is extremely useful to make sure the sailing direction and position for the navigation.

4.4.2 Gauss-Kruger Projection

Gauss-Kruger projection is a Transverse tangent cylindrical conformal projection, which was first created by Carl Friedrich Gauss (1777-1855), a mathematician, physicist, and astronomer from Germany around 1820. Later, the projection formulas were enriched by Geodesist Johannes Kruger (1857-1928) in 1912. That's how its name comes. This method works like using a cylinder to be transverse tangency with the central meridian. The projection principle at here is keeping the projected central meridian as a straight line with the same length, and the equator line as a straight line. Projecting the two parts divided by the central meridian within certain scope of longitude degree to the cylinder surface by conformal projection. At last, cut the cylinder surface alone the bus line that is past polar to unfold the projection map, which is the Gauss-Kruger Projection plane.

On the Gauss-Kruger Projection plane, except the central meridian and the equator line keep as a straight line, other longitude lines are symmetric arcs to the central meridian. Furthermore, there is no angle distortion, little length and square dimension distortion, and the central meridian is the same as it is. The distortion gains momentum from the central meridian to the borders, therefore, the two equator end points has the highest distortion. Since its high precise, low distortion degree, and easy to calculate (the coordinate system are the same for all the projected zone, so we just need to work out data in one zone which could be used in all other zones), it is popular in mapping large scale terrain maps which are necessary to a variety of military application. Additionally, it offers the precise measurement of distance.

In Gauss-Kruger Projection, the earth ellipsoid is divided into zones according to certain longitude value scope, which contains the length distortion effectively. In order to control the length distortion within the measurement error, and to contain the number of the zones to decrease the calculation times. As a result, the earth ellipsoid is divided into equal size of melon-shaped zones from the prime meridian to do the zone projection. Usually, there are two kinds of dividing zones: the Six Degree Zone and the Three Degree Zone. The Six Degree Zone means dividing from the west to the east, starting at the 0 degree meridian with a 6 degree interval. The number of the divided zones is 1, 2...60. The Three Degree Zone is carried on the basis of the Six Degree Zone. With the same central meridian and sub zone's central meridian, it divides from the west to the east, starting at the 1.5 degree meridian. The number of the divided zones is 1, 2 ...120.

4.4.3 UTM Projection

UTM Projection, short for universal transverse Mercator projection, which is a transverse secant cylindrical conformal projection. An elliptical cylinder is secant with the earth at southern latitude 80 degree and northern latitude 84 degree. There is no distortion on the two secant longitude lines, while the ratio of the central longitude is 0.9996. UTM projection system is created for the war time, whose calculation is finished by American in 1946. UTM projection has no angle distortion, similar with the Gauss-Kruger Projection, and a straight central meridian line as the symmetric axis. The ratio of 0.9996 can make sure there are two lossless longitude lines symmetric to the central meridian with 330m respectively.

UTM Projection is a Six Degree Zone method.

4.4.4 Lambert Projection

Lambert Projection, also named Secant Cone conformal projection, was created by Mathematician J.h.Lambert in 1772. It works like using a regular cone to be tangent or secant the earth ellipsoid surface, which is projected to the cone surface by conformal angles. Finally, cutting the cone alone a bus line to unfold it, the Lambert projection is produced, on which the latitude lines are concentric circles, and the longitude lines are their radii.

Lambert Projection using secant method to obtain double standard latitude lines, rather than tangency approach to get single standard latitude lines; therefore, the distortion is less and evenly. The distribution patterns of the distortion caused by Lambert Projection are:

Lossless angle distortion: the projected differential area keeps similar with the original one. As a result, it is also named conformal projection.

The distortion on each latitude line is the same to any sections.

The two standard lines have no distortion.

To each longitude, the part outside the two latitude lines is positive deformation (length ratio is larger than 1), and the part between the lines are negative deformation (length ratio is less than 1). As a result, the absolute value of deformation is smaller and evenly distributed.

Equal longitude interval values will give equal latitude line length. The latitude lines or longitude lines between any two parallels are kept in the same length.

4.5 Map Projection Conversion

In map projection conversion, the coordinates for every point of the map will be changed; furthermore, if the geographic coordinates between the two projection approaches are different, we have to convert the reference system also.

