ACCURACY TEST AND METHOD CHOICE FOR MAP DIGITIZATION

Feng-Tyan Lin
Graduate Institute of Building and Planning
National Taiwan University
Taipei, Taiwan106, R.O.C.

ABSTRACT

The measurement of accuracy is one of the most important features of data quality. Many statistical and practical criteria have been set for paper map digitization under various situations and considerations. This article explores the theoretical relationship between statistical and practical accuracy tests, and proposes a framework of cost-accuracy analysis for choosing appropriate digitization methods. Eight trials using three digitization methods on two Taiwan zoning maps with different original qualities were performed to illustrate the differences between statistical and practical methods. The results showed that (1) the test for the mean of the errors should be included in the practical criteria, (2) the error tolerance standard for maps in poor condition can be raised from 0.5mm to 0.3mm, (3) it is sufficient to digitize maps in good condition using the 100dpi-screen method, (4) appropriate digitization methods can be varied according to different map qualities, accuracy criteria, and budget.

I. INTRODUCTION

To utilize powerful capabilities of spatial queries and analyses in Geographical Information Systems, a great deal of preliminary work must be done converting paper maps into digital forms. Since different map digitization processes will introduce various degrees of errors, it is necessary to establish some criteria to ensure the data quality.

Accuracy, which is the degree of conformity between original maps and digitized maps with a standard or accepted value, is one of the most important aspects of data quality [12, 13]. While the accuracy standard of map digitization is commonly stated in terms of error tolerance ε and threshold ratio of bad products β in practice [2, 3, 6, 8, 10, 15], it can also be stated in a statistical way involving mean $\overline{X}$ and standard deviation σ in a level of significance α [1, 4, 16]. Although there is a certain relationship between the practical and statistical measurements, they are not equivalent and need to be explored further.

Moreover, one has to consider various factors, including the purposes of the maps, the data quality of original paper maps, production costs, and budget, when choosing appropriate methods of accuracy measurement and digitization [14]. In practice, data authorities usually follow some conventions of data accuracy requirements. However, it is also usually found that the measurement methods and critical criteria need to be fine-tuned to accommodate various situations. It will be very helpful for data authorities to have a scheme for choosing appropriate accuracy standards and digitization methods.

This article will review current data accuracy standards, suggest a centripetal method for verifying data accuracy of zoning map digitization in Taiwan, and propose a cost-accuracy analysis to help data authorities formulate their digitization policy.

The structure of this article is as follows. Section 2 will explore the relationship and the difference between statistical and practical accuracy measurements. Section 3 will introduce the scheme of cost-accuracy analysis. Section 4 will discuss the centripetal method for data accuracy measurement, and introduce an exploratory study involving two map cases and eight trials. Section 5 will reveal and discuss the results, and suggest possible new criteria and digitization policies based on these two cases. Finally, Section 6 provides be the conclusions from this study.

II. DATA ACCURACY TESTS

In a digitization process, data accuracy may be affected by gross, systematic, and random errors[15]. Gross errors are caused by carelessness or inattention of the observer during digitization. Normally, some standard procedures are designed to detect gross errors during or immediately after digitization. Systematic errors might be caused by instruments and/or the quality of the original map, while random errors are mostly associated with the skill of the digitization operator.

As mentioned above, systematic and random errors can be identified in a statistical or practical way. These two approaches are highly related but different. However, they can take advantage of valuable information from each other to establish more concrete and consistent criteria. A theoretical exploration is discussed below.

To identify if there is a systematic error in a digitization process, one may statistically test the mean of the errors against an expected error to see if there is a significant difference. Since the expected error is zero, the null hypothesis and the alternative are H_0: $\mu=0$ and H_1: $\mu\neq0$, respectively. By choosing a level of significance α, the mean of errors of the digitization can be tested. Conventionally, levels of significance are set to be 0.01 or 0.05 and are associated with corresponding critical regions. If the standardized normal value Z calculated from the digitization falls into the critical region, the null hypothesis will be rejected and the alternative will be accepted, which means that the average error of the digitization is highly significantly (when $\alpha=0.01$) or significantly (when $\alpha=0.05$) different from zero. Otherwise, the null hypothesis is accepted.

