Study on the Method of Conversion from Beidou Coordinate System to Local Coordinate System

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Abstract. The coordinate system involved in surveying and mapping is rather complicated. The combination transformation of coordinate systems can solve many problems in real life and work. At the same time, the transformation between coordinate systems is also a difficult problem to be solved urgently. Aiming at the parameters and characteristics of Beidou coordinate system and the projection parameters of local city coordinate system, a set of transformation methods suitable for Beidou coordinate and local city coordinate system are developed by combining parameter transformation algorithm, the feasibility of the algorithm is verified by transforming the known control points.

1. Introduction

The feasibility of the algorithm is verified by transforming the known control points. Surveying and mapping work mainly touches on three commonly used geodetic coordinate systems, namely, local independent coordinate system, geocentric coordinate system and reference coordinate system. Geocentric coordinate system: the coordinate system based on the earth's center of mass, including WGS84, CGCS2000, etc. Reference ellipsoid coordinate system, including BJ54, XIAN80, etc. Independent coordinate system: The coordinate system established according to the local conditions is projected onto the Gauss plane by using a new ellipsoid[1]. The calculation parameters are settled, including the coordinate systems of various cities. The combination of coordinate system has great value in practical application, and has solved various engineering surveying problems in real life. In order to combine the application of Beidou positioning, it is very important to study the transformation relationship between national unified coordinate system and local coordinate system, which is also a problem to be solved at present[2].

Based on the study and study of the parameters of CGCS2000 coordinate system and local city coordinate system, Ellipsoid Transformation Method and projection method, combined with actual coordinates as sample points, this paper summarizes a set of transformation model suitable for CGCS2000 coordinate system and local city coordinate system, and verifies it on the spot. Through the error analysis, the paper concludes a set of transformation model suitable for CGCS2000 coordinate system and local city coordinate system. The analysis proves the feasibility of the transformation model.

2. Research on Conversion Method

The coordinate system of Beidou system is China Geodetic Coordinate System (CGCS2000), which belongs to the geocentric coordinate system. The definition of CGCS2000 is basically the same as that...
of WGS84, i.e. coordinate origin, scale, orientation and orientation evolution are the same. The reference ellipsoids used in the two coordinate systems are also very similar. Specifically, the parameters of the four reference ellipsoids are $\alpha$ (long half axis), $f$ (flatness), $GM$ (gravity), $\omega$ (rotation angle of the earth). Only the flatness is slightly different. The coordinate errors are in centimeter level and the corresponding accuracy requirements are not high[3]. This paper is also applicable to WGS84 seats. Conversion from Mark to Local Coordinate.

On the basis of studying the method of establishing CGCS2000 coordinate system and Independent coordinate system, reference ellipsoid, projection parameters, and combining with mathematical methods such as ellipsoid transformation, Gauss projection and space coordinate transformation[4], the transformation model is designed as follows:

The main steps:
1. Convert CGCS2000 latitude and longitude coordinates to space rectangular coordinates;
2. Converting CGCS2000 space rectangular coordinates to BJ54 space rectangular coordinates by using seven-parameter transformation;
3. Converting BJ54 space rectangular coordinate system into BJ54 longitude and latitude coordinate system;
4. Converting BJ54 latitude and longitude to BJ54 plane rectangular coordinate system by Gauss forward calculation;

Figure 1. Conversion process
5. The BJ54 plane coordinate is transformed into local city coordinate system by inverse calculation parameters of known control points.

2.1. Conversion of latitude and longitude into space rectangular coordinates
The formulas for calculating the coordinates in the space rectangular coordinate system are as follows:

\[ X = (N + H) \times \cos B \times \cos L \]
\[ Y = (N + H) \times \cos B \times \sin L \]
\[ Z = [N \times (1 - E^2)] + H \times \sin B \]

Among them: B is longitude, L is latitude, H is height.

2.2. Conversion of Spatial Cartesian Coordinate System into Longitude and Latitude
The formulas for calculating latitude and longitude of coordinate transformation in space rectangular coordinate system are as follows:

\[ L = \arctan \left( \frac{Y}{X} \right) \]
\[ B = \arctan \left( \frac{Z + e^2 \sin^3 \theta}{\sqrt{X^2 + Y^2 - e^2 \cos^3 \theta}} \right) \]
\[ H = \frac{\sqrt{X^2 + Y^2}}{\cos B} - N \]

Among them: \( e \) For the first eccentricity, \( a \) Long axis.