Each projection method causes the projection deformation, therefore, the conversion between projection methods are not completely reversible. That is to say, you may convert a map from its current projection into another projection pattern; however, you probably cannot transform it back in a totally original result. Hence, it is recommended to backup the original file before your conversion process. Moreover, the conversion times should be as few as possible to secure the precise result.

Each projection is designed to deal with a kind of specific region with the least distortion. As a result, you'd better convert the map within the adjacent coordinates scope, otherwise, the conversion result will display a greatly distortion map. For instance, when converting a world map projected by Mercator projection into the Gauss projection pattern, the areas around the central meridian is accurate; while the far areas away it illustrate large distortion.

How to convert the reference system?

There are six methods are usually employed to convert between projection methods: Geocentric Transalation, Molodensky, Abridged Molodensky, Position Vector, Coordinate Frame, Bursa-wolf. The following paragraphs are the detail introductions.

The datum applied by a country or region is the development result of history. Usually, there were many reference ellipsoid and position approaches used across the history, with more perfect and accurate shape. Most of the Datum used by many countries takes their individual ellipse-centered rectangular coordinate systems, which are different from the geocentric rectangular coordinate system unified globally. Therefore, the conversion requirements between these datum coordinate systems are frequently

A simple method for reference system conversion is Geocentric Translation. Based on mathematic model which only considers the spatial origin from one datum as translation to the other origin's position, the Geocentric Translation does not involve other factors. Please look at the left diagram below. This method is mostly used in conversions between different geocentric spatial rectangular coordinate systems, as the simple calculation method and the lower accurate result.

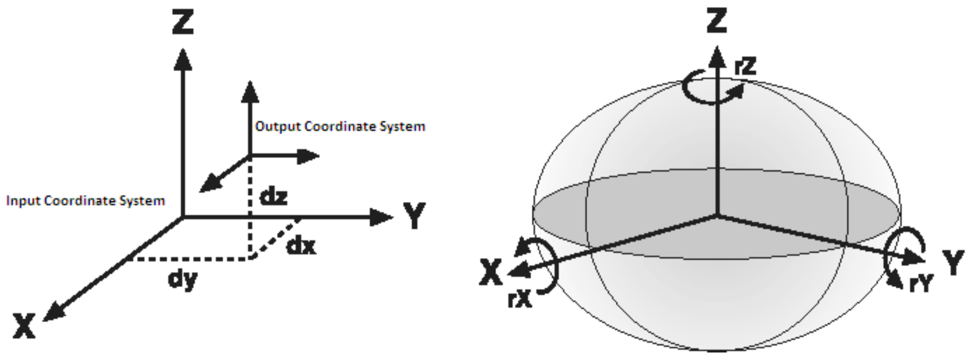

Diagram 13 Geocentric Translation

The seven-parameter produces map with more complicated procedure and higher accuracy. The mathematic model involves coordinate system's translation, rotation, and various scales. As a result, there are another three rotate parameters and a scale parameter, besides the three translation parameters. The above right diagram displays its conversion principle.

Molodensky converts different reference coordinate systems directly without the spatial rectangular coordinate system. There is another Abridged Molodensky approach provides a more simple calculation.

The accuracy of the stated three conversion approaches is not high. Three translation converted parameters are required by the Geocentric Translation, (ΔX, ΔY, ΔZ), which are also necessary in the other two methods.

Position Vector, Coordinate Frame, Brrsa-Wolf are methods with higher accuracy. There are seven parameters involved to adjust and convert, three translation parameters (ΔX, ΔY, ΔZ), three rotate parameters (rx, ry, rz), and a ration parameter (s). Actually, they are the same method with the different names from different countries.

In practical, which conversion approach is applied depends on the specific situation. Moreover, if you can obtain satisfied result depends on the setting of parameters. You may refer to the official measurement institutions or data provider to get the proper parameters. Alternatively, you can calculate the parameters according to your personal measurements. The control points should be located in both reference systems.

5

Map Projection

The projection will affect the map's accuracy and practical value. Any projection method will cause distortion, but they build different altitude-longitude net with different distortion regulations and distribution. It is recommended to use the projection with as less deformation as possible. We should take consideration of the region scope, shape and geographic position, and the appication purpose when choosing map projections.