Random errors can be statistically examined by testing the standard deviation s of the trial against the expected variance σ_0. On the other hand, most data authorities usually state this requirement in a practical way such that the proportion of error points exceeding a certain tolerance ε should be less than a threshold ratio β. Conventionally, the error tolerance

Table 1. Expected Standard Deviations σ_0 with $\beta=10\%$

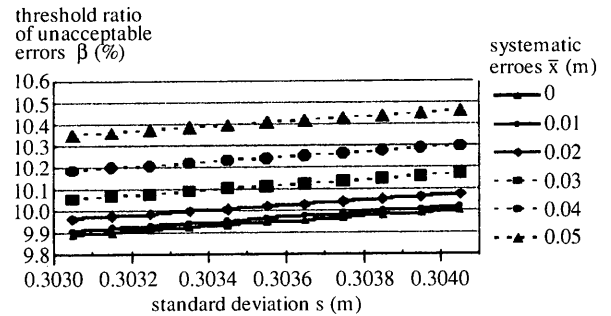|	Error tolerances on maps			
	0.2mm	0.3mm	0.4mm	0.5mm
1/1000 maps	0.12158	0.18237	0.24316	0.30395
1/3000 maps	0.36474	0.54711	0.72948	0.91185

Fig. 1. Theoretical relationships among systematic errors, standard deviation, and threshold ratio of unacceptable errors.

ε is set between 0.2 mm to 0.5 mm on maps, and the threshold ratio β is 10% [2, 3, 6, 8, 10]. Thus, a relationship between the standard deviation s and practical criteria ε and β can be established by the following formula:

$$Z_{\beta/2}=\varepsilon/\sigma_0 \quad \text{or} \quad \sigma_0=\varepsilon/Z_{\beta/2} \tag{1}$$

where $Z_{\beta/2}$ is the Z-value corresponding to $\beta/2$ in the standard normal distribution, and the value of error tolerance ε should be in terms of ground distances. The values of critical standard deviations associated with different levels of tolerances and different scales, say 1/1000 and 1/3000, of maps are illustrated in Table 1. Then, the standard deviation of the errors can be examined by performing the χ^2 test with the hypothesis: H_0: $\sigma^2=\sigma_0^2$, H_1: $\sigma^2>\sigma_0^2$.

It is surprising to find that practical criteria rarely test if the mean of the errors of a digitization is not statistically different from 0 at a certain level of significance. This implies that practical tests might accept a digitization with systematic errors. Fig. 1 illustrates some examples. The combinations of systematic errors and standard deviations below the line $\beta=10\%$ with error tolerance $\varepsilon=0.5$mm on a map of the scale of 1/1000 are acceptable for practical purposes. The lowest dotted line indicates cases of various standard deviations where the systematic error $\overline{X}=0$. It is noted that, for example, the case of ($\overline{X}=0.02$m, $s=0.3030$) is accepted because the corresponding ratio $\beta=9.96\% <10\%$. Since, it is desirable to eliminate as many systematic errors as

possible, practical tests should also include tests of the mean of errors.

Moreover, conventional criteria of error tolerance ε and threshold ratio of unacceptable errors β could be reviewed based on digitization trials. The possibly smaller error tolerance $\tilde{\varepsilon}$ and smaller threshold ratio $\tilde{\beta}$ hold the following equivalent relations.

$$\tilde{\varepsilon} = s \times Z_{\tilde{\beta}/2} \quad \text{or} \tag{2}$$

$$Possibility(\overline{x} \geq \tilde{\varepsilon} \ \text{and} \ \overline{x} \leq - \tilde{\varepsilon}) = \tilde{\beta} \tag{3}$$

It is not difficult to see that better digitization quality with a smaller standard deviation s is able to afford a more rigid digitization accuracy requirement of a smaller error tolerance $\tilde{\varepsilon}$ and threshold ratio $\tilde{\beta}$. Since it is convenient to have $\tilde{\beta}=\beta$, Eqs. (2-3) can be rewritten as follows.

$$\tilde{\varepsilon} = s \times Z_{\beta/2} \quad \text{or} \tag{4}$$

$$Possibility(\overline{x} \geq \tilde{\varepsilon} \ \text{and} \ \overline{x} \leq - \tilde{\varepsilon}) = \beta \tag{5}$$

III. COST-ACCURACY ANALYSIS FOR DIGITIZATION METHOD CHOICE

In addition to accuracy, cost is another important consideration when performing map digitization. A cost-accuracy analysis will be very helpful in making decisions about choosing an appropriate digitization method, setting up a budget and defining accuracy requirements.

