One kind of networking mode ATC system coordinate projected optimization method

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Abstract: The traffic management system in civil aviation adopts map projection when processing the target track position, but the distortion caused by the coordinate projection error will affect the processing accuracy of the system. In order to solve this problem, this paper proposes an optimization method based on the networking mode, constructs multiple networking centers and processing units to form a target tracking report relationship, implements distributed processing splicing according to the regional target situation, and discusses the coordinates in the system networking mode Principles of the use of the system and coordinate conversion. By updating the calculation, the effect of dealing with large-area projection errors is effectively reduced, which provides ideas for my country to establish a nationwide air traffic management system.

1. Introduction

The air traffic management system needs to access the air traffic radar and other information to process the air target's trajectory. The position processing is the most important. The distance and angle need to be calculated during the processing. This needs to be converted into XY coordinates of the plane and project the map. However, the projection process will lead to the deformation of the map, which is commonly used in Gaussian projection and Mercator projection [1].

Recently, the civil aviation ADS-B processing system has constructed a networking system consisting of primary, secondary, and tertiary processing centers. Referring to such networking methods, this paper proposes a multi-level network system to reduce error of coordinate projection in large-scale airspace area [2].

2. Brief introduction of target monitoring function of air traffic control system

ATC system target monitoring generally has the following basic functions or some functions [3]:

- It can receive the original signal of the analytical processing signal source and form the integrated signal of the system after comprehensive processing;
- The position of the air target and other auxiliary parameter information can be displayed on the map background;
- It can transmit comprehensive system signals.

In order to achieve these functions, the generally adopted methods and steps are:
The received original signal needs to be unified in an XY rectangular coordinate system that is large relative to the center of the system during the system calculation process. Because as if to signal a right angle to sit in the newspaper standard or polar coordinates are relative to the signal source, not centrally, if reported to the geographic coordinates, needs to be translated, could not be completed because the distance between the geographic coordinates quickly and efficiently, Bearing and other calculations. Of course, except for systems that use purely original signals.

Under the uniform XY rectangular coordinates of the system, calculate the position, distance, heading, etc. of the target;

The result information of the latitude and longitude calculation of the target can be displayed on the background of the map, and can also be transmitted to other systems.

This article focuses on this type of air traffic control system with monitoring capabilities. Geographical coordinates and plane required to rectangular coordinate conversion when the projector.

3. Application of projection
This article takes Gaussian projection as an example, and other projection methods have the same principle.

3.1. Definition of Gaussian projection
Gauss-Kruger projection German mathematician, physicist, and astronomer Carl Friedrich Gauss (Carried Friedrich Gauss) was drafted in the 1920s, and was later supplemented by the German geodeticist Johannes Kruger (Johannes Kruger) in 1912. Therefore, it is a projection of an ellipsoidal cylinder with a transverse axis equiangular cut. It is a tangent to an ellipsoidal cylinder transverse to the surface of the ellipsoid of the earth and the surface of the ellipsoid as a meridian, which is called the central meridian in the projection, and then according to a certain The constraint condition is the projection condition, and the points within the limited range on both sides of the central meridian are projected onto the elliptic cylinder surface, thereby obtaining the Gaussian projection of the points.

3.2. Gaussian projection features
The central meridian and the projection of the earth's equator become a straight line and the axis of symmetry of the projection;

Has the property of isometric projection;

There is no length distortion after the central meridian projection.

3.3. Gaussian projection is used in the system
The geographical coordinates (latitude and longitude) and the rectangular coordinates of the plane relative to the projection center are mutually converted;

The rectangular coordinates relative to a base point and the rectangular coordinates relative to the center of the projection are converted to each other;

The polar coordinates relative to a base point and the rectangular coordinates relative to the plane of the projection center are converted to each other;

The geocentric coordinates and the rectangular coordinates of the plane relative to the projection center are mutually converted;

A series of calculations involving rectangular coordinates relative to the plane of the projection center.

4. Accuracy requirements and error analysis caused by projection

4.1. system accuracy requirements
The accuracy requirements of target monitoring in air traffic control systems are generally higher. For example, the traffic control in civil aviation prevents target flight conflicts, yaw warnings, and cross-border judgments in military applications all place high requirements on the accuracy of target
positions. If the projection error generated by the system during target processing and transmission exceeds the accuracy requirements, it cannot meet the requirements for use. Of course, there are many reasons for the error, mainly including the following factors.

