Simulation design of bursa-wolf coordinate transformation model based on the access

Gong Yusheng*

School *of Civil Engineering, University of Science and Technology Liaoning, Anshan, China*

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Abstract

With the popularity of GNSS technology, problems of conversion between different spatial rectangular coordinate systems are often encountered, which are difficult to solve. This paper introduces Bursa-Wolf coordinate transformation model in detail, this model is widely used in the conversion between different spatial rectangular coordinate system, In order to improve the efficiency of calculation, This paper writes a simulation program using tables, forms, macros and VBA in Access, also the simulation program has been verified by production instances, and the reliability of its results is ensured.

Keywords: Access, VBA, Spatial rectangular coordinate system, Bursa-Wolf Model, Simulation

1 Introduction

With the development of modern surveying and mapping science and technology, especially the emergence of space satellite navigation and positioning technology, the conventional geodetic methods have been gradually replaced by satellite geodetic methods, the location of ground points can be measured and expressed in a three-dimensional geocentric coordinate system by means of satellite geodesy .Both can be expressed as three-dimensional space rectangular coordinate, and earth latitude and longitude of a ellipsoid corresponding to the earth, Based on the above, space geodetic rectangular coordinate system and its transformation in modern geodetic surveying carries more practical significance[1].

There are certain connections between the space rectangular coordinate system and the geodetic coordinate system in one ellipsoid – They can convert to each other. The representing forms of coordinate of a same point are different in two coordinate systems, this is just two different but mutually equivalent representing forms. But when measured in space technologies including GNSS positioning technology, conversions between different datum is often needed, for example, the conversion between the two different geocentric coordinate systems – WGS84 and ITRF; and the conversion between two different ellipse-centered coordinate systems – Beijing geodetic coordinate system 1954 and the 1980 national geodetic coordinate system [2-6].

2 Bursa-Wolf transformation model

Bursa-Wolf transformation model (which is often called Bursa model in short) is also called 7-Parameter Transformation or 7-Parameter Helmert Transformation, as is shown in Figure1. There are 7 Parameters in the model, which contains 3 Translation parameters: T_X, T_Y, T_Z and 3 Rotation parameters: ω_X, ω_Y, ω_Z (also known as the 3 Euler angles) and 1 scale parameter m [7-8].

Suppose that there are two space rectangular coordinate system based on different datum O_A-$X_AY_AZ_A$ and O_B-$X_BY_BZ_B$, Bursa-Wolf model can be used to transform coordinate of O_A-$X_AY_AZ_A$ to coordinate of O_B-$X_BY_BZ_B$ by the following steps [9]:

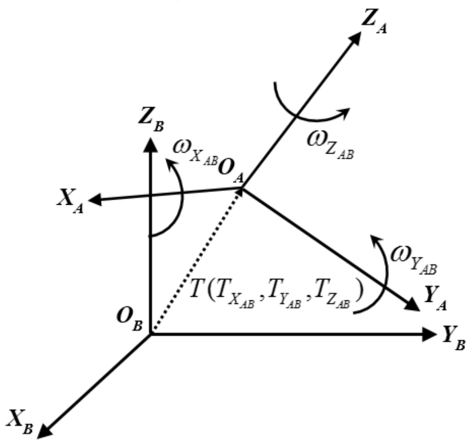

FIGURE 1 Bursa - Wolf seven-parameter transformation

(1) Look at the origin O_A from the side of X_A, O_A is a fixed point in rotate process, the *OA-XAYAZA* around the X_A axis is counterclockwise rotated ω_{XAB}, so that axis Y_A after rotated is parallel to the O_B-X_BY_B plane;

* Corresponding author - Tel: +86-412-592-9611; fax: +86-412-592-9610;
E-mail: gys_long@qq.com

(2) Look at the origin O_A from the side of Y_A, point O_A is a fixed point in rotate process, the O_A-$X_AY_AZ_A$ around the Y_A axis is counterclockwise rotated ω_{YAB}, so that axis X_A after rotated is parallel to the O_B-X_BY_B plane. Obviously, the Z_A axis parallel with the Z_B axis;

(3) Look at the origin O_A from the side of Z_A, point O_A is a fixed point in rotate process, the O_A-$X_AY_AZ_A$ around the Z_A axis is counterclockwise rotated ω_{ZAB}, so that axis X_A after rotated is parallel to the X_B. Obviously, three axes of O_A-$X_AY_AZ_A$ are parallel to three axes of O_B-$X_BY_BZ_B$;