While data authorities expect high data accuracy, data producers try to reduce their costs as long as a certain level of accuracy is satisfied. One might think that the higher the accuracy, the greater the cost. However, this is not necessarily true. It is possible that higher accuracy can be achieved at a lower cost due to new, cheaper equipment and choosing an appropriate digitization method.

Figure 2 conceptually illustrates some possible combinations of costs and accuracy. Combination G does not meet the minimum accuracy requirement, and combination E exceeds the budget. Both of them would be discarded. Combination A would be the optimal choice since it has the lowest cost and highest accuracy. If combination A did not exist, the data producer would most likely choose combination C. On the other hand, data authorities pursuing higher data accuracy would try to rise the minimum accuracy requirement to somewhere between B and C to exclude combination C.

It is worth noting that cost-accuracy analysis does not require actual costs of digitization. Ordinal ranks of costs are sufficient for deciding or choosing
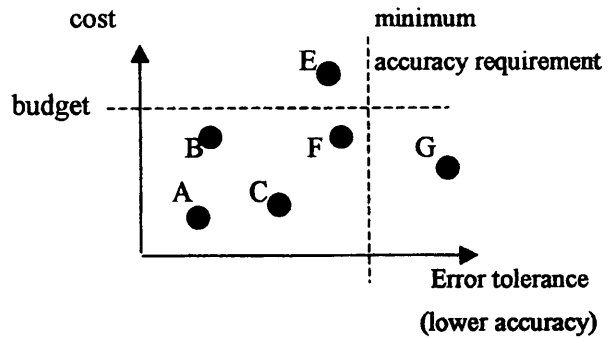

Fig. 2. Conceptual illustration of cost-accuracy analysis.

an appropriate cost-accuracy combination.

IV. EXPLORATORY STUDY

In 1982, N. R. Chrisman introduced the epsilon model of cartographic lines to describe positional accuracy and measurement errors [4]. Since then, many experiments concerning data accuracy have been made. Each study had its own concern and particular approach. Ho [5] and Maffini, Arno and Bitterlich [11] respectively studied systematic and random errors where original maps were generated by CAD. Lay [7], Lin and Chang [9], and Maffini, Arno and Bitterlich [11] studied the problems of data accuracy when maps were overlaid. Warner [17] and Ho [5] studied errors associated with standard tablets. Tsai [14] and Ho [5] were concerned with the digitization accuracy of contours on topological maps, while Liu [10] was concerned with the same subject, but on cadastral maps.

In Taiwan, there is a large number of zoning maps of urban plans which need to be digitized. To generate useful guidelines for the practice of zoning map digitization, some trials were conducted in this research, based on the framework of accuracy tests and cost-accuracy analysis mentioned above.

It is noted that many archival zoning maps in Taiwan lack the recording of absolute coordinates on the ground; moreover, many topographical objects on the maps can no longer be found on the ground due to buildings, roadways, or infrastructure (re)constructions. Therefore, data authorities might only be able to assert a certain level of relative accuracy against the original zoning map instead of checking the absolute position against the ground truth.

A centripetal approach is taken in this article to handle issues concerning relative accuracy in the cases of archival zoning maps in Taiwan. The approach can be summarized as follows.

First of all, a precise rectangle bounding the whole map and a centroid are drawn on each original map whose area corresponds to 400m×600m on the

Table 2. Criteria for Testing Digitization Accuracy

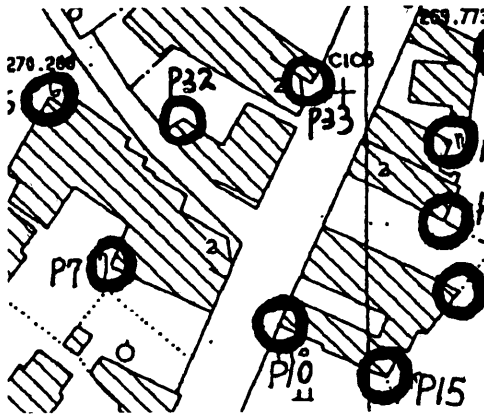| Map scale	Expected mean of the errors	The level of significance for testing the mean	Threshold deviations (on ground distance)	Threshold ratio of unacceptable points
1/1000	$\mu_0=0$	$\alpha=0.01$	$\sigma_0=0.30395$m	$\beta=0.1$
1/3000	$\mu_0=0$	$\alpha=0.01$	$\sigma_0=0.91185$m	$\beta=0.1$