4.1. **Geodetic coordinate system**
The geodetic coordinate system can be understood as using a "digital ellipsoid" to describe the earth. The "digital ellipsoid" includes ellipsoid parameters, the center position of the ellipsoid, and the direction of the coordinate axis. The results of projections using different geodetic coordinate systems are inconsistent.

4.1.2. **Coordinate projection**
A map using a map projection can completely represent the surface of the earth on a plane, but such completeness is achieved by uniformly stretching one area within the projection range and uniformly reducing another area. Some projections need to be stretched at different locations, and some to be reduced. Only through conditional uniform stretching and shrinking, can the surface of the earth be described on the plane, and the integrity and continuity of the figure can be maintained. The problem is obvious. The distance, area and shape of the projected earth surface pattern cannot be kept the same as the original earth ellipsoid, and the amount of deformation in different regions is also different. At present, the main types of projections used are azimuth projection, cylindrical projection, and conical projection.

4.1.3. **Other factors**
Including system processing, transmission delay, system transmission format accuracy, system using distance unit accuracy, system calculation accuracy, etc. This article focuses on the analysis of the error generated by the projection [4].

4.2. **Error generated Gauss projection**
Gauss-Kruger projection is an isometric, rear projection angle without distortion, the shape in the smaller ranges and FIG similar field, the direction and the relationship between the position of haunt was correct. In terms of length, after projection, the length is deformed (except for the meridian of the projection center). If the projection area is large, it is difficult to ensure that the length deformation does not exceed the allowable range [5].

According to the description of the Gaussian projection above, the error is that the central meridian projection has no length deformation. On the same latitude, the length deformation increases with the increase of the difference in length, and on the same meridian, the length deformation increases with the increase of latitude. Large and reduced, the largest deformation at the equator. In sub-band projection, the maximum deformation is at both ends of the equator in the projection zone.

5. **Group network system architecture**
The networking system consists of a networking center and a processing unit. The nationwide management center can be divided into 7 networking centers, and each networking center is divided into 3-5 processing units by region. details as follows:

5.1. **Processing area division**
The upper-level system is used as the networking center, and the lower-level system is used as the processing unit. The information source and the processing unit have a affiliation relationship. The processing unit and the networking center have an information reporting relationship. Multiple processing units correspond to a networking center and there are multiple networking centers. Assign responsibility areas for processing units and networking centers to maintain seamless connection of the responsibility areas assigned by each processing unit, and form the responsibility area of the networking center after the merger. The responsibility area of each processing unit expands to the surrounding area.
by 150 kilometers to form the processing unit. Expand the responsibility area. The expanded
responsibility areas of the processing units are combined to form the processing area of the networking
center.

5.2. Information reporting and processing methods
Each processing unit sends a status report every 1 second, and the networking center judges that the
processing unit is in the networking or independent state according to the status report.

The information source is sent to the processing unit according to the affiliation and sent to the
processing unit's superior networking center at the same time; the processing unit receives the
monitoring source information, merges and expands the responsibility area part, forms a fusion
situation and reports it to the networking center, and the networking center allocates according to the
responsibility area and adopts Each processing unit reports the target's position, altitude, speed and
other information to form a comprehensive situation.

6. Solutions for Projection Errors in System Networking

6.1. Network Distributed Processing
The distributed mode is adopted in the networking mode. The processing unit forms a comprehensive
track report to reduce the processing range of each system. Each processing system uses the geographic
centroid longitude of the system as the central meridian. Due to the small calculation range, the
difference in longitude is small. The deformation of the length and area is small, the X value relative to
the coordinate conversion center is small, and the calculation error is small.

Certain results of the treatment system is formed in the form of geographic coordinates latitude and
longitude of each communications or report, the receiving system is not turned with respect to the
present system, the center of the X, the Y value, directly informed of the geographic coordinates
latitude and longitude results. The effect of this method in larger-scale air target processing systems is
obvious [6].