5.1 Factors in Map Projection Choice

5.1.1 The factors of mapping region scale, shape and location

Map deformation is relative with the mapping region scale, with larger region area more complicated projection involved. To the very small area, the deformation will be very little by using any projection approach. For instance, Xinjiang Uygur Autonomous Region is the largest autonomous region in China; however, it is "small" in a world map. Therefore, no matter which projection method used to project it, the result is acceptable. However, like world map, hemisphere map, continent map, and ocean map, which cover large scale of terrain, their projection methods will play decisive role in the deformation. As a result, the projection procedure for them becomes complicated as there are many projection schemes should be considered. Usually, the scale of the map is determined by the largest deformation value in accordance with the projection. The rule is: an area within 5 to 6 million square kilometers, with a length deformation of 0.5%, is considered as "Not Large"; an area within 35 to 40 million square kilometers, with a length deformation of 2-3%, is taken as "Median"; an area, with a length deformation larger than 3% in the projection, is considered as "Large".

To project a world map, the Mercator projection is usually employed to map the world navigation map, world transport map, and world time zone map. Meanwhile they are sometimes projected by arbitrary cylindrical projection.

Besides the region scale, the area shape and location can also direct us which projection method should be used. It is recommended to keep the distortion isograms with the similar outlines of the area. The shapes of the distortion isograms of Azimuth Projection are the circles-centered projection center. It is obvious that this approach is suitable to display the zones with circle outlines. The areas around the polar usually apply the normal azimuth projection; the areas centered the equator the abscissa azimuth projection; the regions of mid-latitude the oblique-axis azimuth projection. In the case a mid-latitude area covers a long region from the east to the west direction, the normal conic projection should be used. For instance, China, America, etc. While for the Indonesia located near the equator extending from the east to the west, the normal cylindrical projection should be employed. For the areas stretching from the south to the north, the transverse cylindrical projection and polyconical projection should be used. For instance, Argentina, and Chile. Finally, for the irregular areas stretching to arbitrary directions, the oblique-axis cylindrical projection should be used.

5.1.2 Map Application

The applications for the map is also a factor for us to select a projection method. The administrative division map, population density map and economy map require high precision degree; therefore, the equal-area projection is the best choice. However, the equal-angle projection will display correct directions for nautical chart, aerial route map, weather diagram, military topographic map, providing similar terrain shape in a small area. The maps used in teaching, publicity are projected by arbitrary projection.

Some maps with special purposes should select a specific projection method. For instance, the time zone map requires the latitude lines and longitude lines be parallel respectively; therefore, it is the normal cylinder projection that should be applied.

5.2 The Choice of Map Projection

According to the scale of regions, the map projection methods are listed as below:

The projection of the world map: make sure the outline of the global outline has little distortion, projecting by polyconical projection and pseudocylindric arbitrary projection and so on.

The projection of hemisphere map: the eastern hemisphere and western hemisphere apply conformal projection; while the south hemisphere and north hemisphere usually employ conformal projection and azimuthal equidistant projection.

The projection of continents: the oblique azimuthal equal area projection is used to project many continents. But Asia and the north America are projected by Bonne projection; the Europe and the Oceania map are produced by the normal equal-conic projection; the south America map by Sanson projection.

6

Map Projections of SuperMap Objects Java

6.1 Coordinates System in SuperMap Objects Java

In SuperMap GIS, there are three types of coordinate systems: the plane coordinate system, latitude-longitude coordinate system, and projected coordinate system.

6.1.1 Plane coordinate system

Usually it is used to display data without geographic information, for instance, the image scanned from the paper maps, CAD design map, and the default coordinate system for new created data. Plane coordinate system is a two-dimensional coordinate system, with origin at (0, 0). Each point can be located by their coordinates with the vertical distance to the X axis and the horizontal distance to the Y axis.