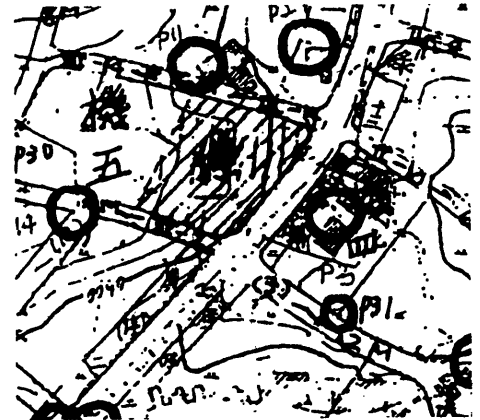Fig. 3. Map of Chi-shang (portion). Circles indicate locations of test points.

Fig. 4. Map of Dan-shui (portion). Circles indicates locations of test points.

ground. The centroid and the four corners of the rectangle serve as control points. These five control points are digitized. If a systematic error is detected by checking the relative distances among the control points on the computer, the digitization equipment has to be adjusted before further digitization. After digitization, 40 test points are selected from each original map. The test points should be evenly scattered on the map. The distances between each test point and the centroid are measured on the original map and the computer using CAD software to avoid unnecessary plotting errors [4]. Digitization errors, which are the differences between corresponding distances, are then further calculated. Thus, the epsilon model can be applied to our exploration. Finally, an accuracy standard can be applied to determine if the digitized maps can be accepted.

Generally speaking, the quality of original zoning maps in Taiwan can be roughly classified into two levels according to their scale. Maps of the scale of 1/3000 being drawn in pencil at least thirty years ago are in bad condition, while those of 1/1000 are good. Therefore, two experimental maps, Chi-shang of 1/1000 and Dan-shui of 1/3000, were selected for the trials. Portions of these two maps are illustrated in Figs. 3 and 4, respectively.

Recalling that the main purpose is to find out appropriate standards at a reasonable cost instead of the standard corresponding to the highest or the average accuracy as in practice, the data authority considers the resulting standards based on the following test environment. Components in the test environment were (1) workers with at least 3 months' digitization experience, (2) a drum-based gray-scale scanner of model LS-3600™, Microtek, which can process maps of A0 size in 300 and 100 dpi, (3) an image processing and screen digitization software, CAD Overlay™, Image Systems Technology, Inc., (4) Tablet digitizer, DrawingBoard III™, Calcomp, of A0 size with 1200 lpi, and (5) two maps, one in good condition and one in poor condition.

Three common digitization methods were used in the exploration: (1) scanning in 300dpi and digitizing on the screen, called '300dpi-screen' for short, (2) scanning in 100dpi and digitizing on the screen, called '100dpi-screen' for short, (3) digitizing on the tablet, called 'tablet' for short.

Table 2 illustrates the criteria of statistical tests corresponding to the practical accuracy standard. The ratio of unacceptable error points exceeding 0.5 mm on maps should be less than 10% out of 40 tested points, for digitizing zoning maps in Taiwan.

In addition to measuring, calculating, and testing the means and standard deviations of the errors, the F-test was also employed to see how the original map quality affected the quality of the digitization, and to verify if various methods of map digitization showed any significant difference in the quality of the digitization on a specific map.

Table 3. Results of Statistical Tests

Map name	Digitization methods		Mean ($\overline{X}$)	Standard deviation (s)	Z-value	Test for mean	Test for variance	Possibly smaller error tolerance (ε)
Chi-shang	screen	300dpi	-0.035	0.1984	1.1130	Pass	Pass	0.3
		100dpi(1)	0.1332	0.2157	3.9044	Fail	--	--
		100dpi(2)	-0.0118	0.2200	0.3384	Pass	Pass	0.3
	tablet		0.0540	0.1842	1.8526	Pass	Pass	0.3
Dan-shui	screen	300dpi	0.050	0.5088	0.6161	Pass	Pass	0.3
		100dpi(1)	-0.6183	1.5329	2.5510	Pass	Fail	--
		100dpi(2)	-0.1371	1.0908	-0.7951	Pass	Fail	--
	tablet		0.1245	0.7142	1.1028	Pass	Pass	0.4

