Data Capture Quality Control Issues in Cadastration

Prof. Penggen CHENG, Associate Prof. Rong LIU and Chengrui WANG, China

Key words: Cadastration, Data Quality, Control, Grade Adjustmen, Gross Error Detectiont.

ABSTRACT

Cadastral data quality directly influences the veracity and authority of cadastral. One of the main problems to build cadastre information system is the data quality problem. In general, some courses, such as proprietary investigation, boundary point and feature point data capture, and the surveying data handle, are the key of influencing cadastral data quality. The objective of this paper is to explore the data capture quality control issues in digital cadastre taking into account Chinese situation.

Firstly, the quality control of property investigation and boundary point surveying are discussed based on data collecting procedures of digital cadastre. For this purpose, in practice, work units can be defined on bases of street blocks. Property investigation follows the mode of 'application-investigation-surveying' so as to finish one block by one work group in one-step. This mode can effectively avoid mistakes and omission, and thus guarantee the quality of property investigation in the field. Secondly, Some geometric conditions, such as orthogonal conditions, line conditions and distance conditions, which the boundary points should be satisfy to, are discussed, and conditional adjustment method is adopted in surveying data procession. Thirdly, Graded adjustment method for large amount of boundary points in one area is proposed. There can be 1 grade to 3 grades in graded adjustments according to the complexity of feature points. In cases of simple figures and few conditions, there is no need for graded adjustment, just list all condition equations and adjust them integrally. In cases of more complex figures, 2 grades, or even 3 grades of adjustment may be necessary. Exterior boundary points of a street block are used as first grade control, forming a closed route. Then list condition equations for them and adjust them. The coordinates of those exterior points are then used as fixed in the adjustment next grade, and the interior points of buildings can be adjusted with respect to orthogonal conditions. Lastly, a feasible technical method to eliminate gross errors is presented. Data detection and thresholding method, for instance, are adopted to find and eliminate gross errors.

In summary, the work mode of 'application-investigation-surveying' can finish work in one-step by one group, and thus can guarantee the quality of property investigation in field. Graded adjustment can solve the batch adjustment of boundary points within an area. Adjustment, accuracy assessment, and feasible technical method to eliminate gross errors can enhance the accuracy of captured data, and thus are helpful to the quality control of cadastral data capture.

CONTACT

Penggen CHENG, Professor
Surveying Department, East China Geological Institute
14 Huanchengxi Road, Fuzhou city
Jiangxi Province
CHINA, 344000
Tel. + 86 0794 8258491
Fax + 86 0794 8258828
E-mail: pgcheng@21cn.com

Rong LIU, Associate Professor
Surveying Department, East China Geological Institute
14 Huanchengxi Road, Fuzhou city
Jiangxi Province
CHINA, 344000
Tel. + 86 0794 8258022
Fax + 86 0794 8258828
E-mail: rong_lliu@263.net

Chengrui WANG, Engineer
Surveying and Mapping Department, Jiangxi CoalField Geology Survey Bureau
Nanchan city, Jiangxi province
China, 330000
Tel. + 86 0791 5225453
Fax + 86 0791 5231772
E-mail: jxmtch@sina.com.cn

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1. INTRODUCTION

The quality of cadastral data influences the accuracy and authority of cadastral information. One of key problems in establishing a cadastral information system is the quality of data. Generally speaking, the quality of property investigation, boundary point and feature point surveying, and data processing are key factors to the quality of a cadastral data set. To ensure the quality and reliability of cadastral data, strict quality control measures should be taken in processes such as property investigation, boundary point survey, data processing, data input and quality checking. Quality control methods of cadastral data capture are discussed in this paper based on the practice of the authors.

2. QUALITY CONTROL OF PROPERTY INVESTIGATION AND BOUNDARY POINT SURVEYING

Fieldwork of property investigation is the process of attribute data capture for a cadastral information system. This process involves many complicated aspects of a property and the result of the investigation has legal status. In practice, work units can be defined on bases of street blocks. Property investigation follows the mode of 'application-investigation-surveying' so as to finish one block by one work group in one-step. This mode can effectively avoid mistakes and omission, and thus guarantee the quality of property investigation in the field.

Currently, boundary point and terrain feature point data are captured by field analytical methods, and softwares used in fieldworks includes Qinghua's EPSW digital mapping system, CASS by Southern Company, and Wuhan READER's RDMS. The data capture processes are generally as follows: check boundary points, survey boundary points and feature points, input code and connecting information, draw draft, input data, edit data, draft cadastral maps, create cadastral database. Practical steps are as following:

(1) Check cadastral elements at first, and then do surveying, computation and drafting. This will ensure the precision of the data from field property investigation.