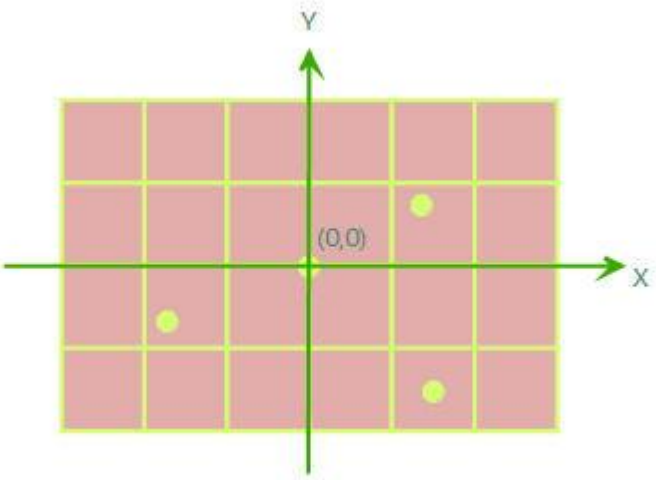

Diagram 14 A Plane coordinate System

6.1.2 Latitude-longitude coordinate system

Mark the position of a point on the ellipsoid by the latitude and longitude degree. A latitude-longitude coordinate system contains the definitions of datum, central meridian and angle unit. The frequently used geographic coordinate system includes WG884, Beijing1954, and Clarke 1866 and so on. For instance, the KML data on the Google Earth and the acquired data from the GPS apply the WGS84 coordinate system are all based on WGS84. The control points acquired by geodetic survey is on the basic of Xi'an80 or Beijing1954. The diagram is a world map based on the WGS84 coordinate system.

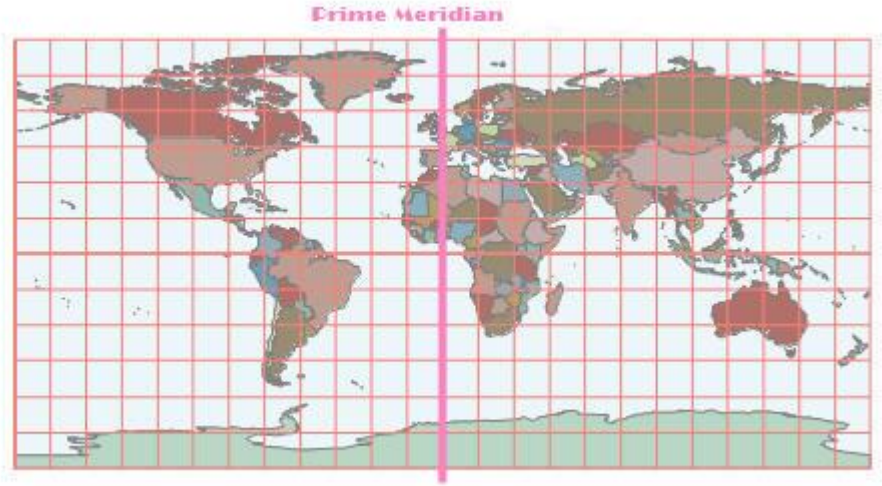

Diagram 15 A World Map on the WGS84 Coordinate System

6.1.3 Projection Coordinate System

Project any point on the ellipsoid on a plane by a projection method and projection type, and illustrate the phenomena like points, lines, and regions on the earth by a two-dimensional plane coordinates (X, Y). In a projection coordinate system, the definitions of geographic coordinate system, map projection, projection parameters and distance unit are declared. The frequently used projection coordinate system includes UTM, Gauss-Kruger, Albers, Mercator and so on. Usually, the projected geographic data can be used to measurement calculation, a variety of spatial analyses, mapping expression and so on. For instance, the terrain map recorded by a scale of 1: 1 million usually applies the Albers projection. Other maps use the Six Degree Zone or the Three Degree Zone of the Gauss-Kruger. In the large scale map, for instance, the road construction map recorded by a scale 1: 500, and 1: 1000 apply plane coordinate system. The diagram below is a world map on the WGS84 coordinate system projected by Robinson.

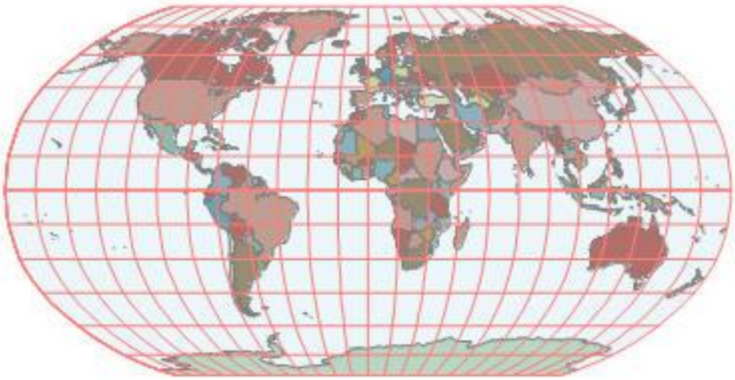

Diagram 16 A world map on the WGS84 coordinate system projected by Robinson projection

6.2 Projection System in SuperMap Objects Java

6.2.1 Projection System

Projection coordinate system is mainly used in two aspects. First, to define a coordinate system that reflects the input data's meaning. Second, to transfer data between various coordinate systems. Since the spatial data has a wide collection source, we usually have to do some transformation work to correctly display or store them in the database. Projection systems offered by SuperMap Objects Java includes some predefined coordinate systems, as well as customized coordinate systems.

