CORRELATION OF PADDY FIELD FOR LAND BOUNDARY RECORD

Conrad TANG and Linda GUAN, Hong Kong

Key words: District Sheet, correlation, land boundary record, paddy field

SUMMARY

Land boundary rights are legally documented in land leases in Hong Kong. Demarcation District Sheets (DD Sheet), which have no coordinate reference, are still the legal reference for boundaries of the Block Government Leases in the New Territories, Hong Kong. Land boundary re-establishments are done by the land surveyors in the private sector. Traditional correlation is done with DD Sheet and 1:1000 detailed map. This paper introduces a precise correlation method using ortho-images of the 1960's aerial photos. The method provides correlations with resultant accuracy. It has a potential to be the industrial method of land boundary re-establishment in Hong Kong.

CORRELATION OF PADDY FIELD FOR LAND BOUNDARY REOCRD

Conrad TANG and Linda GUAN, Hong Kong

1. INTRODUCTION

Demarcation District Sheets (DD sheet) were the cadastral survey plans produced by Indian surveyors between November 1899 and May1903 in the New Territories of Hong Kong. The systematic survey was done to identify land ownership and to assess Crown rents. Making use of the DD sheets, the Land Court published announcements urging landowners to give evidence of their titles by producing the old deeds under the late Ching Dynasty and to claim their land as recognized on the DD sheets [Tang & Zhang, 2008].

DD sheets have no coordinate reference information. They give shape and scale of the paddy-field lots. When the physical boundary features still existed, a DD sheet was best used to identify fields with respect to adjacent fields. In recent decades, when traditional agricultural activities were overwhelmed by urban developments, the original field-bunds, which were portrayed as lot boundaries on DD sheets, were destroyed. [Leung et al, 2008]

It is the duty of surveyors to reconstruct the reference frame of DD sheets. A land surveyor may determine boundaries on different preferences according to the shape of DD lots, registered area, previous or existing boundary features and previous survey results.

Although a DD sheet is correlated with a coordinated detailed survey plan showing the previous field-bunds, the limitations on land boundary fixing become apparent and problematic. In many cases, a land surveyor simply correlated the subject lot onto the coordinate survey plan at an arbitrary best-fit location. Some might perform a best mean fit of the subject lot and surrounding lots using DD sheets and survey sheets. Aerial photos were used as a visual reference only.

In recent years, with the advent of digital photogrammetry and GIS platforms, correlation exercises are handily performed between DD sheet and aerial photograph to determine the boundary position of DD sheet nowadays. It is a common knowledge to surveyors that aerial photograph is an image with perspective projection where errors exist because of the tilt of camera axis and terrain relief. It is not suitable for correlating with DD sheet directly, thus orthophotos are used.

2. TECHNICAL SCHEME

The photogrammetry method for the production of digital orthophoto from original aerial photos is well illustrated in [Linder, 2003]. The set of 1963 9-inches black-and-white vertical aerial photos covers the whole territory of Hong Kong. The year 1963 was a record dry year in decades and the aerial photos are an excellent record of the agricultural land use still in practice during the period. By current digital photogrammetric operation, the location of the field-bunds and houses can be determined with sub-meter accuracy. A geo-referencing scheme of a DD sheet is listed as Figure 1.

