Research on the Transformation Area Deformation of Topographic Map Under the Background of "Multi Conformity"

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Abstract: The urban independent coordinate system based on CGCS2000 has a relatively strict conversion correspondence with CGCS2000 coordinate system. Based on the surveying and mapping technical force of class a unit, the conversion of control points can be realized and high precision can be achieved. In the process of topographic map transformation, due to the influence of side length projection deformation, it will have an impact on the area of engineering construction plot. Through the coordinate conversion function of the digital mapping software, the topographic map is transformed to explore the change rate of the converted area and provide decision-making basis for the planning and construction departments.

1. Introduction
According to the notice on accelerating the use of 2000 national geodetic coordinate system issued by the State Bureau of surveying, mapping and geographic information of the Ministry of land and resources on March 10, 2017 (GTZF[2017] No. 30), since July 1, 2018, 2000 national geodetic coordinate system has been adopted in all the natural resource systems. Lei Yong [1-4] et al. Proposed the conversion relationship between the independent coordinate system established by the ellipsoid expansion method and the national geodetic coordinate system 2000 based on the CGCS2000 ellipsoid, which achieved good results in the process of coordinate conversion of control points and met the needs of engineering construction. However, in the process of coordinate system transformation, the area of engineering construction land will be affected by the projection deformation of side length [5], and the contradiction of the area of the same plot in different coordinate systems will be obtained, which increases the difficulty of planning approval.

2. Research significance
According to the requirements of the national development and Reform Commission, counties and cities across the country gradually carry out the work of multiple compliance and integration, unifying various plans into one map, "one blueprint to the end" [6]. According to the requirements of the Ministry of natural resources, the mapping benchmark of this blueprint must be the 2000 national geodetic coordinate system. The central urban area of Bijie Experimental Area is close to the central meridian (105°) of 2000 national geodetic coordinate system, but its absolute elevation is higher, so the projection
deformation value of side length in 2000 national geodetic coordinate system is larger, about 20cm / km. It is far beyond the requirement that the urban construction specification is no more than 2.5cm/km[7].

From the point of view of planning, the national geodetic coordinate system 2000 is a newly established geocentric coordinate system, which is more scientific, and has practical significance for improving the accuracy of Surveying and mapping, promoting the integration of multiple standards and other large-scale surveying and mapping. However, the design of engineering construction is carried out on the drawings, and each index is calculated according to the data on the drawings. In order to ensure the safety of engineering construction, the projection deformation between the design drawings and the actual side length must meet the requirements of engineering construction. In order to ensure the quality of the project construction, the local coordinate system that meets the requirements of the urban construction specifications must be used in the urban construction of Bijie downtown, which will inevitably produce the transformation of the coordinate system.

The coordinate transformation of Gauss projection includes translation, rotation and scaling. Translation and rotation can be strictly deduced according to the mathematical formula, which has little effect on the accuracy of the converted results. However, since the side length deformation is related to the coordinate y value and y value difference of the side, it is an indefinite value, so the conversion is more complex, which has a greater impact on the accuracy of the converted results. The coordinate transformation of control points is also discussed. This study focuses on the transformation and application of topographic map.

3. research methods

3.1. CGCS2000

In 2000 national geodetic coordinate system, CGCS2000 ellipsoid is adopted, and the central meridian is 105° (central urban area of Bijie). The specific parameters are as follows [8]:

- Long half axis \( a = 6378137 \) m;
- Flatness \( f = 1/298.257222101 \);
- Gravity constant \( GM = 3.986004418 \times 10^{14} \) m³ s⁻²
- Angular velocity \( \omega = 7.292115 \times 10^{-5} \) rad s⁻¹

3.2. Urban independent coordinate system of Bijie Downtown

The independent urban coordinate system of Bijie City Center uses the 2000 national geodetic coordinate system, adopts the ellipsoidal expansion method, does not change the oblateness, only changes the long half axis of the ellipsoid, and the elevation of the projection surface is equivalent to the expansion (expansion) of the ellipsoid to form a new ellipsoid [8]. The long axis of the ellipsoid is the mean radius of curvature of CGCS2000 ellipsoid plus the elevation of the projection surface, that is, on the datum point of the central region or the center point of the region.

\[
R_{\text{new}} = R + H = \frac{a\sqrt{1-e^2}}{1-e^2 \sin^2 \beta} + \Delta H
\]

Mean radius of curvature of new ellipsoid:

New ellipsoid long half axis:

\[
a_{\text{new}} = a + \Delta a = a + \frac{1-e^2 \sin^2 \beta}{\sqrt{1-e^2}} \Delta H
\]