6.2.2 Data Model

Map projection systems in the SuperMap Objects Java apply the model in the below diagram, with simplified models contributed to the coordinate system.

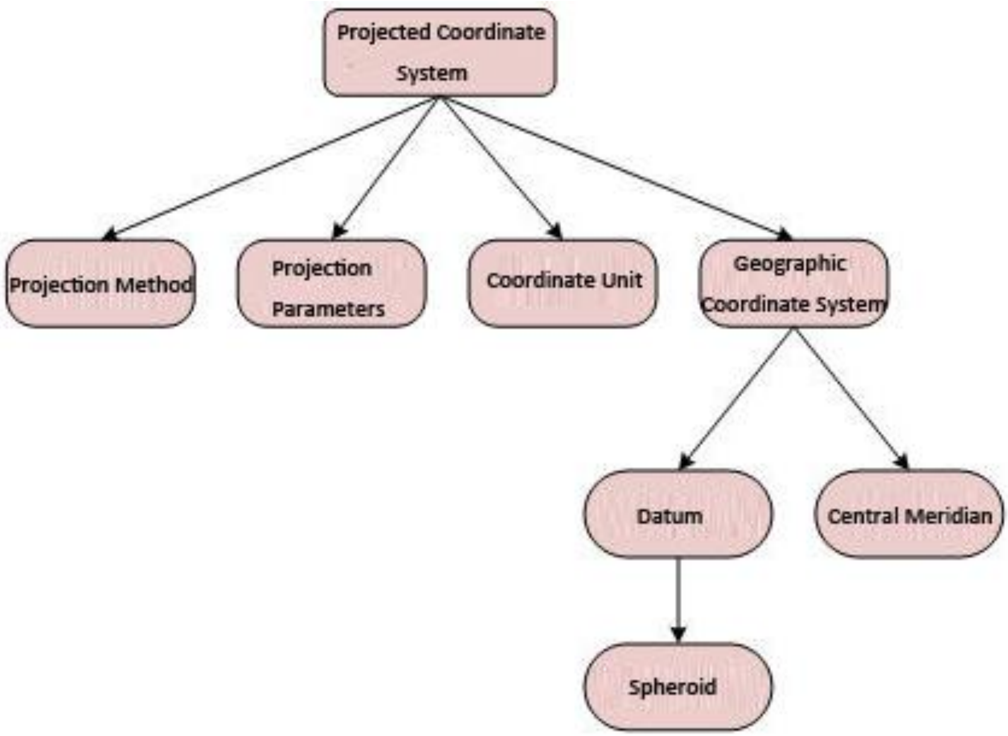

Diagram 17 Projected data model

Correspondent with the stated data model, SuperMap Objects Java encapsulates a series programmable objects. Users are able to control the program. The relationship and structure of the projection objects are showed in the below diagram.