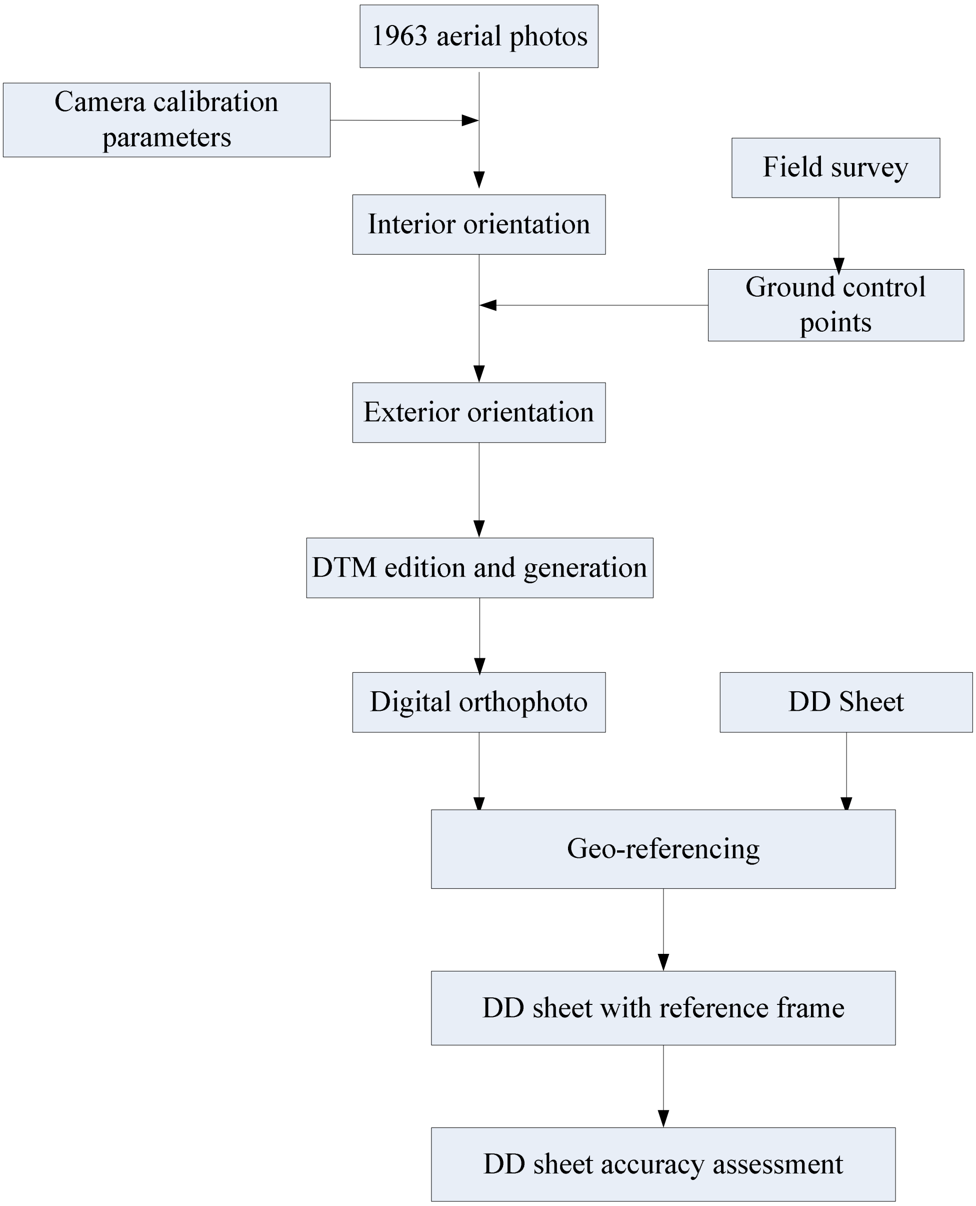

Figure 1 Flowchart of DD sheet geo-referencing

DD sheets are the land grant plans in the Block Government Leases for which the British regime surveyed and granted out leasehold land rights to the people in the New Territories in 1905. In this sub-tropical Asian area, paddy field-bunds were the physical boundaries and they were delineated on the plan-table survey sheets where the lot boundaries corresponded to the field-bunds on ground. To locate the lot boundaries not referring to any existing physical features, as these field-bunds were destroyed in urban developments, the aerial photos of 1963 are of great assistance. In this project, orthophotos are generated from the 1963 set of aerial photos for which control points are still available today. The control points are used to perform geo-referencing on the DD images. Check points are also used to evaluate the positional accuracy of a DD sheet.

2.1 Points distribution

This project studies the position accuracy of the orthophoto adjusted DD images. The field-bund junctions were used as tests points. Figure 2 is the distribution of selected points on a DD sheet. They are Y-junction or T-junction points such that they can be identified and measured on the DD image and the aerial photo. They are used as control points and check points.

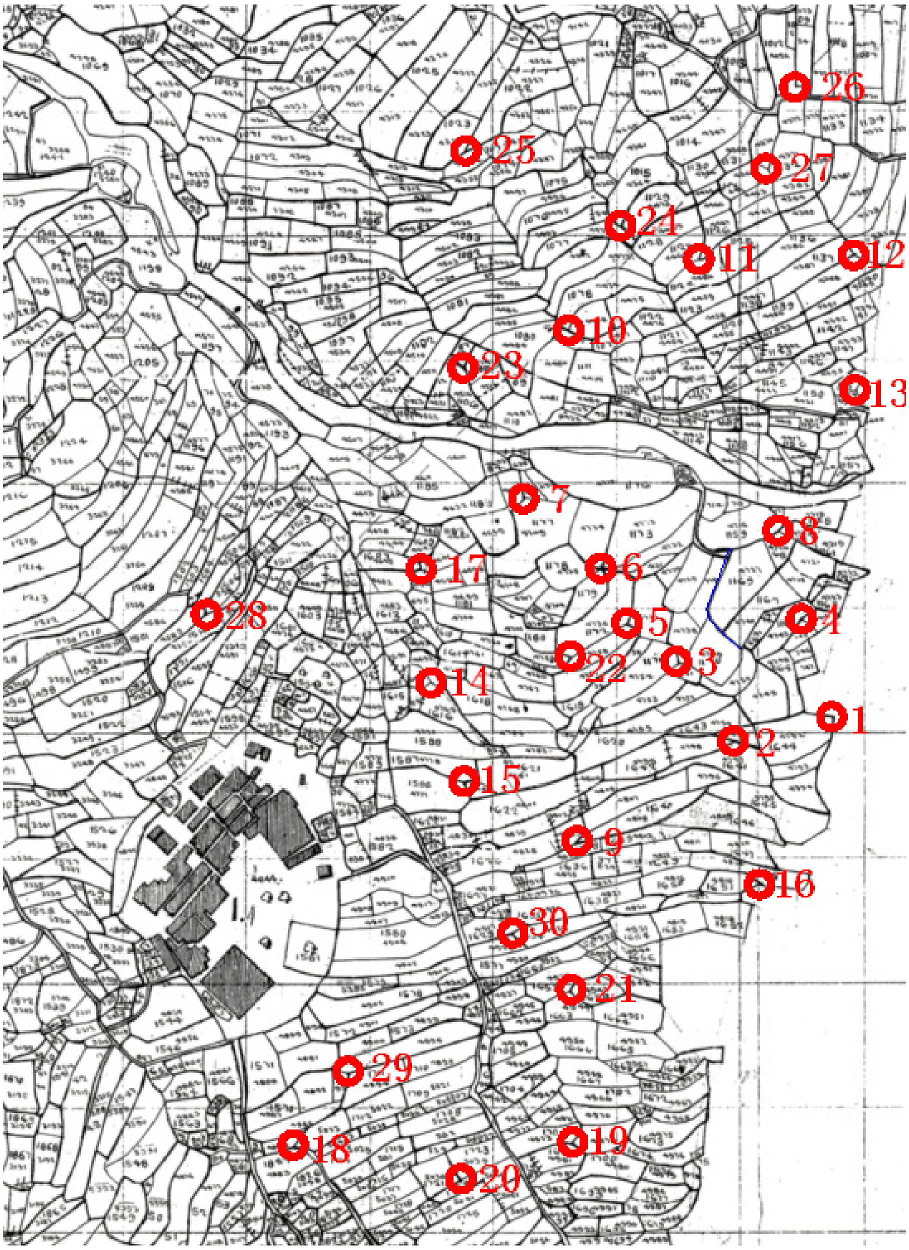

Figure 2 Points distribution

Figure 3 illustrates a junction point (No.4) on DD sheet and on orthophoto.