Table 4. F-test between Digitization Methods

	300dpi	100dpi(1)	100dpi(2)	Tablet
300dpi	--	1.18	1.23	1.16
100dpi(1)	9.08	--	1.04	1.37
100dpi(2)	4.60	1.97	--	1.43
Tablet	1.97	4.61	2.33	--

[†]$F_{0.01}(39,39)=2.1$; $F_{0.05}(39,39)=1.7$. A number falls in critical regions, if it is greater than the corresponding F value.

[††]The upper-right triangular portion shows the case of Chi-shang, while the lower-left is Dan-shui.

V. RESULTS

1. Statistical Tests

The means $\overline{X}$, standard deviations s, Z-values, results of the statistic tests, and the possibly smaller error tolerance ε, where $\hat{\beta}=\beta=0.1$ in Eqs. (4-5), of the trials upon two maps are shown in Table 3. Please note that the method of scanning in 100 dpi of both maps is performed twice due to failure to pass the tests. These two results are denoted as 100dpi(1) and (2), respectively.

The comparisons of the variances σ^2 between different methods by the *F*-test are shown in Table 4, where the upper-right triangular corner is the case of Chi-shang, while the opposite lower-left corner is Dan-shui.

In the case of Chi-shang, both the 300dpi-screen and tablet trials passed the mean test at the 0.01 level of significance and the variance test at the error tolerance 0.5mm on the maps. However, the first 100dpi-screen trial failed the mean test due to a large Z-value in the critical region, which implies a systematic error. After rechecking the process, the second 100dpi-screen trial passed the mean and variance tests. It is noted that there is no difference in the digitization performances of the first and second 100dpi-screen trials according to the corresponding low *f*-value (1.04) in Table 4.

Moreover, the second 100dpi-screen trial had a smaller mean value (−.0118) than that of the 300dpi-screen trial, but it had the same possible error tolerance ($\varepsilon=0.3$) as that of the 300dpi-screen trial. This experience shows that it is not necessary to use higher resolution scanning to get better data accuracy. High data accuracy can be achieved by the 100dpi-screen method without spending unnecessary memory and processing time necessary for the 300dpi-screen method.

In the case of Dan-shui, both tablet and 300dpi-screen trials passed the mean and variance tests. As to the two screen trials, both of them passed the mean tests but failed the variance tests. This experience suggests that the 100-dpi screen method is not suitable for digitizing maps of poor quality.

Table 4 also reveals the influence of the original map quality upon the digitization process. The values in the upper-right triangular portion are smaller than the critical *F* value. This means that the performances of different methods are able to maintain the same quality level when maps of good quality, such as Chi-shang, are digitized. On the other hand, most values in the lower-left corner fall in the critical region. This implies that it is very difficult to maintain the same quality of performance, when maps of poor quality, such as Dan-shui, are digitized.

Table 5. Results of Practical Tests

Map name	Digitization methods		Number of error points				Practical test* (ρ)	Statistical test for variance and ε**
			≥ 0.5mm	0.5-0.4 mm	0.4-0.3 mm	0.3-0.2 mm		
Chi-shang	screen	300dpi	1	1	3	7	Pass (0.4)	Pass (0.3)
		100dpi(1)	2	3	4	8	Pass (0.5)	Fail
		100dpi(2)	1	0	2	5	Pass (0.3)	Pass (0.3)
	tablet		1	0	1	7	Pass (0.3)	Pass (0.3)
Dan-shui	screen	300dpi	0	2	3	2	Pass (0.4)	Pass (0.3)
		100dpi(1)	8	4	2	8	Fail	Fail
		100dpi(2)	1	1	2	6	Pass (0.4)	Fail
	tablet		0	0	3	7	Pass (0.3)	Pass (0.4)

  * ε=0.5mm on the map; achievable accuracy threshold ρ is reported in parentheses.
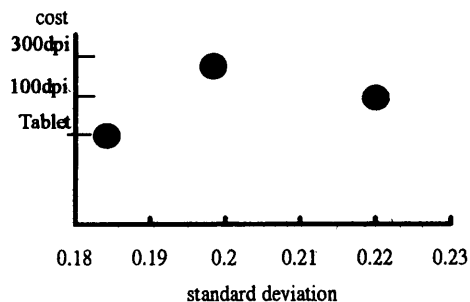** From Table 3.