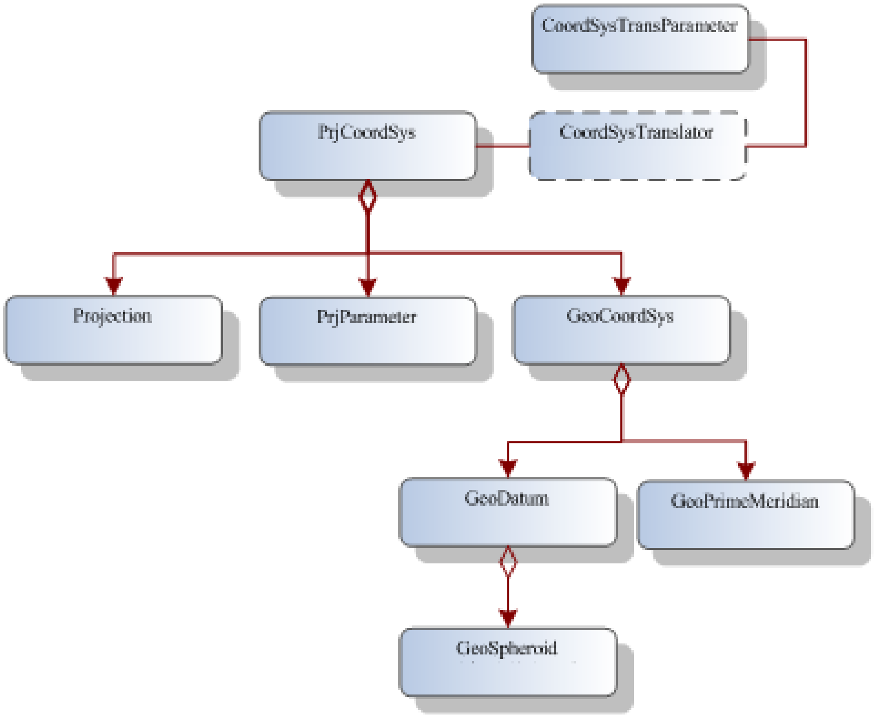

Diagram 18 The relationship and structure of the projection objects

6.2.3 Map Projection Functions of SuperMap Objects Java

The most commonly used basic projection types, both from domestic and abroad, are included in the subsystem of SuperMap Deskpro, which can transform from geographic coordinates into projection coordinates on a plane, according to certain projection scheme, as well as the functional interface obtained by the inverse calculation. Consequently, users can make full use of the existing data resources of various coordinate systems.

Currently, SuperMap Objects Java offers 30 projection types to users. For their detail deformation characters, features, usage scope, please refer to the related books:

- Conformal conic projection
- Equidistant conic projection
- Equivalent cylindrical projection
- Conformal azimuthal projection (spherical projection)
- Equidistant aimuthal projection (Postel Projection)
- Equivalent azimuthal projection (Lambert Projection)
- Orthographic projection
- Gnomonic projection
- Equidistant Gnomonic projection
- Equidistant Orthographic projection
- Normal cylindrical equidistant projection
- Normal cylindrical conformal projection (Mercator)
- Normal cylindrical equivalent projection
- Transverse tangency cylindrical conformal projection
- Transverse tangency cylindrical equidistant projection
- Transverse tangency cylindrical equivalent projection
- Gauss - Kruger Projection
- Universal Transverse Mercator (UTM)
- Equivalent Pseudo-conic projection (Bonne Projection)
- Sanson projection

- Eckert VI Equal-Area
- Mollweide projection
- Eckert elliptic projection
- Ordinary Polyconical projection (USA Polyconical Projection)
- Tangent Difference Latitude polyconical projection (China 1976 Scheme)
- ...

6.2.4 Projection Information Documents of SuperMap Objects Java

SuperMap projection information documents record the projection coordinate systems, geographic coordinate systems, earth ellipsoid, the prime meridian, and map projection information. The file format consists of six parts.

File name: PrjConfig.xml

Route: setup direction\Bin\ PrjConfig.xml

```
+ <sml:PrjCoordSystems>
+ <sml:GeoCoordSystems>
+ <sml:HorizontalDatums>
+ <sml:Spheroids>
+ <sml:PrimeMeridians>
+ <sml:Projections>
```

Diagram 19 Projection File Format

Each part has its own configuration. Projection coordinate system requires name, type, projection coordinate unit, distance unit, projection method, geographic coordinate system, as well as some projection parameters. Geographic coordinate system requires to set its name, type, and coordinate system unit, distance unit, Datum, and prime meridian. The Datum has to set its name, type and its earth ellipsoid. The earth ellipsoid also requires the name, type, the long-radius and flattening. Prime meridian should have its name, type and the central longitude value. Map projection information needs the name and type of the projection.

Note: All the stated configurations involve "Type" settings. Type is a group of values, which is like a mark of the current settings. For instance, in the projection coordinate system configuration, the geographic coordinate system will usually be employed. Take the configuration as <sml: GeoCoordType>4326</ sml: GeoCoordType >, it indicates that the "Type" of the geographic coordinate system used by the current projection coordinate system is the one numbered 4326.