6.2. Networking Center zoning projection
The center of each group of networks adopts the method of sub-band projection to divide the entire
ellipsoid along a meridian into a number of narrow zones with equal differences. Each band is projected
separately, so several different projection bands can be obtained. The meridian at the center of each
zone is called the central meridian, and the meridian used to divide the zone (the meridian at the edge of
the projection zone) is called the meridional zone. Since zoning limits the projection area to the narrow
range on both sides of the central meridian, it effectively limits the length deformation. Obviously,
within a certain range, the more the number of bands, the narrower the bands, the smaller the length
deformation. From the perspective of limiting length deformation, the more bands, the better.

After the sub-band projection, each projection has its own different coordinate axis and origin, so as
to form a Gaussian plane coordinate system independent of each other. In this way, the points on both
sides of the subzone meridian belong to two different coordinates. The processing area of the system is
often divided into different projection zones, which need to be transformed into the same coordinate
system, so the coordinate conversion between different projection zones must be performed. From this
point of view, it is also necessary not to divide too much. In the actual distribution, the above two
requirements should be taken into consideration. The projection zoning in China mainly adopts two
zoning methods: 6 degree zone and 3 degree zone. The largest distortion due to Gaussian projection is
on the equator. And increase with the increase of the difference in longitude, so limiting the longitude
range of the projection can control the deformation size within a certain range to meet the application
requirements. After projecting each zone separately, establish respective coordinate network [7].
6.3. After networking Projection formula efficiency optimization

Suppose that the geographic coordinates of the target are \((B, L)\): longitude \(L\) and latitude \(B\), the geographic coordinates of the origin of the \((B_0, L_0)\) rectangular coordinates are \(B_0, L_0\), the rectangular coordinate system is the tangent plane of the point, where true north is the X axis and true east is the Y axis.

6.3.1. Gaussian projection

The process of \((B, L)\) calculating the rectangular coordinates \((x, y)\) of the plane after the Gaussian projection from the geodetic coordinates is called the Gaussian projection forward calculation. The Gaussian projection forward calculation formula is as follows:

\[
\begin{align*}
    x &= X + \frac{1}{2} N \sin B \cos B \tan\theta + \frac{1}{24} N \sin B \cos B (5 - l^2 + 9\eta^2 + 4\eta^4) \tan^4 \theta + \frac{1}{720} N \sin B \cos B (6l - 5l^3 + l^5) \tan^6 \theta \\
    y &= N \cos B l + \frac{1}{6} N \cos B (l - l^3 + \eta^2) \tan^3 \theta + \frac{1}{120} N \cos B (5 - 18l^2 + 14\eta^2 - 58\eta^4) \tan^5 \theta
\end{align*}
\]

(1)

Wherein \(X\) the vertical axis of the projection Gauss, \(y\) Gaussian projection abscissa, \(l\) for the difference in longitude from the central Adventure, \(B\) is a geodetic latitude, \(t = \tan B\), \(\eta^2 = e^2 \cos^2 B\), \(N = C(1 + e^2 \cos^2 B)^{-\frac{3}{2}}\). Wherein \(C\) the reference ellipsoid polar radius \(C = 6399596.6520 m\), \(e^2 = 6.739501819 \times 10^{-9}\).

For the meridian arc length from the equator, \(X\) the cosine rising power formula is expressed as follows:

\[
X = 6367452.13288 - [32144.5189 - (135.3646 - 0.7034 \cos^2 B) \cos B] \sin B \cos B
\]

(2)

6.3.2. Optimization of the positive calculation process of Gaussian projection

After parameter optimization and mathematical transformation of the Gaussian projection forward calculation formula (1), the following formulas can be derived:

\[
\begin{align*}
    x &= 6367452.13288 - (P_0 - (0.5 + (P_4 + P_6 l^2) l^2) N_1) \sin B \\
    y &= (1 + (P_3 + P_5 l^2) l^2) l N_1
\end{align*}
\]

(3)

In the formula,

\[
\begin{align*}
    N_1 &= (6399596.652 - (21565.045 - (108.996 - 0.603 \cos^2 B) \cos^2 B) \cos B) \cos B \\
    P_0 &= (32144.5189 - (135.3646 - 0.7034 \cos^2 B) \cos B \cos B) \cos B \\
    P_3 &= (0.33333333 + 0.00112333 \cos^2 B) \cos^2 B - 0.1666667 \\
    P_4 &= (0.25 + 0.00253 \cos^2 B) \cos^2 B - 0.04167 \\
    P_5 &= (0.00878 - (0.1702 - 0.20382 \cos^2 B) \cos^2 B \\
    P_6 &= (-0.083 + 0.167 \cos^2 B) \cos^2 B
\end{align*}
\]

(4)

The inverse calculation process is omitted here. The optimized Gaussian positive and negative calculation formula can accelerate the speed of projection calculation, and at the same time can ensure that the maximum error of the positive calculation does not exceed 0.001m, and the maximum error of the inverse calculation does not exceed 0.0001 m.