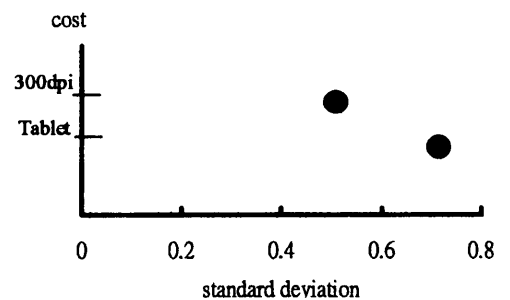Fig. 5. Cost-accuracy analysis of Chi-shang digitization.

Fig. 6. Cost-accuracy analysis of Dan-shui digitization.

2. Practical Tests

It is interesting to compare the results of accuracy tests based on statistical and practical criteria. As mentioned above, the practical criterion in Taiwan for accepting a digitized zonal map is that the proportion of error points exceeding 0.5 mm on maps should be less than 10% out of 40 tested points. Table 5 shows the numbers of tested points exceeding 0.5mm at intervals of 0.1mm between 0.5mm and 0.2 mm on the map. If the point count exceeding 0.5mm is more than 4, which is the 10% of 40 points, the result of the trial will be rejected. If a trial is accepted according to the practical criterion, an achievable accuracy threshold ρ is also reported. Achievable accuracy threshold ρ is the smallest error tolerance where the total number of points beyond ρ is equal to or less than 4. Table 5 also includes the statistical test results from Table 3 for comparing each other.

It is noted that trials of Chi-shang 100dpi-screen(1) and Dan-shui 100dpi-screen(2) passed the tests based on practical criteria but failed the statistical tests. Additionally, the digitization accuracy reported by the statistical tests had better scores than those of the practical tests except the trial of the

Dan-shui tablet. These two observations reflect the fact that the statistical test gives a more complete consideration of mean and variance, and gives a sound evaluation of data accuracy.

3. Cost-Accuracy Analysis

Figures 5 and 6 plot diagrams of cost-accuracy analyses of Chi-shang and Dan-shui, respectively. The X-axis indicates the degree of accuracy in terms of standard deviations, while the Y-axis indicates the relative costs of three digitization methods. In the case of digitizing zoning maps, the tablet method is relatively cheaper than 100- and 300-dpi scanning-and-screen-editing methods. Each dot in the diagrams represents a digitization method.

In the case of Chi-shang, there is an optimal combination that corresponds to the tablet method. On the other hand, the case of Dan-shui is different. While the 300dpi-screen method has better data accuracy, the tablet method has a lower cost. In this situation, the data authority has two choices: acceptable results at a lower cost or set up a more rigid accuracy requirement within an affordable budget. The final decision will be made according to further considerations on other factors.

VI. CONCLUSIONS

The measurement of accuracy is one of the most important features of data quality. Under the conditions of employing operators with more than 3 months experience, using a common digitization instrument, applying the centripetal method, and testing two representative maps in statistical and practical ways, this research found that: (1) the test for the mean of the errors should be included in the practical criteria to detect and reduce systematic errors, (2) the error tolerance standard for digitizing zoning maps in poor condition such as the case of Dan-shui could be raised from 0.5mm to 0.3mm at a reasonable cost, (3) it is sufficient for original maps in good condition to have high data accuracy using the 100dpi-screen method without spending unnecessary memory and processing time that are needed in the 300dpi-screen method, (4) cost-accuracy analysis can help to make digitization policies for different situations of original map quality, digitization methods, accuracy requirements, and budget considerations.