The "Type" of the customized projection coordinate system, geographic coordinate system, horizontal reference, ellipsoid, central meridian, should be -1. The diagram below is an instance of customized projection coordinate system.

```
- <sml:PrjCoordSystems>
  - <sml:ProjectionCoordinateSystem>
      <sml:Name>User-defined Projection </sml:Name>
      <sml:Type>-1</sml:Type>
      <sml:Units>METER</sml:Units>
      <sml:DistUnits>METER</sml:DistUnits>
      <sml:GeoCoordType>4326</sml:GeoCoordType>
      <sml:ProjectionType>43001</sml:ProjectionType>
    - <sml:Parameters>
        <sml:FalseEasting>0</sml:FalseEasting>
        <sml:FalseNorthing>0</sml:FalseNorthing>
        <sml:CentralMeridian>0</sml:CentralMeridian>
        <sml:StandardParallel1>0</sml:StandardParallel1>
        <sml:StandardParallel2>0</sml:StandardParallel2>
        <sml:ScaleFactor>1</sml:ScaleFactor>
        <sml:CentralParallel>0</sml:CentralParallel>
        <sml:Azimuth>0</sml:Azimuth>
        <sml:FirstPointLongitude>0</sml:FirstPointLongitude>
        <sml:SecondPointLongitude>0</sml:SecondPointLongitude>
      </sml:Parameters>
    </sml:ProjectionCoordinateSystem>
```

Diagram 20 Customized projection coordinate system

6.2.5 Classes Related to Map Projections of the SuperMap Objects Java

There is a series of programmable objects offered by SuperMap Objects Java to achieve the functions of map projection. The structure of the map projection function objects are as follows:

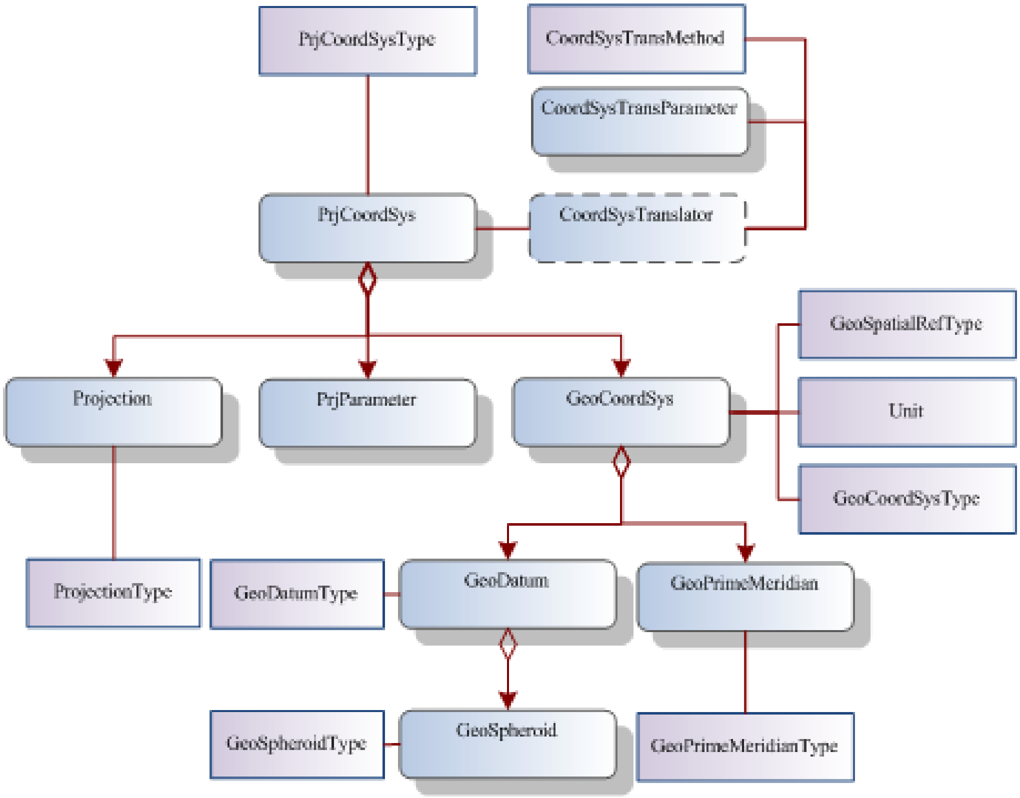

Diagram 21 Structure of the map projection function objects

The classes in lavender are enumeration classes related to map projection:

GeoCoordSysType

Enumeration class of Geographic coordinate system

GeoSpatialRefType

Enumeration class of spatial coordinate system is used to distinguish the enumeration constants from plane coordinate system, latitude-longitude coordinate system, and projected coordinate system.