Then there are

\[
W = \sqrt{(1-e^2 \sin^2 B)} ; \quad M = a \left(1-e^2 \right) W^3 ; \quad a - \text{semimajor axis of ellipsoid} ; \quad B_0 - \text{Raise the projection surface (geodetic height)}. \quad (1)
\]

In style: 
Datum latitude, Mean latitude of the survey area; \( \Delta H \) Raise the projection surface (geodetic height).
3.3. necessity of topographic map conversion
Because the Ministry of Natural Resources clearly stipulates that the 2000 national geodetic coordinate system shall be used in the natural resources system. However, due to the influence of projection deformation on the project construction, the coordinate system with side length projection deformation less than 2.5 cm/km must be used. Therefore, the coordinate system of topographic map must be transformed. At the same time, the transformation is mainly aimed at the transformation of 2000 national geodetic coordinate system to local coordinate system (Urban Independent Coordinate System of Bijie central city).

3.4. feasibility of topographic map conversion
Bijie central city independent coordinate system is based on the 2000 ellipsoid, which is established by translating the central meridian and adopting the ellipsoid expansion method. It has a close conversion relationship with the 2000 national geodetic coordinate system, so the conversion of topographic map is feasible.

3.5. technical route of coordinate transformation

3.5.1. ellipsoidal expansion method for conversion
Because the ellipsoid used in the independent urban coordinate system of Bijie City Center is CGCS2000 ellipsoid, both of them have strict mathematical model and transformation relationship. The specific technical route is shown in Figure 1.

![Figure 1: Technical roadmap of coordinate transformation](image)

2000 national coordinate system to geodetic coordinate system
The longitude and latitude are calculated according to the back calculation formula of Gauss projection.

\[
B = B_0 - \frac{t_1}{2M} + \frac{t_2}{24M^3} N \left(5 + \frac{3}{2}t_1 + \frac{29}{24}t_1^2 - \frac{1}{16}t_2 + \frac{5}{96}t_1t_2 \right) y_6 + \frac{t_1}{720M} N \left(6 + \frac{9}{2}t_1 + \frac{45}{16}t_2 \right) y_6
\]

\[
L = L_0 - \frac{t_1}{6N} \cos B_0 + \frac{y_7}{120N} \cos B_0 \left(1 + \frac{3}{2}t_1 + \frac{19}{14}t_2 \right) + \frac{y_8}{720N} \cos B_0 \left(5 + \frac{28}{3}t_1 + \frac{24}{5}t_2 + \frac{6}{13}t_1^2 + \frac{8}{9}t_2^2 \right)
\]

Where: angle is radian

B is the latitude of the point, \( L_0 \) is the longitude of the central meridian;

from the geodetic coordinate system to the urban independent coordinate system of Bijie Downtown:
Calculation of urban independent coordinate system of Bijie City Center Based on Gauss projection forward calculation (using independent coordinate ellipsoid parameter)

\[
x = X + \frac{N}{2r^2} \sin B \cos B r^2 + \frac{N}{24r^4} \sin B \cos^3 B \left(5 - t_1^2 + 9\eta^2 + 4r^4 \right) l^4 + \frac{N}{720r^6} \sin B \cos^5 B \left(61 - 58r^2 + t_1^4 \right) l^6
\]

\[
y = \frac{N}{r^3} \cos B \cos^3 B \left(1 - t_1^2 + \eta^2 \right) l^3 + \frac{N}{120r^5} \cos^5 B \left(5 - 18r^2 + t_1^4 + 14\eta^2 - 58\eta^2 r^2 \right) l^5
\]

Where: angle is radian

B is the latitude of the point, \( L = L - L_0 \), L is the longitude of the point, \( L_0 \) is the longitude of the central meridian;

\[
N = a \left(1 - e^2 \sin^2 B \right)^{1/2}, \quad t = \tan B
\]
3.5.2. **Conversion of Seven Parameter Method**

Through the C-level control points established in the establishment of the independent urban coordinate system of Bijie City Center, the BRSA seven parameter model [5] (3D, model as follows) is obtained to transform the coordinate system:

\[
\begin{align*}
X_2 &= dx + 0 - Z \ Y_2 \ Y_1 \\
Y_2 &= dy + Z 0 - X \ Y_2 + m \ Y_2 \\
Z_2 &= dz - Y X 0 \ Z_2
\end{align*}
\]

(6)

Side: \([dx \ dy \ dz]^T\) - 3 translation parameters;

\([\omega_x \ \omega_z \ \omega_y]^T\) - 3 rotation parameters;

\(m\) - Scale parameter;

\([X_1 \ Y_1 \ Z_1]^T\) - Coordinates before conversion;

\([X_2 \ Y_2 \ Z_2]^T\) - Coordinates after conversion.