(2) Select the best configuration and keep important bolt distance in the course of the surveying and drafting.

(3) In the course of coordinate surveying for unknown points, always refer to known points and known distances; always pay attention to combining conditions between unknown points and conditions of known points for the purpose of overall check and mutual check.

(4) Check distances and coordinates for all boundary points and boundary lines.

Errors, even blunders, always exist in coordinate surveying of boundary points and features points due to observer factors or non-observer factors. Errors within certain limits are acceptable and can be brought down or eliminated by certain measures in data capture. But blunders, if not eliminated, can disrupt original geometric relationships between feature points. For example, corners of a rectangular building are not orthogonal, buildings that should be parallel are not parallel, electric power poles that are actually on a line do not form a line in the map, etc. So data should be preprocessed to remove blunders before they are put into databases.

3. GEOMETRIC CONDITION BETWEEN BOUNDARY POINTS AND DATA PROCESSION

Boundary points often coincide with some artificial feature points or natural feature points. Conditions between feature points usually include orthogonal conditions, parallel conditions, distance conditions, line conditions and area conditions. Thereby, boundary points should also fulfill these conditions, amongst which orthogonal conditions, line conditions and distance conditions are most common(Cheng,1997). Let (X_i^0, Y_i^0)¡¢$(\hat{X}_i, \hat{Y}_i)(i = 1,2,...,n)$ denote observed values and adjusted values of coordinates of feature points respectively, then

$$\left.\begin{aligned} \hat{X}_i &= X_i^0 + x_i \\ \hat{Y}_i &= Y_i^0 + y_i \end{aligned}\right\} (i = 1, 2, ..., n) \quad (1)$$

Here x_i, y_i denote residuals the of X_i^0, Y_i^0 respectively.

3.1 The Orthogonal Conditions and Line Conditions

As shown in (a), (b) of Figure 1, provided that point *i, j* and k form an angle β, then there exists following condition:

$$\hat{\alpha}_{ik} - \hat{\alpha}_{ij} = \beta \quad (2)$$

Where $\hat{\alpha}_{ik}$¡¢$\hat{\alpha}_{ij}$ denote azimuth of line *ik* and *ij* respectively. This condition can be decomposed as:

$$a_{ik}x_k + b_{ik}y_k - (a_{ik} - a_{ij})x_i - (b_{ik} - b_{ij})y_i - a_{ij}x_j - b_{ij}y_j + w_i = 0 \quad (3)$$

where $a_{ij} = -\frac{Y_j^0 - Y_i^0}{(S_{ij}^0)^2}\rho'', b_{ij} = \frac{X_j^0 - X_i^0}{(S_{ij}^0)^2}\rho'', a_{ik} = -\frac{Y_k^0 - Y_i^0}{(S_{ik}^0)^2}\rho'', b_{ik} = \frac{X_k^0 - X_i^0}{(S_{ik}^0)^2}\rho''$, and

$$w_i = arctg\frac{y_k - y_i}{x_k - x_i} - arctg\frac{y_j - y_i}{x_j - x_i}.$$

When $\beta = \frac{\pi}{2}$ or $\beta = \frac{3}{2}\pi$, equation (3) indicates a orthogonal condition, while $\beta = \pi$, equation (3) becomes a line condition.

If *n* points of building corners are surveyed and there exist *r* orthogonal conditions and line conditions among them, from equation (3) we have:

$$\underset{r,2n}{A}\ \underset{2n,1}{V} - \underset{r,1}{W} = 0 \quad (4)$$

where $\underset{2n,1}{V} = (x_1, y_1, ..., x_n, y_n)^T$.

3.2 Distance Condition

As shown in (C) of Figure 1, provided that the distance between point *i* and point *j* is $\hat{L}_k$ £¬and the observed value is L_k^0 , then there exists a condition as following:

$$\hat{L}_k = \sqrt{(\hat{X}_j - \hat{X}_i)^2 + (\hat{Y}_j - \hat{Y}_i)^2} \quad (5)$$

Equation (5) can be decomposed as:

$$-b_{ij}x_i + a_{ij}y_i + b_{ij}x_j - a_{ij}y_j - v_k - l_k = 0 \quad (6)$$

where $a_{ij} = -\frac{Y_j^0 - Y_i^0}{S_{ij}^0}, b_{ij} = \frac{X_j^0 - X_i^0}{S_{ij}^0}, l_k = L_k^0 - S_{ij}^0 = L_k^0 - \sqrt{(X_j^0 - X_i^0)^2 + (Y_j^0 - Y_i^0)^2}$.