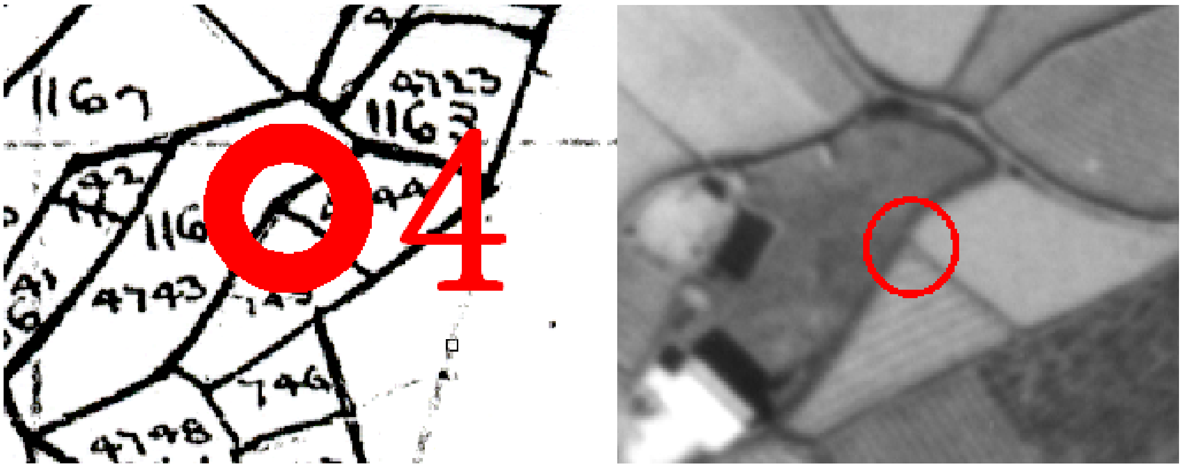

Figure 3 A point on DD sheet and on orthophoto

2.2 Geo-referencing operation

Affine transformation is applied in the geo-referencing of a DD sheet. The affine transformation models six kinds of distortion in the DD sheet, including translation in x, y; scale changes in x, y; skew and rotation distortion. The formula is as follows:

$$x = a_0 + a_1 x' + a_2 y'$$
$$y = b_0 + b_1 x' + b_2 y' \qquad (1)$$

Where

x, y is point coordinates in orthophoto;

x', y' represents corresponding positions on DD sheet;

Coefficients a_0, b_0 control translation in x,y direction respectively, scale changes in x,y are controlled by coefficients $a_{1,} b_2$ respectively. Skew and rotation distortion in x, y are controlled by a_2, b_1 respectively [Jensen, 2005].

Using at least 3 pairs of points coordinates and applying indirect adjustment method to determine the six coefficients, coordinates for each point on DD sheet can be computed. In order to determine how well the six coefficient transformation parameters account for the geometric distortion in the DD sheet, the root mean square error for each of the control points are computed [Jensen, 2005]. In theory, points coordinates computed using six coefficients (x, y) should be equal to coordinate measured on the orthophoto $(x_{measured}, y_{measured})$. In this application, owing to the existing of errors in the original DD survey and the subsequent imperceptible movements of the field-bunds, the DD image may not match the orthophoto perfectly. The discrepancy between them shows the DD sheet distortion not corrected by the affine transformation. The root-mean-square error gives the average positional accuracy of the geo-referenced DD image.

3. EXPERIMENTS AND RESULTS

Two schemes were tested. The average size of lots in the area is about 0.03 acre, or 120 m2. The first scheme was tested within a small area of 4 hectares where the control points were selected adjacent to the shaded subject lot (Figure 4). The second scheme was tested in a larger area of 1 hectare. It was to see whether the distribution of control points had an impact on the accuracy of the geo-referencing DD sheet.

3.1 Experiment scheme 1 and its results

In this scheme, four control points (No. 3, 4, 6, 8) near the subject lot (Lot 1169) are applied in affine transformation (Figure 4). Control points are chosen near to the subject lot in the centre.