GeoPrimeMeridianType

Enumeration class of the central meridian.

Enumeration class of the Datum is used to describe the long radius and the flattening of the earth.

GeoSpheroidType

Enumeration class of the earth ellipsoid.

PrjCoordSysType

Enumeration class of projected coordinate systems.

ProjectionType

Enumeration class of map projection methods

CoordSysTransMethod

Enumeration class of projection conversion approaches.

Unit

Define various unit constants.

The classes in light blue are referred by map projection:

GeoCoordSys

Geographic coordinate system consists of the Datum, the central meridian, coordinate unit which could be degree, minute, and second. The scale of the east-west (horizontal) directions is from -180 degree to 180 degree; while the north-south (vertical) directions is from -90 degree to 90 degree. The geographic coordinate system is a spherical surface coordinate system displaying terrain by latitude and longitude degree.

GeoPrimeMeridian

Central meridian class is mainly used in geographic coordinate system, which consists of the central meridian, reference system or Datum, and the angle unit.

GeoDatum

Datum class includes earth ellipsoid parameters. Since the earth ellipsoid is only able to illustrate the size and shape of the earth, we need the Datum to describe the precise position of phenomena on the earth. The Datum gives us the relative position of the earth ellipsoid to the earth geocentric, offering a reference framework for measurement on the earth surface. Meanwhile, the zero point and direction of the latitude-longitude net is settled down, which are the position and direction of the ellipses. Datum takes the spherical center of the earth ellipsoid as the origin. The ellipsoid of a datum for a district cannot take the true geocenter as its geocenter. In order to display the earth surface's features of the district, the coordinates system of the earth surface is created referring to the spherical center of the ellipsoid. The current widely used datum is WGS84, which is taken as the basic framework of the datum. Every country or district has different datum, as one datum cannot applied to all the places.

GeoSpheroid

Earth ellipsoid parameters class describes the long-radius and the flattening of the earth. we usually use the spheroid to describe the shape of the earth. Sometimes, it is considered as a sphere for calculation convenient. However, in most time it is taken as a spheroid. Usually, when the scale is lower than 1:1,000,000, the earth is considered as a sphere, as the difference between a sphere and a spheroid cannot be tell in this case. However, when the scale is higher than 1:1,000,000, we use the spheroid as the earth shape. The spheroid is on the basis of ellipse, which displays the earth by two axes, the major axis (equatorial radius) and the minor axis (polar radius).

The results produced by one projection method, the same data, and different ellipsoid parameters are significantly different. Hence, it is very important to apply suitable ellipsoid parameters. The earth ellipsoid parameters employed by countries across the history are different. China uses Krasovschi ellipsoid parameters, and the North America continent, Britain and France used Clark ellipsoid parameters.

PrjParameter

Map projection parameters class includes map projection parameters, for instance, the central meridian, origin latitude, the first and second latitude lines of the double standard parallels. For the detail information, please refer to the Programmer Reference of online help document.

Projection

Map projection class offers methods converting the earth coordinate system into plane coordinate system. Generally speaking, map projection methods could be classed by their distortion characters, including conformal projection, equidistant projection, and equivalent projection. In practice, the conformal projection is suitable in navigation map. There is an arbitrary projection has distortions on the stated aspects, which is widely used in teaching and reference. According to map projection's constitution, it may be grouped as geometric projection and non-geometric projection. Geometric projection projects the latitude-longitude net to the geometric surface, unfolding the geometric surface to obtain a plane. The azimuthal projection, cylinder projection, and cone projection are all geometric projection. None-geometric projection depends on mathematical analysis method to confirm the function relationship between points on the spherical surface and plane, including azimuthal projection, Pseudo-cylindrical projection, Pseudo-conic projection, and polyconical projection.

CoordSysTranslator

Map projection conversion class. The conversion from geography coordinate system to projected coordinate system applies "forward" method; from projected coordinate system to geography coordinate system uses "inverse" method; the conversion between them employs "convert" method

CoordSysTransParameter

Coordinate system conversion parameters class, including translation, rotation of parameters, and scale zoom factor. If the source projection has different geographic coordinate system with the converted one, you have to transform the coordinate system by methods like Geocentric Translation, seven parameters. All the parameters used in the transformation will be provided by this class.