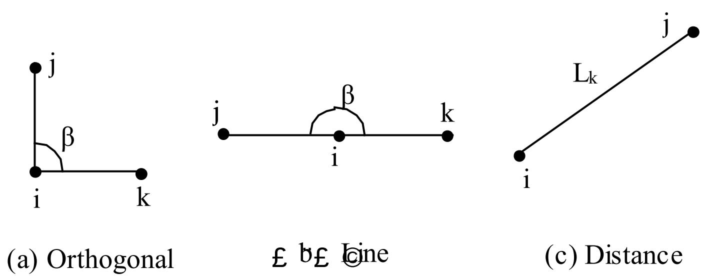

Figure 1. Geometric Conditions for Boundary Points

If *m* distances among *n* boundary points are measured, then we get the following distance condition equations from equation (6):

$$\underset{m,2n}{A}\,\underset{2n,1}{V} - \underset{m,1}{W} = 0 \quad (7)$$

where $\underset{2n+m,1}{V} = (x_1, y_1, ..., x_n, y_n, v_1, ..., v_m)^T$.

3.2 Data Procession

Assuming that the number of the boundary points constituting the conditions is *n*, the number of observed distances is *m*, define *u=2n+m,* and the total number of the conditions is r. Integrating formula (4), (7) we can get the general model of the condition equations as:

$$\underset{r,u}{A}\,\underset{u,1}{V} - \underset{r,1}{W} = 0 \quad (8)$$

where $\underset{u,1}{V} = (x_1, y_1, ..., x_n, y_n, v_1, ..., v_m)^T$.

The random model is:

$$\underset{u,u}{D} = \sigma_0^2 \underset{u,u}{Q} = \sigma_0^2 \underset{u,u}{P}^{-1} \quad (9)$$

According to condition adjustment method, we obtain normalized equation:

$$\underset{u,u}{N_{aa}} K - W = 0 \qquad (10)$$

Its solution is:

$$K = N_{aa}^{-1}W \quad (11)$$

The residual equation is:

$$V = P^{-1}A^{T}K \quad (12)$$

The equation for adjusted observation values is:

$$\hat{\underset{u,1}{L}} = L^{0} + V \quad (13)$$

where $\underset{u,1}{L^{0}} = (X_{1}^{0}, Y_{1}^{0}, ..., X_{n}^{0}, Y_{n}^{0}, L_{1}^{0}, ..., L_{m}^{0})^{T} = (l_{1}, l_{2}, ..., l_{u})^{T}$.

The estimated value of unit weight variance is:

$$\hat{\sigma}^{2} = \frac{V^{T}PV}{r} \quad (14)$$

where $V^{T}PV = W^{T}K$.

The cofactor matrix of V is:

$$Q_{VV} = QA^{T}N_{aa}^{-1}AQ \quad (15)$$

4. THE METHOD OF GRADED ADJUSTMENT OF THE BOUNDARY POINTS

In order to enhance accuracy and reliability, the results of field surveying need to be processed and adjusted. In practice, not only specific orthogonal conditions, line conditions, parallel conditions should be processed, the more usual case is that all boundary points or feature points of buildings in an area need to be adjusted in batches. Because of all sorts of conditions and the inter-relationship of houses, the methods used to deal with only rectangular conditions are obviously not adequate any more. The method of graded control and graded adjustment is applicable in case of batch adjustment of boundary points (Dong ,1998).

There can be 1 grade to 3 grades in graded adjustments according to the complexity of feature points. In cases of simple figures and few conditions, there is no need for graded adjustment, just list all condition equations and adjust them integrally. In cases of more complex figures, 2 grades, or even 3 grades of adjustment may be necessary. Exterior boundary points of a street block are used as first grade control, forming a closed route. Then list condition equations for them and adjust them. The coordinates of those exterior points are then used as fixed in the adjustment next grade, and the interior points of buildings can be adjusted with respect to rectangular conditions. As indicated in Figure 2, at first points 10~16 in block A and B are adjusted as traverse network points, then these points are used as control points and other boundary points inside block A and B are adjusted respectively.