6.4. System network mode geographic coordinate system used

The description of the spatial location of geographic points needs to select a certain reference system and coordinate system, define a spheroid surface that is quite close to the geoid as the reference surface.
for measurement calculation, which can be understood as using a "digital ellipsoid" to describe the earth. The "digital ellipsoid" includes ellipsoid parameters, the center position of the ellipsoid, and the direction of the coordinate axis. The "digital ellipsoid" is not exactly the same as the earth, but provides a method of scientific research. The currently used global geodetic coordinate system includes the Beijing coordinate system in 1954 (BJZ54), the Xi’an coordinate system in 1980, the world geodetic coordinate system (WGS-84), the 2000 national geodetic coordinate system (CGCS2000), and some regional local coordinates. system.

The geodetic coordinate systems used by air traffic control systems of various levels and types are different. There will be no error if geographic coordinates are transmitted between the systems, but the positions displayed on the map may not be at the same point, for example, the target is at (116.30, 28.5) above the sky, it is transmitted to other systems (116.30, 28.5). However, because of the different geodetic coordinate systems, the location of map elements is different, and there are differences in the display on the map. In the perspective analysis of the projection, the projection formula uses the long axis, short axis, and flatness of the ellipsoid parameters of the geodetic coordinate system. If the geodetic coordinate system used is different, when the latitude and longitude are converted to rectangular coordinates, the rectangular coordinates are also different. However, in general the error geodetic coordinate system formed is still small, the planet same point BJZ54 and WGS-84 error between approximately tens of meters, at the same point in WGS-84 and CGCS2000 maximum error between latitudes About 0.11 mm.

Therefore, in the system networking mode, you must choose a unified geographic coordinate system, or use the same geographic coordinate system for coordinate conversion calculation.

6.5. Networking mode of a unified, simplified principles

It is recommended that the networking system should follow the following principles.

The interconnected target monitoring system should adopt a unified geographic coordinate system and projection parameters.

The geographic coordinates are uniformly used when reporting the location of monitoring information.

Minimize the link of projection conversion.

This can effectively reduce the effect of errors produced by the target during projection. Detection equipment with a small detection range follows the following principles.

It can be reported based on its own characteristics. For example, if the radar reports the target position according to the echo, it is more suitable to use the rectangular coordinates or polar coordinates relative to the radar base point to report the most original information.

6.6. Data analysis

The longitudes of the projection center of System A and System B are 117 and 80 degrees east longitude, respectively, and the latitudes are 31 degrees, respectively, and the statistical errors are respectively. The distance between each point and the reference point is compared with the measured or three-dimensional distance to unify the error. The results show that the way of separately processing and splicing is obviously better than processing in a single system. Result is shown in Table I.

| Target | Target latitude and longitude | System A conversion result | System B conversion result | System A processing error | Error of splicing method |
|--------|-------------------------------|---------------------------|---------------------------|--------------------------|-------------------------|
| Datum point | B:31.3 L:118.1 | X:3487000.88366499 Y:610839.546207079 | X:4203794.99412788 Y:4243409.23823444 | - - | - - |
| point 1 | B:32.5312 L:118.3123 | X:3641207.69717949 Y:642523.075531723 | X:4385867.97152198 Y:4209730.69614191 | 0.373% 0.175% | 0.175% |
| point 2 | B:32.11 L:116.41 | X:3562225.93272633 Y:470136.79892375 | X:4224505.64088186 Y:4057460.99188722 | 0.423% 0.16% | 0.16% |
7. Conclusion
This paper analyzes the application of coordinate projection in the air target monitoring system, explains the application environment, application method, and the error generated by the projection. A system networking mode is proposed to solve the effect of coordinate projection error when processing the target track of a large area. This article has a certain reference value for the construction of ATC surveillance system.

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