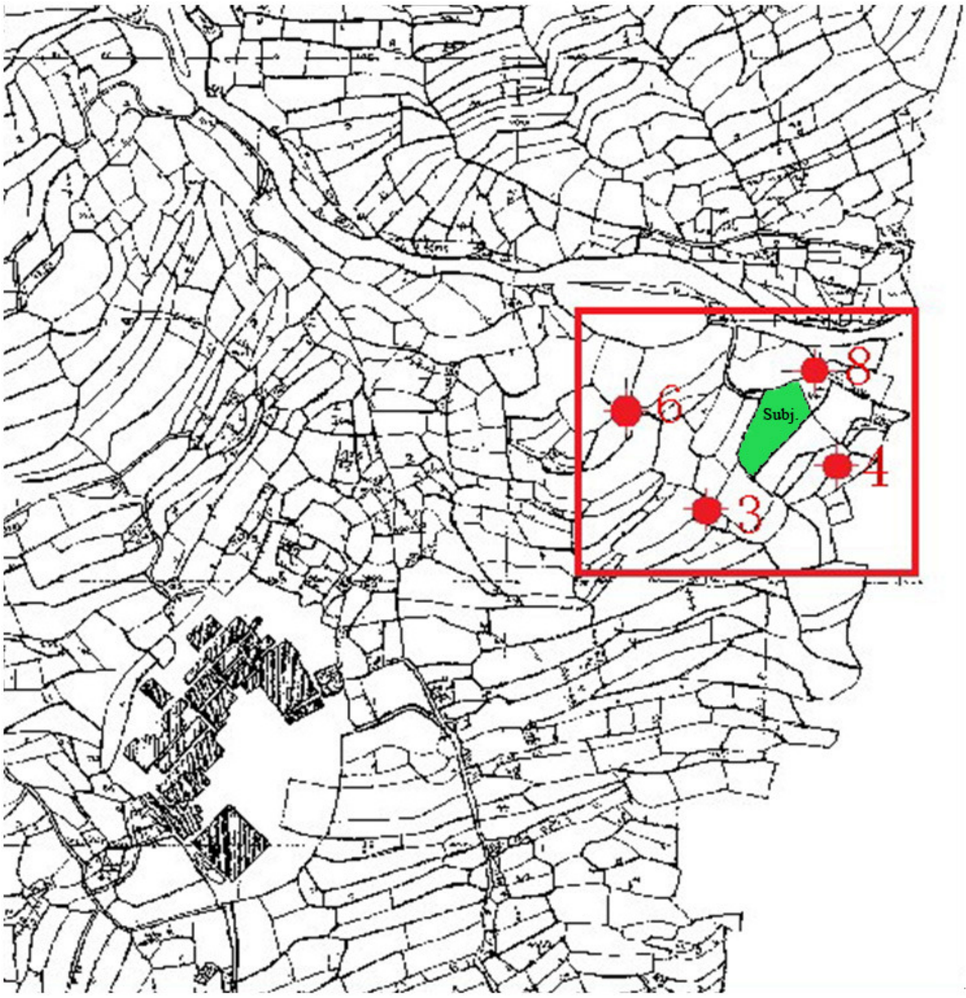

Figure 4 Control points distribution in scheme 1

Performing geo-referencing in ArcGIS 9.3, the result is seen in Figure 5.

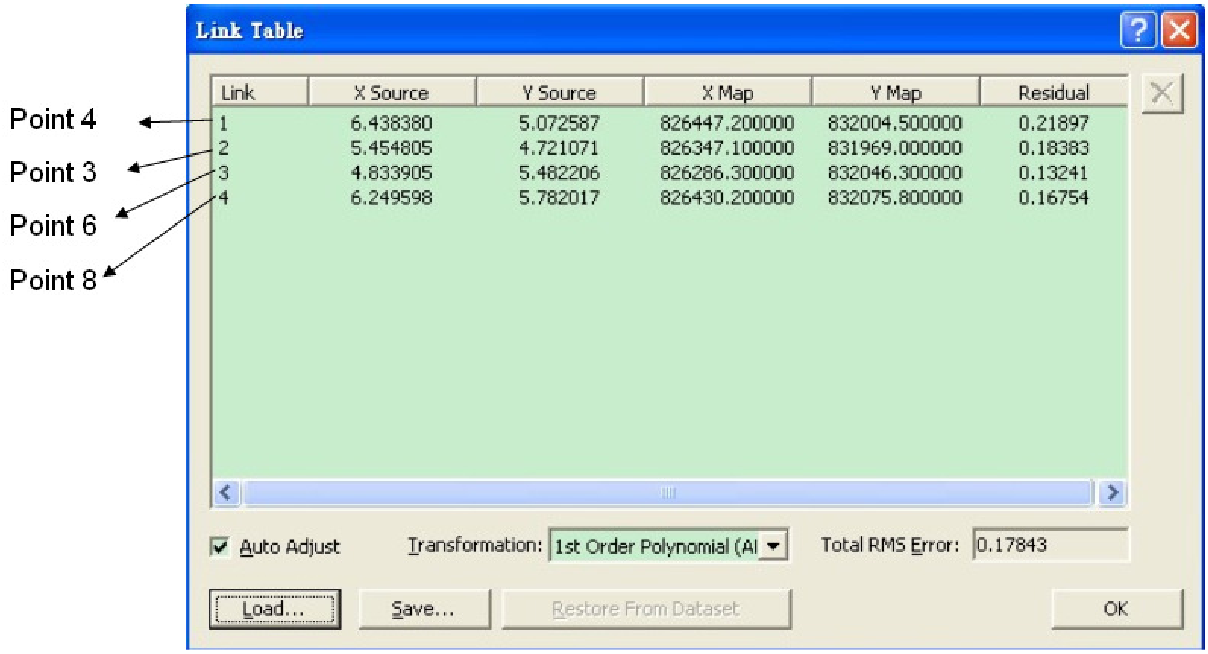

Figure 5 Affine transformation results

The total RMS error here is about 0.2 meters. It represents the discrepancy between the coordinate accuracy of the ortho-image and the point selection error in the operation. Using the 4 ground control points (GCP) to perform geo-referencing on the DD image, there is an overall accuracy of about 2 meters. The result represents a high accuracy land boundary determination, as compared with the 4-meter general accuracy of the 1:3900 DD sheets.

Matching a small selected area showed good result. To compare the transformation on a large area revealed other intrinsic errors. Other control points are used as check points and the result is seen in Table 1.