2.3. Seven parameter
As CGCS200 belongs to the geocentric system and the local city coordinate system belongs to the reference system, this paper uses seven parameters to make ellipsoid transformation[5]. The seven parameters conversion formula is as follows:

\[ \begin{bmatrix} \Delta L \\ \Delta B \end{bmatrix} = \begin{bmatrix} -\frac{\sin L}{N \cos B} & \frac{\cos L}{N \cos B} & 0 \\ -\frac{\sin B \cos L}{M} & -\frac{\sin B \sin L}{M} & \frac{\cos B}{M} \rho'' \end{bmatrix} \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} -\frac{N e^2 \sin B \cos B}{M} \rho'' \frac{2 - e^2 \sin B}{1 - f} \sin B \cos B \rho'' \\ \end{bmatrix} \begin{bmatrix} \Delta \alpha \\ \Delta f \end{bmatrix} \]

Among them: \( \Delta X \), \( \Delta Y \), \( \Delta Z \) are translations for three coordinates; \( \varepsilon_x \), \( \varepsilon_y \), \( \varepsilon_z \) are rotation for three coordinate axes; M are radius of Curvature of Meridian Circle; N are radius of curvature of unitary circle; e is the radius of curvature of unitary circle is the first eccentricity.

2.4. Projection method
The local city coordinate system uses the projection of Gauss 3-degree band. This paper uses Gauss positive calculation to project the longitude and latitude coordinates and calculate the plane coordinates. The specific formulas are as follows:

\[ x = X + N \cos B \rho^2 \left[ 0.5 + \frac{1}{24} (5 - t^2 + 9 \eta^2 + 4 \eta^4) \cos^2 B \frac{B''}{\rho^2} + \frac{1}{720} (61 - 58 t^2 + 1 - t^4) \cos^4 B \frac{B''}{\rho^2} \right] \]
\[ y = N \cos B \frac{L}{\rho^2} \left[ 1 + \frac{1}{6} (1 - t^2 + \eta^2) \cos^2 B \frac{B''}{\rho^2} + \frac{1}{120} (15 - 18 t^2 + 1 + 4 \eta^2 - 58 \eta^2 t^2) \cos^4 B \frac{B''}{\rho^2} \right] \]

Among them: \( f \) is ellipticity of ellipsoid, \( X \) is meridian arc length.
3. Coordinate system research

3.1. CGCS2000 coordinate system

The collects coordinates are longitude and latitude of CGCS2000 coordinates, and its reference ellipsoid parameters are public data. Specific parameters are obtained by inquiring relevant data as the precondition of conversion. The specific information is as follows.

3.1.1. Reference ellipsoid. CGCS2000 coordinate system adopts GRS-80 ellipsoid, which is a geocentric coordinate system. The specific parameters of reference ellipsoid are as follows:

| Parameter name                      | Parameter value |
|-------------------------------------|-----------------|
| Long axis a                         | 6378137m        |
| Oblate f                            | 1/298.257222101 |
| Flattening gravitational GM         | 3.986004418×10^{14} m^{3} s^{-2} |
| Rotation angular velocity \( \omega \) | 7.292115×10^{-5} rad s^{-1} |
| Short radius                        | 6356752.31414   |
| First eccentricity square           | 0.0066943800229 |
| Second eccentricity square          | 0.00673949677548 |

3.2. Local coordinate system

Local coordinate system is a kind of plane rectangular coordinate system. According to the establishment method of coordinate system, we obtain the related parameters of the coordinate system, including the reference ellipsoid parameters, projection methods and projection parameters[6]. The specific information is as follows.

3.2.1. Reference ellipsoid. The Local coordinate system of reference ellipsoid in this study adopts Krasovsky ellipsoid, which is a kind of parametric coordinate system. The specific parameters of reference ellipsoid are as follows:

| Parameter name                      | Parameter value |
|-------------------------------------|-----------------|
| Long axis a                         | 6378245m        |
| Oblate f                            | 1/298.3         |
| Flattening gravitational GM         |                 |
| Rotation angular velocity \( \omega \) |                 |
| Short radius                        | 6356752.31414   |
| First eccentricity square           | 0.0066934216296594323 |
| Second eccentricity square          | 0.0067385254146834912576 |

3.2.2. Projection parameter. The local city coordinate system belongs to the plane coordinate system, and the coordinate projection is designed. The projection method is based on the Gauss projection with 3 degree band. The specific parameters are as follows:

| Parameter name                      | Parameter value |
|-------------------------------------|-----------------|
| Central longitude line              | 117             |
| False East                          | 555484.8092     |
| False North                         | -4114948.631    |
| Specific factor                     | 1.0             |
| Company                             | m               |
| Projection origin latitude          | 0               |
4. Experimental research
Based on the research of the algorithm model in this paper, we independently design and develop a program of coordinate automatic transformation. At the same time, two sets of coordinates of several control points are acquired by sampling in the field through Beidou positioning and traditional surveying and mapping. After the conversion verification of the software, the error between the coordinate values converted and the coordinate values sampled in the field is sub-meter level, which can meet the error accuracy requirements of Surveying and mapping work in the actual work, and fully verify it. The feasibility of the conversion algorithm is discussed.

5. Summary
This paper summarizes the research on the reference ellipsoid parameters and projection methods of Beidou coordinate system and local coordinate system. Combined with ellipsoid parameter transformation and Gauss projection algorithm, this paper establishes a set of transformation model between coordinate systems. After verification, the conversion accuracy meets the error requirements in engineering survey, and fully proves the conversion model is feasibility.

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