One New Viewpoint Of The Projection In The Distributed Map Resources

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[Abstract]:
With the Internet has spread quickly in 20th century, all kinds of map resources are threw on the Internet. All kinds of projections are used in these resources. These phenomena urge the need in building distributed system for the speed and integrality in the intercommunion of the projections between the different systems. The old science, projection, is owning a new chance to evolve itself in new century.

In traditionally, the projection is a topological transformation between the 2-D surface of ellipse and the plane space. All the functions of maps on the view, measure, and calculate, are based on only one kind of the projection space in one printed map or an ordinary GI application. The fix space, in which the coordinates be viewed, measured and calculated, is often on a same projection space. Now, with research of many years, authors put forward a new viewpoint to separate them into different projection spaces in one map application. It's very useful in the integration of all kinds of map resources on the large geographic information systems through the Internet/Intranet.

First, the paper simply reviews the history of the development of projection, then analyses the influence to the projection from the new technology of the computer and Internet, and describes the need from integrating the distributed map resources.

Second, the paper explains the viewpoint about the multi-layer projection system existed in one net map application. In the different segments about storage, index, analyze, view and print, the projection cluster can be separated into multi-layer and used many kinds of projections for different purpose. It can improve the speed of view and calculation in a map application, and can easily integrate many map resources into a large-scale GIS through the Internet/Intranet, with the help of the new distributed technology, such as Component, Agent and Ontology.

Third, authors give some examples about actual applications to illustrate the good qualities from this concept.

[Keywords]: GIS, Projection, Transform, Mathematical Resource

Introduction:

The development of the technology of computer and Internet has greatly pushed the GIS forward. But, with the booming of GIS, many problems have appeared. All kinds of map resources with different kinds of projections are used to build GIS. This caused great inconvenience to intercommunication. Lots of experts are marching for the "Standard spatial mathematical base". In this article, we will cast our viewpoint on it.

Chapter Ⅰ. Dilemma of map-projection in GIS

When the problem that how to express the spatial information came to the human beings long time age, map projection was on its way. As the time went on, mathematics had been bringing it forward. The more people knew, the better they expressed the world. So many kinds of map projections were used for different purposes: Mercator projection for oceanic map, conic orthomorphic projection to keep the angle, azimuthal equal-area projection to eliminate the distortion of area, cylindrical equidistant projection for area near the equator, etc. Each of them plays an important role.

Viewing the history of the map, we can find that many kinds of map projections were used for different purposes. Each of them has its advantages and disadvantages. They compose the rich and colorful map world and bring us much convenience.

However, with the development of computer technology, the situation has been changing. Computer provides a new way of managing geographical information, and this comes into the field of GIS. It works in a convenient and efficient way. The Internet has been booming with the computer technology, letting people all over the world share the available information. The diversity of map projection results in lots of discommodiousness.

It's known that most GIS systems these days are using maps as data source. So the map projection works as the mathematical reference for GIS. That is to get the coordinates from the formula as follows:

$$X=f1(\phi、\lambda)$$
$$Y=f2(\phi、\lambda)$$

ϕ the longitude, λ the latitude, f1, f2 the function for transform
X, Y plane coordinates of the point

Through reverse-transform, we get the longitude and latitude from the X,Y coordinates:

$$\Phi = f3(X, Y)$$
$$\lambda = f4(X, Y)$$

ϕ the longitude, λ the latitude, f3, f4 the function for transform
X, Y plane coordinates of the point

Generally speaking, map projection transform with analytic formula has its theoretical accuracy and conceptual strictness. But it only exists in the theoretical maps or spatial databases since there is distortion in the actual maps or images, and it wouldn't match the analytic formula. So there are four kinds of inter-transform:

1. **Transform between the maps with different analytic formulas;**
2. **Transform from the actual maps to the maps with analytic formulas;**
3. **Transform from the maps with analytic formulas to actual maps;**
4. **Transform between actual maps;**

The most important virtue of the Internet is the share of information. However, if we use original map projection to build GIS and the map resource, how can people with the different needs make use of these system and resource? Let alone the share in the Internet for GIS and resource.

So, with the booming of GIS and Internet, the variety of map projection results in so many problems. The difference among maps with different projections makes it difficult or even impossible to transplant data from one platform to another. Because of the four kinds of transforms just above, plenty of work has to be done to accomplish these transforms. Usually it will reach n^2 level in number of the exchange each other and it is really a great waste of labor and fee. It is the same in measuring calculating.

How can we use the maps with different projection on the same platform? What shall we do to share the spatial information through Internet? Can we find the better *projection* to most the GIS platforms? This paper comes up with our opinion.

Chapter Ⅱ. Important virtues needed for large GIS

There are various data sources in large GIS and digital earth, and their spatial systems are complex. Considering the development of the technology and the expansion of need, following virtues are required in them:
① The data structure should be simple, and the mathematical foundation should be rigorous. Measuring and calculating should be convenient to perform to get accurate result.
② Large GIS should be able to meet the need of multi-resolution visualization.

③ The system should be glabrate and can be continuously visualized in large area or even all over the earth.
④ In order to communicate with other systems, it should be easy to accomplish data exchange.
⑤ The system itself should be ready for dynamic changes such as adding multi-dimension information.

Chapter Ⅲ. Can Gauss Projection be the choice?

The choice of projection is based on three main facts: the usage of a map, the map scale and the shape and location of the mapping area on the earth's surface. As a result of that the map is the data source in GIS, Gauss-Projection is the most commonly used projection for GIS these days, especially in China. Choosing Gauss-Projection for maps has some historical reasons. The page of the paper is limited for making printing, carrying and using, and Gauss Projection is suitable for a good projection in paper map and for reducing length distortion.