Table 1 Position error of check points in scheme 1 (unit: metre)

NO	orthophoto		Rectified DD sheet		Difference		RMS	remark
	X	Y	X	Y	X	Y		
1	826473.2	831925.4	826471.2	831925.0	2.0	0.4	2.0	CPs
2	826390.6	831903.4	826389.9	831906.0	0.7	-2.6	2.7	
3	826347.1	831969.0						GCPs
4	826447.2	832004.5						
5	826305.1	831998.6	826306.6	832000.8	-1.5	-2.2	2.7	CPs
6	826286.3	832046.3						GCPs
7	826225.0	832101.0	826225.7	832102.7	-0.7	-1.7	1.8	CPs
8	826430.2	832075.8						GCPs
9	826264.2	831824.0	826260.3	831823.6	3.9	0.4	3.9	CPs (Check Points)
10	826260.8	832238.3	826265.5	832237.9	-4.7	0.4	4.7	
11	826365.1	832295.3	826372.2	832295.3	-7.1	0	7.1	
12	826490.5	832301.0	826498.0	832298.7	-7.5	2.3	7.8	
13	826492.0	832189.8	826496.7	832189.8	-4.7	0	4.7	

14	826145.1	831950.7	826146.1	831954.5	-1.0	-3.8	3.9	
15	826174.9	831871.9	826171.5	831872.7	3.4	-0.8	3.5	
16	826415.2	831786.9	826408.5	831790.6	6.7	-3.7	7.7	
17	826134.2	832045.5	826140.5	832046.1	-6.3	-0.6	6.3	
18	826030.2	831575.4	826025.3	831578.5	4.9	-3.1	5.8	
19	826262.3	831579.7	826250.3	831580.8	12.0	-1.1	12.1	
20	826170.2	831549.5	826159.3	831551.1	10.9	-1.6	11.0	
21	826261.2	831702.7	826252.3	831703.5	8.9	-0.8	8.9	
22	826261.4	831971.5	826260.4	831974.0	1.0	-2.5	2.7	
23	826168.5	832206.0	826179.6	832207.9	-11.1	-1.9	11.3	
24	826304.5	832324.5	826310.1	832322.4	-5.6	2.1	6.0	
25	826173.7	832378.3	826185.0	832383.2	-11.3	-4.9	12.3	
26	826442.6	832438.8	826454.4	832435.4	-11.8	3.4	12.3	
27	826424.7	832366.0	826430.0	832368.3	-5.3	-2.3	5.8	
28	825958.4	832011.0	825965.3	832009.5	-6.9	1.5	7.1	
29	826080.5	831637.8	826071.1	831637.9	9.4	-0.1	9.4	
30	826218.0	831751.5	826206.6	831750.2	11.4	1.3	11.5	
Position error			x		7.2			
			y			2.2		
			horizontal				7.5	

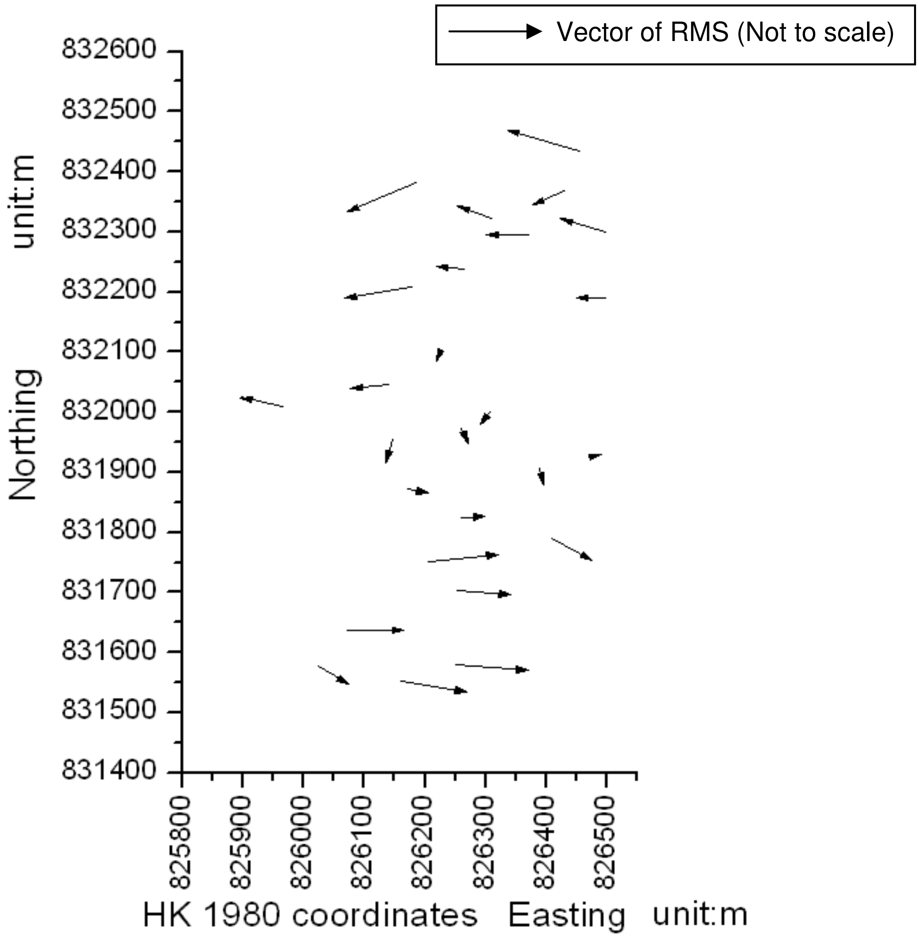

Figure 6 is the position error distribution.