(4) Zoom the unit of length in the O_A-$X_AY_AZ_A$ 1+m times so that it is the same as the unit of length in the O_B-$X_BY_BZ_B$;

(5) Respectively move the origin of O_A-$X_AY_AZ_A$ along X_A axis, X_B axis and X_Z axis -T_{XAB}, -T_{YAB}, -T_{ZAB} so that it coincides with the origin of O_B-$X_BY_BZ_B$. Formulas can be used to express the conversion process as follows:

$$\begin{bmatrix} X_B \\ Y_B \\ Z_B \end{bmatrix} = \begin{bmatrix} T_{X_{AB}} \\ T_{Y_{AB}} \\ T_{Z_{AB}} \end{bmatrix} + (1+m_{A,B}) R_3(\omega_{Z_{A,B}}) R_2(\omega_{Y_{A,B}}) R_1(\omega_{X_{A,B}}) \begin{bmatrix} X_A \\ Y_A \\ Z_A \end{bmatrix} . \quad (1)$$

In the formula:

$$R_1(\omega_{X_{A,B}}) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega_{X_{A,B}} & \sin\omega_{X_{A,B}} \\ 0 & -\sin\omega_{X_{A,B}} & \cos\omega_{X_{A,B}} \end{bmatrix},$$

$$R_2(\omega_{Y_{A,B}}) = \begin{bmatrix} \cos\omega_{Y_{A,B}} & 0 & -\sin\omega_{Y_{A,B}} \\ 0 & 1 & 0 \\ \sin\omega_{Y_{A,B}} & 0 & \cos\omega_{Y_{A,B}} \end{bmatrix},$$

$$R_3(\omega_{Z_{A,B}}) = \begin{bmatrix} \cos\omega_{Z_{A,B}} & \sin\omega_{Z_{A,B}} & 0 \\ -\sin\omega_{Z_{A,B}} & \cos\omega_{Z_{A,B}} & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

Take the normal circumstances into consideration, Three Euler angles of ω_X, ω_Y, ω_Z of rotation between the two different datum are all very small, so Bursa-Wolf model can eventually be simplified and shown as following [10-12]:

$$\begin{bmatrix} X_B \\ Y_B \\ Z_B \end{bmatrix} = \begin{bmatrix} X_A \\ Y_A \\ Z_A \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & 0 & -Z_A & Y_A & X_A \\ 0 & 1 & 0 & Z_A & 0 & -X_A & Y_A \\ 0 & 0 & 1 & -Y_A & X_A & 0 & Z_A \end{bmatrix} \begin{bmatrix} T_X \\ T_Y \\ T_Z \\ \omega_Z \\ \omega_Y \\ \omega_X \\ m \end{bmatrix} . \quad (2)$$

3 Solving for seven parameters

While do Spatial coordinate transformation, if the number of control points n is greater than 3, seven parameters of spatial coordinates model can be solved by using indirect adjustment method, as the following method:

3.1 COLUMN ERROR EQUATION

Coordinates of B coordinate system can be considered as observations, suppose coordinates of B coordinate system are error-free, and then error equation can be columned

$$\begin{bmatrix} v_{x_1} \\ v_{y_1} \\ v_{z_2} \\ \vdots \\ v_{x_n} \\ v_{y_n} \\ v_{z_n} \end{bmatrix}_B = \begin{bmatrix} 1 & 0 & 0 & 0 & -Z_1 & Y_1 & X_1 \\ 0 & 1 & 0 & Z_1 & 0 & -X_1 & Y_1 \\ 0 & 0 & 1 & -Y_1 & X_1 & 0 & Z_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & 0 & 0 & 0 & -Z_n & Y_n & X_n \\ 0 & 1 & 0 & Z_n & 0 & -X_n & Y_n \\ 0 & 0 & 1 & -Y_n & X_n & 0 & Z_n \end{bmatrix} \begin{bmatrix} T_X \\ T_Y \\ T_Z \\ \omega_Z \\ \omega_Y \\ \omega_X \\ m \end{bmatrix} - \left[\begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \\ \vdots \\ X_n \\ Y_n \\ Z_n \end{bmatrix}_B - \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \\ \vdots \\ X_n \\ Y_n \\ Z_n \end{bmatrix}_A \right] . (3)$$

Written in matrix form $V = B\hat{X} - L$

Coordinates of each point can be regarded as independent observations of same accuracy, so $P=I$.