NOMENCLATURE

H_0	the null hypothesis
H_1	the alternative hypothesis
s	the standard deviation of sample errors
$\overline{X}$	mean of errors
Z	the standardized normal value
α	level of significance
β	threshold ratio of poor products in practice
$\tilde{\beta}$	possibly smaller threshold ratio
ε	error tolerance
$\tilde{\varepsilon}$	possibly smaller error tolerance
μ	expected error
ρ	achievable accuracy threshold
σ	standard deviation of errors in population
σ_0	the expected variance of errors in population

REFERENCES

1. Detreköi, Á., "Data Quality Management in GIS Systems," *Computers, Environment and Urban Systems*, Vol. 18, No. 2, pp. 81-85 (1994).
2. DoLTCG, The Final Report of Cadastral Map Digitization Project in Taipei, Department of Land Administration, Taipei City Government, *priv. comm.* (1997).
3. DoLTPG, Hand Book of Cadastral Map Digitization, Department of Land Administration, Taiwan Provincial Government, *priv. comm.* (1997).
4. Dunn, R., H.R. Harrison, and J.C. White, "Positional Accuracy and Measurement Error in Digital Databases of Land Use: an Empirical Study," *International Journal of Geographical Information Systems*, Vol. 4, No. 4, pp. 385-398 (1990).
5. Ho, W.-S., "Accuracy Evaluation of Digital Geographic Data," National Science Council, Taipei, Taiwan, NSC 82-0410-E009-078 (1993).
6. Korte, G.B., The GIS Book: A Practitioner's Handbook, 2nd ed., OnWord Press, Santa Fe, NM, USA (1992).
7. Lay, J.-G., "Accuracy Analysis of Digital Land-use Data," *Journal of Geographical Science*, Taipei, Taiwan, No. 19, pp. 91-103 (1995).
8. Lin, F.-T., "The Declarations and Evaluations of Map Transformation Problems," *Bulletin of the College of Engineering*, NTU, Taiwan, No. 64, pp. 1-15 (1995).
9. Lin, F.-T. and C.-C. Chang, "Spatial Relationship among Geographical Data Sets for Regional Disaster Prevention," *City and Planning*, Vol. 25, No. 1, pp. 23-47 (1998).
10. Liu, Y.-Y., "A Study on Integration of Cadastral and Topological Surveying Systems in Taipei," Bureau of Public Works, Taipei City Government, *priv. comm.* (1992).
11. Maffini, G., M. Arno, and W. Bitterlich, "Observations and Comments on the Generation and Treatment of Error in Digital GIS Data," *Accuracy of Spatial Databases*, eds. Goodchild M. and Gopal S., Taylor & Francis, Bristol, PA, USA, pp. 55-67 (1989).
12. Montgomery G.E. and H.C. Schuch, GIS Data Conversion Handbook, GIS World, Inc., Fort Collins, CO, USA (1993).
13. Star, J. and J. Estes, Geographic Information Systems --An Introduction, Prentice-Hall, Englewood Cliffs, NJ, USA (1990).
14. Tsai, B.-W., "An Evaluation on Digitization Methods of Topological Data," *Proceedings of the 2nd ARC/INFO User Meeting*, Taipei, Taiwan, pp. 1-4 (1992).
15. Thapa, K. and J. Bossler, "Accuracy of Spatial Data Used in Geographic Information Systems," *PE&RS*, Vol. 58, No. 6, pp. 835-841 (1992).
16. Walpole, R.E., Introduction to Statistics, 2nd ed., Macmillan, NY, USA (1974).
17. Warner, W.S. and W. Carson, "Errors Associated with a Standard Digitizing Tablet," *ITC Journal*, No. 2, pp. 83-89 (1991).

Discussions of this paper may appear in the discussion section of a future issue. All discussions should be submitted to the Editor-in-Chief.

成圖數化正確性檢核及數化方法之選擇

林峰田

國立台灣大學建築與城鄉研究所

摘　要

　　圖形資料數化成果的正確度評估乃是資料品質的重要一環。目前評估圖形資料正確性的方法及標準可以分為統計方法及實務方法二大類。本文首先從理論上探討了此二種方法之間的關係，並且進一步的提出了成本分析方法，以協助選擇適宜的數化方法。本文以淡水和池上二個不同原圖品質的地區，利用三種不同的數化方法，共計進行了八次的實驗，以比較統計方法及實務方法在檢核都市計畫分區圖數化成果的差異性，並獲得以下的結論：(1) 實務的數化成果正確性評估項目應加入誤差平均值的檢核，(2)即使原圖品質不佳者，其圖的誤差容許值可以由 0.5mm 提升到 0.3mm，(3) 原圖品質良好者，採用 100dpi 之掃描解析度即可，(4)數化方法的選擇將隨著原圖品質、檢核標準、預算額度而有所不同。

關鍵詞：成圖數化、資料正確度、成本－正確度分析。