As seen from table 1, the minimum absolute difference in x direction is about 0.7 meter, the maximum, 12.0 meters, and in average, 6.2 meters. The minimum absolute difference in y direction is about 0.1 meter, the maximum, 4.9 meters, and in average 1.8 meters. The error in x direction is larger than that in y direction. The standard deviation of all points in x, y is about 7.2 meter and 2.2 meter respectively.

As seen from Figure 6, the controls were located in the middle; errors in the vicinity were minimal. On the top, point errors tended to move left; at the bottom, point errors tended to move right. It indicated that the DD sheet, as a plane-table survey product, had systematic localized error effects. The best result, as seen in this test, was achieved within an area of 200m by 200m. The Overlaying DD sheet with orthophoto of this project is seen in Figure 7.

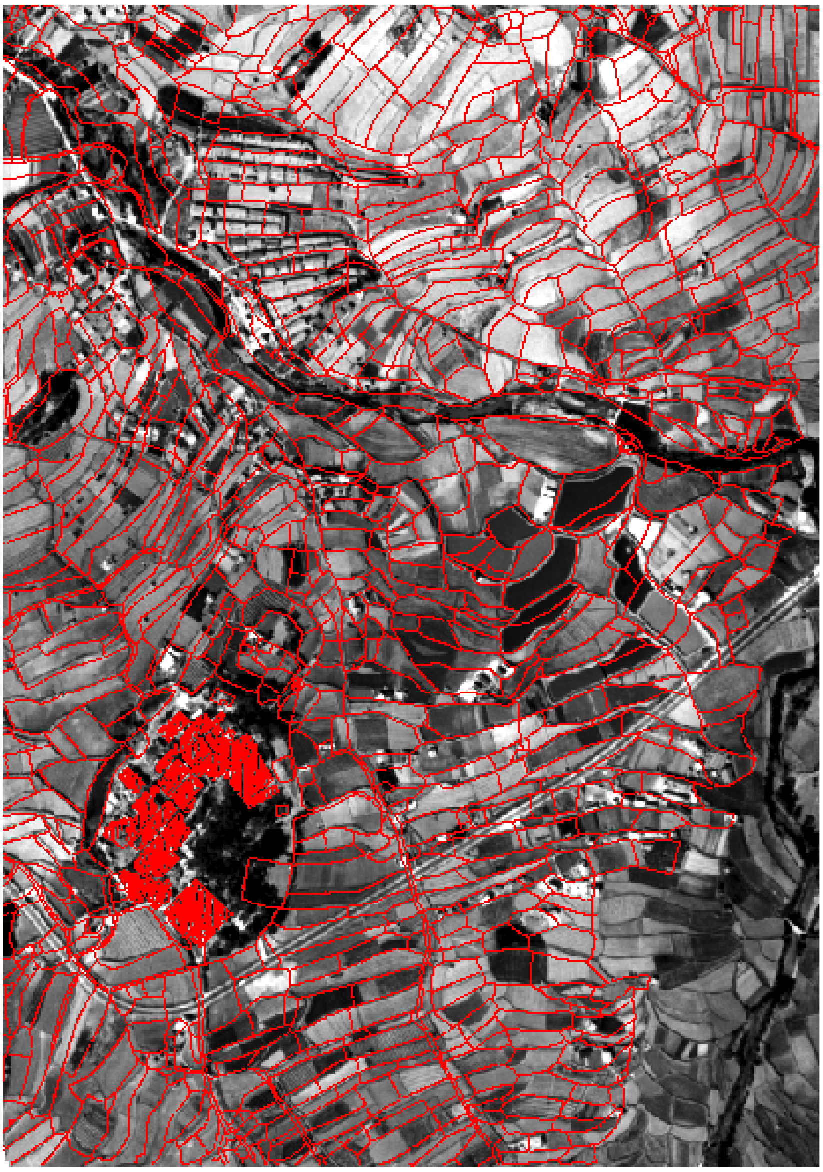

Figure 7 Overlaying DD sheet with orthophoto

3.2 Experiment scheme 2 and its results

In this scheme, four control points 10 , 13 , 15 , 16, covering a square about 400m by 500m, is shown in Figure 8.