3.2 SOLVING FOR PARAMETERS

Put the known coordinate's values of each point into the above error equation, and then solving parameter values according to the following formula:

$$\hat{X} = (B^T B)^{-1}(BL)$$

4 Simulation program design

4.1 CREATE TABLES

3 tables have been designed in the program, structures of each table are shown in table 1-3. Common points data of calculating seven parameters can be saved to the common point table of calculating seven- parameter space rectangular coordinates; Via using the Table of space rectangular coordinate before the seven-parameter conversion, data calls can be achieved, and data storage can also be achieved via using converted seven parameters table [13-14].

TABLE 1 The calculation of common point Tab structure from spatial rectangular coordinate through seven parameters

Field name	Field type	Field length	Decimal digits
Point name	text	50	-
A ellipsoid X	figure	double precision	4
A ellipsoid Y	figure	double precision	4
A ellipsoid Z	figure	double precision	4
B ellipsoid X	figure	double precision	4
B ellipsoid Y	figure	double precision	4
B ellipsoid Z	figure	double precision	4

TABLE 2 The Tab structure from spatial rectangular coordinate before seven-parameter conversion

Field name	Field type	Field length	Decimal digits
Point name	text	50	-
X	figure	double precision	4
Y	figure	double precision	4
Z	figure	double precision	4

TABLE 3 The Tab structure from spatial rectangular coordinate after seven-parameter conversion

Field name	Field type	Field length	Decimal digits
Point name	text	50	-
X	figure	double precision	4
Y	figure	double precision	4
Z	figure	double precision	4

4.2 CREATE FORM OF CALCULATION

Through the form of seven parameters we can achieve:

(1) input space transformation coordinates of the common point, click the command button of "calculate seven parameters" seven transformation parameters can be calculated, as is shown in Figure 2;

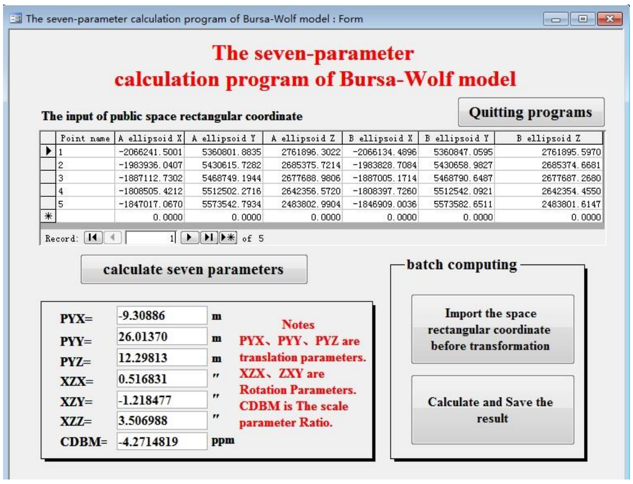

FIGURE 2 The interface of seven-parameter calculation

(2) It can bring out the space rectangular coordinate table before transformation by click the command button of "Import space rectangular coordinate before transformation" and editing it, as is shown in Figure 3, then click the command button of "calculate and save the result" to go on batch conversion, save the calculated data in the converted space transformation coordinate table as well as the Excel table, and eventually saved in the computer - specified directory.

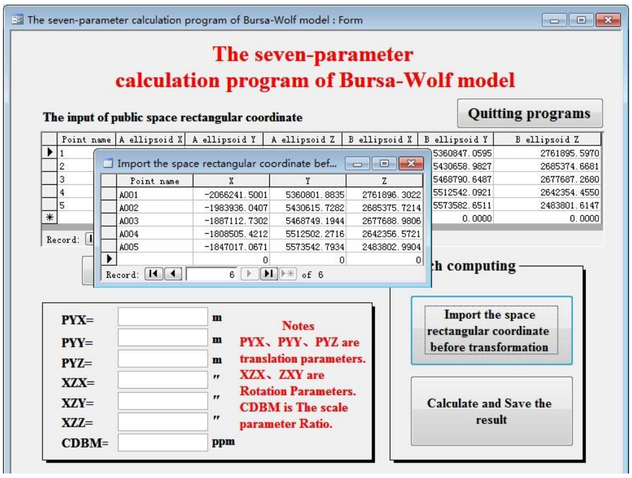

FIGURE 3 The interface of batch calculation

4.3 CREATING MACROS

Using Macros can realize some auxiliary functionalities flexibly in programming, therefore, the Date Input and Export Macro Group is being used in the program design, there into, the export of The Space Rectangular Coordinate Table before The Seven Parameters Transformation can be realized through the use of The Import the Space Rectangular Coordinate Macro before Transformation, the Macro design is shown on Figure 4; Computed data can be saved in The space rectangular coordinate table and also be saved in excel table which eventually being stored in the computer – specified directory, the Macro Design is shown on Figure 5.Lots of programming can be saved just need to use The DoCmd Method to invoke it [15-16].