3.6. **Transformation Method of Topographic Map**

3.6.1. **7-Parameter Conversion Method**

Most of the mapping software of topographic map provides the function of topographic map conversion. Through three or more common point coordinates, the conversion parameters of two coordinate systems are calculated. Convert the existing topographic map by converting parameters. However, the software can be converted as long as there are parameters. There is no requirement for the location of common points and the scope of converted graphics. There is no evaluation on the precision after conversion, so it can not guarantee whether it meets the requirements of engineering construction. In order to ensure the accuracy of the converted topographic map, it is necessary to find a method to select common points, and to test the accuracy of the converted topographic map and the change of plot area.

3.6.2. **Selection of Common Points**

Due to the relatively strict conversion relationship between control points, the accuracy is relatively high. In the process of topographic map conversion, take one point from the East, West, North and south of the project construction land respectively, convert it by strict calculation formula, and obtain the coordinates after conversion as the common point of topographic map conversion.

3.7. **Conversion of Topographic Map**

Through the selected common points, the conversion parameters are calculated and the plot is transformed. The coordinate of the boundary point of the plot is calculated by strict formula, and compared with the coordinate after the transformation of the figure to evaluate the conversion accuracy of the topographic map. The results are shown in Table 1.
Table. 1 comparison table of formula calculation coordinates and graph transformation coordinates

| Serial number | Formula derived coordinates (m) | Drawing conversion coordinates (m) | Discrepancy (mm) | Remarks |
|---------------|---------------------------------|----------------------------------|------------------|---------|
|               | X      | Y      | X      | Y      |                      |
| 1             | *.9050 | *.689  | *.952  | *.689  | 2                    |
| 2             | *.201  | *.031  | *.200  | *.031  | 1                    |
| 3             | *.175  | *.866  | *.175  | *.865  | 1                    |
| 4             | *.293  | *.513  | *.293  | *.513  | 0                    |

In different radius range, according to different common point conversion graphics and change the shape of the plot for conversion, the area change is shown in Table 2.

Table. 2 Changes of plot area before and after the graphic conversion

| Serial number | Radius | Area before conversion (m²) | Converted area (m²) | Difference value (m²) | Rate of change (%) | Remarks |
|---------------|--------|-----------------------------|---------------------|-----------------------|-------------------|---------|
| 1             | 250    | 193019                      | 193102              | 83                    | 0.0430            | Approximate circle (the common point is located at the center of the circle and the circle with a radius of 500m) |
| 2             | 500    | 776058                      | 776389              | 331                   | 0.0427            |
| 3             | 750    | 1753786                     | 1754535             | 749                   | 0.0427            |
| 4             | 1000   | 3113037                     | 3114368             | 1331                  | 0.0428            |
| 5             | 1250   | 4878688                     | 4880773             | 2085                  | 0.0427            |
| 6             | 1500   | 7031720                     | 7034725             | 3005                  | 0.0427            |
| 7             | 250    | 142596                      | 142657              | 61                    | 0.0428            | Arbitrary shape (the common point is located at the center of the circle and the circle with a radius of 500m) |
| 8             | 500    | 586659                      | 586910              | 251                   | 0.0428            |
| 9             | 750    | 1401585                     | 1402183             | 598                   | 0.0427            |
| 10            | 1000   | 2555014                     | 2556106             | 1092                  | 0.0427            |
| 11            | 1250   | 4141378                     | 4143147             | 1769                  | 0.0427            |
| 12            | 1500   | 6073150                     | 6075745             | 2595                  | 0.0427            |

4. conclusion
Due to the influence of side projection deformation, in order to maintain the quality of engineering construction and ensure the safety of engineering construction, Bijie City will have the situation of coexistence of CGCS2000 coordinate system and local independent coordinate system for a long time, which will inevitably lead to the transformation of coordinate system. Relying on the technical force of natural resources department, the control points and topographic map are transformed to meet the needs of engineering construction.

1) coordinate conversion of control points shall be deduced strictly according to coordinate conversion formula (mapping technical force can be organized to write conversion software);

2) the coordinate transformation of topographic map can be carried out by selecting one point from the southeast, northwest and northwest of the topographic map of process construction land, and using these five points to calculate the graphic transformation parameters;

3) in the independent coordinate system of CGCS2000 and Bijie downtown area, the same small area block will produce area deformation with the deformation rate of about 0.043%. The natural resources department can control the change of conversion area according to 0.05%, and calculate the volume ratio, greening rate and other indicators according to the area of independent coordinate system.

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