However, large GIS presents a certain huge area of the earth, or even the earth as a whole. It is hard to define those three facts described above. This shows that the traditional way of selecting map projection cannot match the requirement of the *Digital Earth* with features of the globally continuous resolution. Large GIS does not have to base on the 2D space Gauss Projection defined, that is non-linear and complex. What's more, from the view of visualization, it is hard for the eyes of human being to discovery the distortion difference minimized by Gauss projection. More important, lots of work such as measuring and calculating that is done manually will be done by the computer in large GIS, which works more accurately. As far as Digital earth and large GIS are concerned, the using of Gauss projection would result in the impossibility of globally continuous visualization. It is not capable of multi-resolution and dynamic change or expansion. Adapting the 2D features is impossible, let alone adding time dimension and other dimensions.

Now we say that Gauss projection shouldn't be treated as the unique projection. But it does not mean that each GIS will have its own mathematical reference. Suppose the source number to be m and goal to be n, and then the transform will make workload reach $m*n$ level, even if the transform is perfect. The actual thing is no the perfect transform.

The development of the science requires high information sharing and interaction. A unitive simple rigorous metric space is needed. It is the benchmark of all the spatial information and is the start-point of spatial information standardization. It should act as the footstone of all the GIS systems.

Chapter Ⅳ. What is the feasible solution?

People choose centroid coordinates and geodetic coordinates because they both can present any point in the space in an accurate and exclusive way. Large GIS mainly presents atmosphere, lithosphere, biosphere and hydrosphere, sometimes other spheres in neighbor.

The geodetic coordinates system is defined from the reference ellipsoid. The latitude *L* and longitude *B* show the projection of any point in the space to the surface of the ellipse. The highness from geoid is presented by the following formula:

$$H=Hs+\xi$$

Hs is the orthometric elevation

This presentation of using *(B, L, H)* is unique and accurate.

The centroid coordinates system is defined as below: The origin superposes the centriod of the earth, axis Z is the same with the earth's axis, and axis X is the intersection of equator and prime meridian. Axis Y plumbs with X and Z. All X, Y, and Z fulfill right-hand relationship.

These two coordinate systems have the following rigorous formula for transform:

$$X=(N+H)\cos B\cos L$$

$$Y=(N+H)\cos B\sin L$$

$$Z=[N(1-e^2)+H]\sin B$$

$$L=\arctan(y/x)$$

$$B=\arctan(z(N+H)/\{(X^2+Y^2)^{1/2}(N(1-e^2)+H)\})$$

$$H=Z/\sin B-N(1-e^2)$$

$$N=a/(1+e^2\sin^2 B),\quad e^2=(a^2-b^2)/a^2$$

Because the geoidal surface is irregular and complex, the origin doesn't always fit the centroid accurately. We can get the correction when needed.

Which is the better? As far as we are concerned, the preference is the geodetic coordinates system. Firstly, maps are still an important data source, 2D display is widely used. Secondly, compared with the radius of the earth, distance from the entities in the space to the geoid is weeny. Using the E-G(entity to geoid) distance instead of the E-C(entity to centroid) is universal and convenient, and fits the need for visualization better. Thirdly, when coordinate of centroid is required, the transform work is simple and quick. Moreover, the vector unit used are abstractly

vertically intercrossed.

Based on the explanations above, we come to the conclusion that large GIS should use the geoid reference frame as its mathematical base.

The mode we put forward is:
First project (B, L) from the geodetic coordinates system (B, L, H), then introduce the const k, so we get the X Y coordinates:

$$X = kL$$
$$Y = kB$$

(B L have the unit of radian, k has the unit of meter per radian).
Obviously, k is determined by the resolution, which is the scale.

On the base of one projection with data saved, the system can use other projections for the different purpose in the different phase of operation by user. In the different segments about storage, index, analyzing, viewing, measuring and printing in GIS, the projection cluster can be separated into multi-layer and used many kinds of projections for different purpose. It can improve the speed of view and calculation in a map application, and can easily integrate many map resources into a large-scale GIS through the Internet/Intranet. Besides all the qualities in chapter Ⅱ, this mode has the following features:

1. Geometrical features
Geographical coordinate and planar coordinate meet the linear relationship, and it is easy to perform locating operation. The work that transforming it to centriod coordinate system is simple. It also has the qualities the earth's ellipsoid has.

2. Features of topology
It is topologically homeomorphous with the earth. This is an important virtue for spatial analysis. Much significant information and explanation have a great deal relations with the topology.

Using this mode, and with the help of the new distributed technology on net, such as Component, Agent and Ontology, following projects have been accomplished:

1. **Wuhan Water-Supply Information System in China that integrates maps over 3,300 sheets with the following scales of 1/250,000, 1/50,000, 1/10,000, 1/1,000, and 1/500 together with necessary attribute information.**
2. **Yunnan Frontier Defense Information System in China, which contains topographic maps with following scales: 1/250,000, 1/50,000, 1/10,000 and DEM, integrates lots of multimedia data.**
3. **Xiaogan Hydraulic Information System and Xianlin Hydraulic Information System in Hubei of China are samples of intranet application which based on Web B/S mode**

4. The framework of the National Oceanic Information System integrates maps over 20 with scales in 1/25,000,000, 1/7,000,000, 1/1,000,000.

Chapter V Conclusion

These projects show that with this mode we can set up GIS of large area efficiently, even if to national wide or global scope. The whole area can be continuously viewed as a whole with multi-resolution. Browsing, querying and analyzing can easily be performed. Compared with its low cost, its efficiency is marvelous. The mathematical base we illuminated above acts as the premise of the Success.