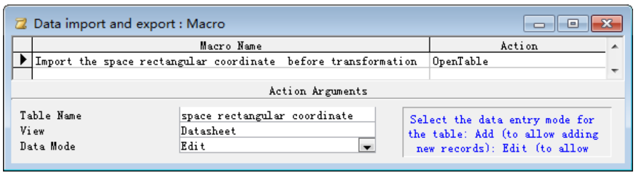

FIGURE 4 Importing the macro of spatial rectangular coordinate before converting

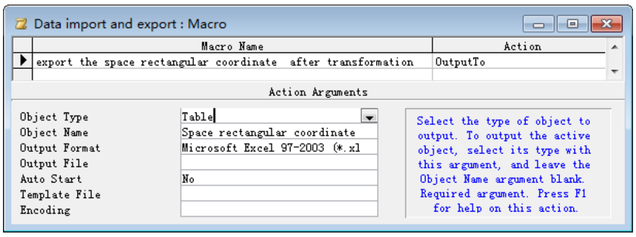

FIGURE 5 Exporting the macro of spatial rectangular coordinate after converting

4.4 CREATING PUBLIC MODULES

In order to make it convenient to realize the Bursa - Wolf Seven Parameters Model Calculation Program, commonly used functions is written into programs and saved in public modules, that will also be convenient for the invoke while the windows program is running, the main content are as follows [17-20]:

'General process of matrix transpose
Public Sub MatrixTrans(A, c)
'Matrix multiplication
Public Sub MatrixMulty(Qn,Qa,Qb)
'List out the general procedures of the Gaussian Pivot Element Reduction Method solving the Liner System of Equations
Public Sub MajorInColGuass(A,B,CX)
'Commonly indirect adjustment
Public Sub InAdjust(A,P,L,CX)

5 Simulation program verification

In order to verify the reliability of the program, two methods were used in production instances to calculate the parameters of the conversion between the WGS84 and Beijing geodetic coordinate system 1954. One is using the established formula and MATLAB together, the other is using the self-programming which is mentioned above. As is shown on table 5, the results are exactly the same, which prove the accuracy of the self-programming.

TABLE 4 Coordinates in the WGS-84, and BJ-54 coordinate systems

Point	X84	Y84	Z84	X54	Y54	Z54
1	-2066241.5001	5360801.8835	2761896.3022	-2066134.4896	5360847.0595	2761895.5970
2	-1983936.0407	5430615.7282	2685375.7214	-1983828.7084	5430658.9827	2685374.6681
3	-1887112.7302	5468749.1944	2677688.9806	-1887005.1714	5468790.6487	2677687.2680
4	-1808505.4212	5512502.2716	2642356.5720	-1808397.7260	5512542.0921	2642354.4550
5	-1847017.0670	5573542.7934	2483802.9904	-1846909.0036	5573582.6511	2483801.6147

TABLE 5 The comparison of the programming and the value of an instance

Point name	Calculate data From arranges	Instance data	Δ
PYX	-9.30886	-9.30886	0
PYY	26.01370	26.01370	0
PYZ	12.29813	12.29813	0
XZX	0.516831	0.516831	0
XZY	-1.218477	-1.218477	0
XZZ	3.506988	3.506988	0
CDBM	-4.2714819	-4.2714819	0

6 Conclusion

Access is one of the Office suites, which is a very powerful tool and easily used in data processing. This paper based on the principle of Bursa-Wolf coordinate transformation model and introduced a self-made simulation program which made full use of the feature that Access VBA can easily link its database. This simulation program has been verified to meet the needs of production by instances. For this, it's easy for non-computer professionals to write a simulation program which is low-cost, convenient, fast, and accurate so that problems in production can be better solved.

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Authors

Yusheng Gong

Current position, grades: lecturer of School of Civil Engineering, University of Science and Technology Liaoning
University studies: master's degree from Liaoning Technical University
Scientific interest: majors in GNSS and research and application of Engineering Survey.