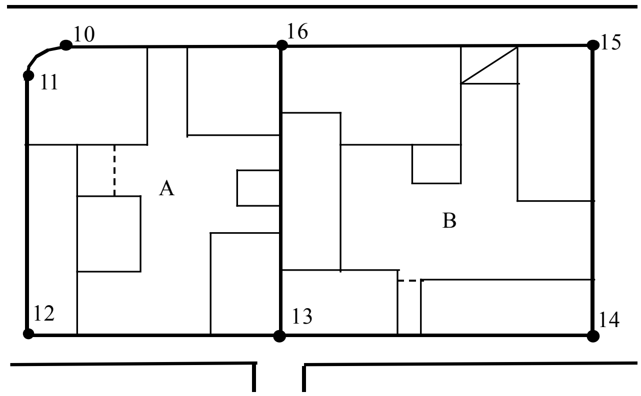

Figure 2. A Street Map

5. THE METHODS OF BLUNDER DETECTION IN BOUNDARY POINTS

5.1 Data Detection

The estimated $\hat{\sigma}_0$ of unit weight variance and self-coefficient matrix Q_{vv} of V may be obtained through (14), (15) in the condition adjustment model. Suppose there is only one gross error in the observation at most, the following statistical value can be obtained according to the method of data detection

$$\omega_i = \frac{v_i}{\sigma_{v_i}} = \frac{v_i}{\sigma_0 \sqrt{q_{v_{ii}}}} \quad (16)$$

where ω_i denotes the normalized residual, $q_{v_{ii}}$ denotes the i^{th} diagonal element in matrix Q_{vv}. Suppose two hypothesis, the first is H_0: E£¨v_i£©=0, the optional hypothesis is H_1: E(v_i)¡Ù0. If there is a blunder in the observation l_i, it can be detected by statistically analyze the normalized ω_i because it obey normal distribution. This can be done by giving a significance level α(α=0.1%), and looking up the limit value from a normal distribution table, which is K_α =3.29. If $\omega_i < K_\alpha$, then the observation is normal, otherwise there it may a gross error.

When there are many blunders in the observations, the effect of data detection for blunders is not significant and other methods may be used, such as iteration and linear programming (Li,1988). The basic idea of iteration method is: adjustment is started with least squares method as usual, the weight of each observation is recalculated according to residuals and related parameters with a selected function, and the recalculated weights are used in the next iteration of adjustment. If a proper weight function is selected, gross errors can be located and the weights of observations which contain blunders will become smaller and smaller and verge to zero.

5.2 Thresholding Method

Gross errors may be eliminated by thresholding. When the angle between two lines does not exceed certain extent from a right-angle or a straight angle, then do adjustment, otherwise gross errors may exist and must be eliminated.

6. CONCLUSIONS

In summary, the work mode of 'pplication-investigation-surveying' can finish work in one-step by one group, and thus can guarantee the quality of property investigation in field. Graded adjustment can solve the batch adjustment of boundary points within an area. Adjustment and accuracy assessment can enhance the accuracy of captured data, and thus are helpful to the quality control of cadastral data capture.

REFERENCES

Cheng, P.G., Liu, R., and Zhen Q.R., 1997, Discussion on the gross error location method of feature point in data collection, Journal of East China Geological Institute, Vol.20(1), 39-47

Dong X.H., Liu D.J., 1998, The Graded Adjustment of Digital Data in GIS, The Proceeding of 1998’ CAGIS, 176-181, Shenzhen

Li D.R., 1988, Errors Procession and Reliability Theory, Beijing: Surveying and Mapping Press

Liu D.J., Meng X.L. 1997, Procession of Orthogonal Features and Line Features in Digitization, Journal of Wuhan Technical University of Surveying and Mapping, Vol 22(2), 125-128

Wuhan Technical University of Surveying and Mapping, 1996, Foundation of Surveying Adjustment, Beijing: Surveying and Mapping Press

Yang D.L., Sun J., 1998, Quality Control of Data Capture for Large Scale Topographic Maps. The Proceeding of 1998’ CAGIS, 186-188, Shenzhen

Zhou Z.J. 1998, Quality Control of Cadastral Information Systems. The Proceeding of 1998’ CAGIS, 186-188, Shenzhen.

BIOGRAPHICAL NOTES

Penggen CHENG is currently Vice-Director of Land and Information Engineering Graduate School and Professor at Department of Surveying, The East China Geological Institute. He is doctor candidate of Wuhan University, commissary of Science and Education Committee of Chinese Geographical Information Systems Association. He was awarded the honor of outstanding contribution mid-youth expert of Nuclear Industry General Corporation in 1998. He has published more than 50 papers. His research interests include engineering suryveying; cadastre surveying; system design and development of GIS; three-dimensional spatial data model; integration of GIS and remote sensing.