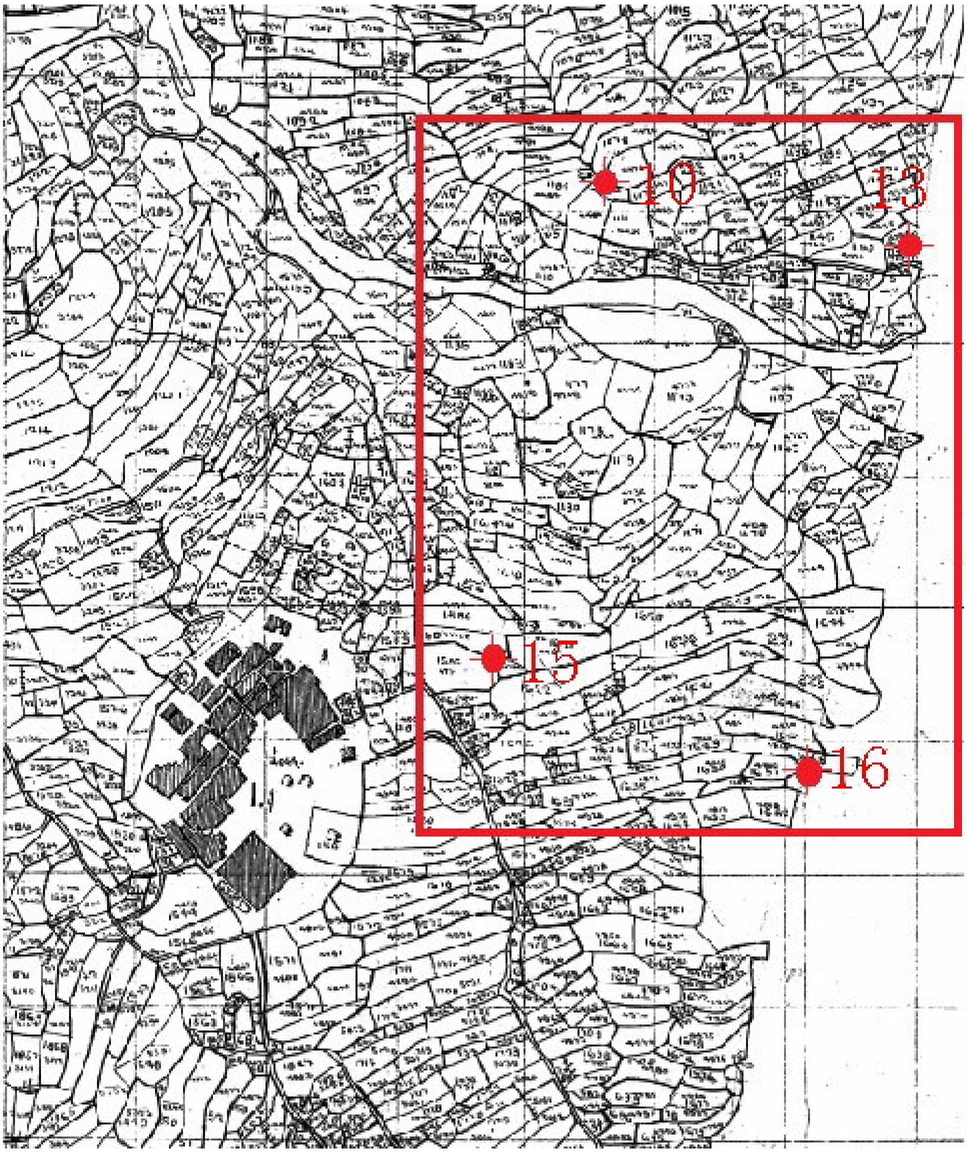

Figure 8 Control points distribution in scheme 2

Geo-referencing result is seen in Figure 9.

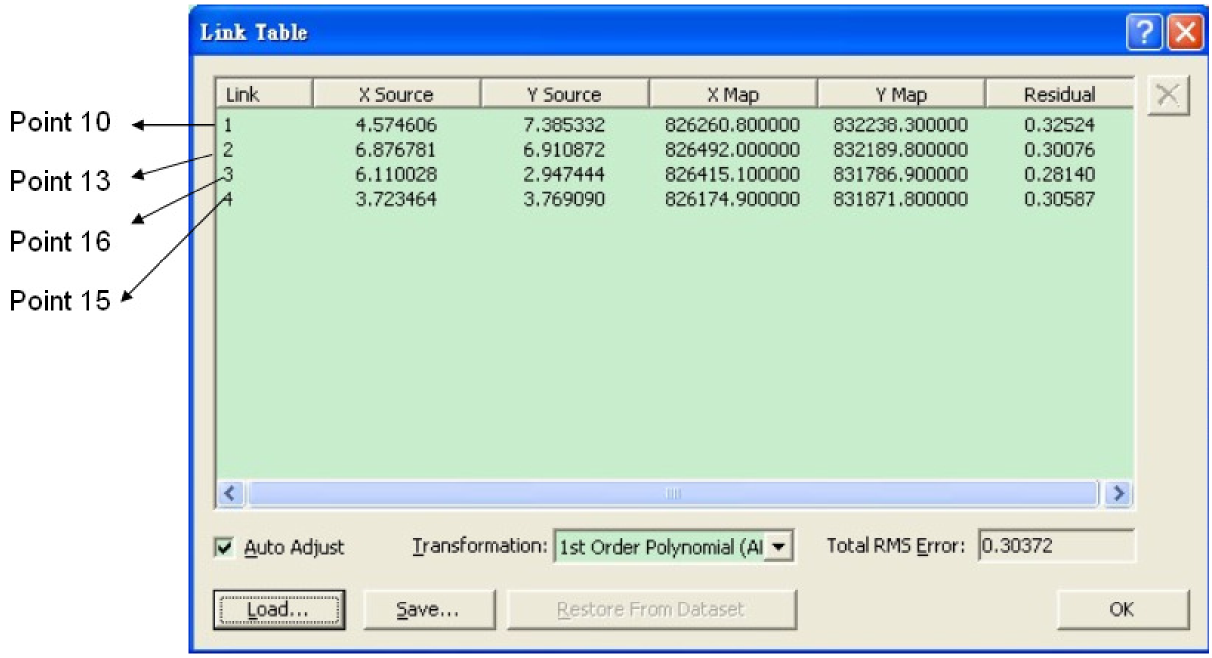

Figure 9 Affine transformation result

Table 2 list differences of check points.

Table 2 Position error of check points in scheme 2 (unit: metre)

NO	orthophoto		Rectified DD sheet		difference		RMS	Remark
	X	Y	X	Y	X	Y		
1	826473.2	831925.4	826473.2	831923.6	0	1.8	1.8	Check points (CPs)
2	826390.6	831903.4	826393.7	831903.8	-3.2	-0.4	3.2	
3	826347.1	831969.0	826349.0	831967.5	-1.9	1.5	2.4	
4	826447.2	832004.5	826448.2	832003.6	-1	0.9	1.3	
5	826305.0	831998.6	826307.8	832000.1	-2.8	-1.5	3.2	
6	826286.3	832046.3	826286.8	832044.8	-0.5	1.5	1.6	
7	826225.0	832101.0	826224.4	832102. 9	0.6	-1.9	2.0	
8	826430.2	832075.8	826429.3	832075.0	0.9	0.8	1.2	
9	826264.2	831824.0	826266.7	831821.4	-2.5	2.6	3.6	
10	826260.8	832238.3						GCPs
11	826365.1	832295.3	826365.4	832296.6	-0.3	-1.3	1.3	CPs
12	826490.5	832301.0	826490.4	832300.2	0.1	0.8	0.8	
13	826492.0	832189. 8						GCPs
14	826145.1	831950.7	826149.4	831952.9	-4.3	-2.2	4.8	CPs
15	826174.9	831871.8						GCPs
16	826415.1	831786.9						
17	826134.2	832045.5	826140. 6	832045.2	-6.4	0.3	6.4	CPs
18	826030.2	831575.4	826038.0	831573.8	-7.8	1.6	8.0	
19	826262.3	831579.7	826263.3	831576.3	-1.0	3.4	3.5	
20	826170.1	831549.5	826173.4	831546.7	-3.3	2.8	4.3	
21	826261.2	831702.7	826261.8	831700.4	-0.6	2.3	2.4	
22	826261.4	831971.5	826262.7	831972.2	-1.3	-0.7	1.5	
23	826168.5	832206.0	826176.1	832209.0	-7.6	-3.0	8.2	
24	826304.5	832324.5	826302.8	832323.6	1.7	0.9	1.9	

25	826173.7	832378.3	826177.0	832385.2	-3.3	-6.9	7.6	
26	826442.6	832438.8	826443.9	832437.1	-1.3	1.7	2.1	
27	826424.7	832366.0	826421.4	832369.8	3.3	-3.8	5.0	
28	825958.4	832011.0	825967. 4	832008.3	-9.0	2.7	9.4	
29	826080.5	831637.8	826083.8	831634.1	-3.3	3.7	5.0	
30	826218.0	831751. 5	826215.0	831747.4	3.0	4.1	5.1	
RMS			X		3.67			
			Y			2.55		
			horizontal				4.47	

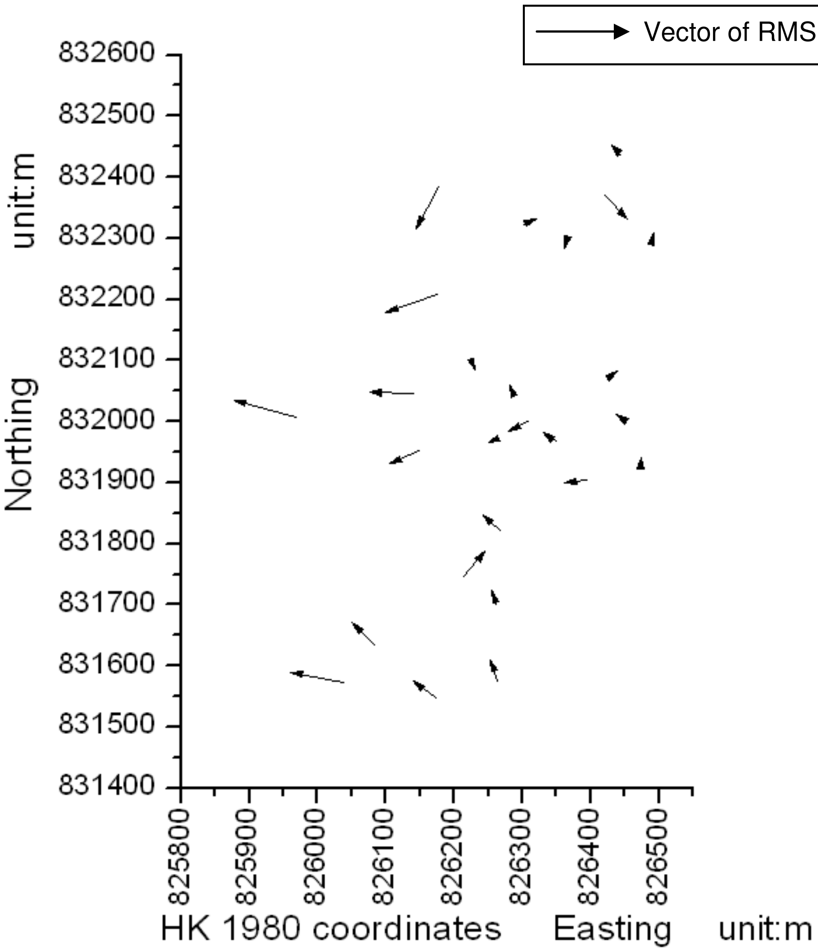

Figure 10 Position error distributions

In this scheme, the minimum absolute differences in x direction is about 0 meter, the maximum is about 9.0 m, average absolute difference is 2.7 m; The minimum absolute differences in y direction is about 0.3 m, the maximum is about 6.9 m, average absolute difference is 2.1 m. So the error in x direction is greater than that in y direction, this means the distortion in x is greater than that in y direction. The standard deviations in x, y is about 3.7 m and 2.6 m respectively.

Again, interpolation of coordinated images is always a preference to extrapolation. The average positioning errors of the points (Point 1 to 6, 8 and 22) within the control rectangle of Point 10, 13, 15 and 16 was about 2.0m. It also displayed a satisfactory accuracy for land boundary determination as compared to the general accuracy of 4m. Overlaying DD sheet with orthophoto is seen in Figure 11.

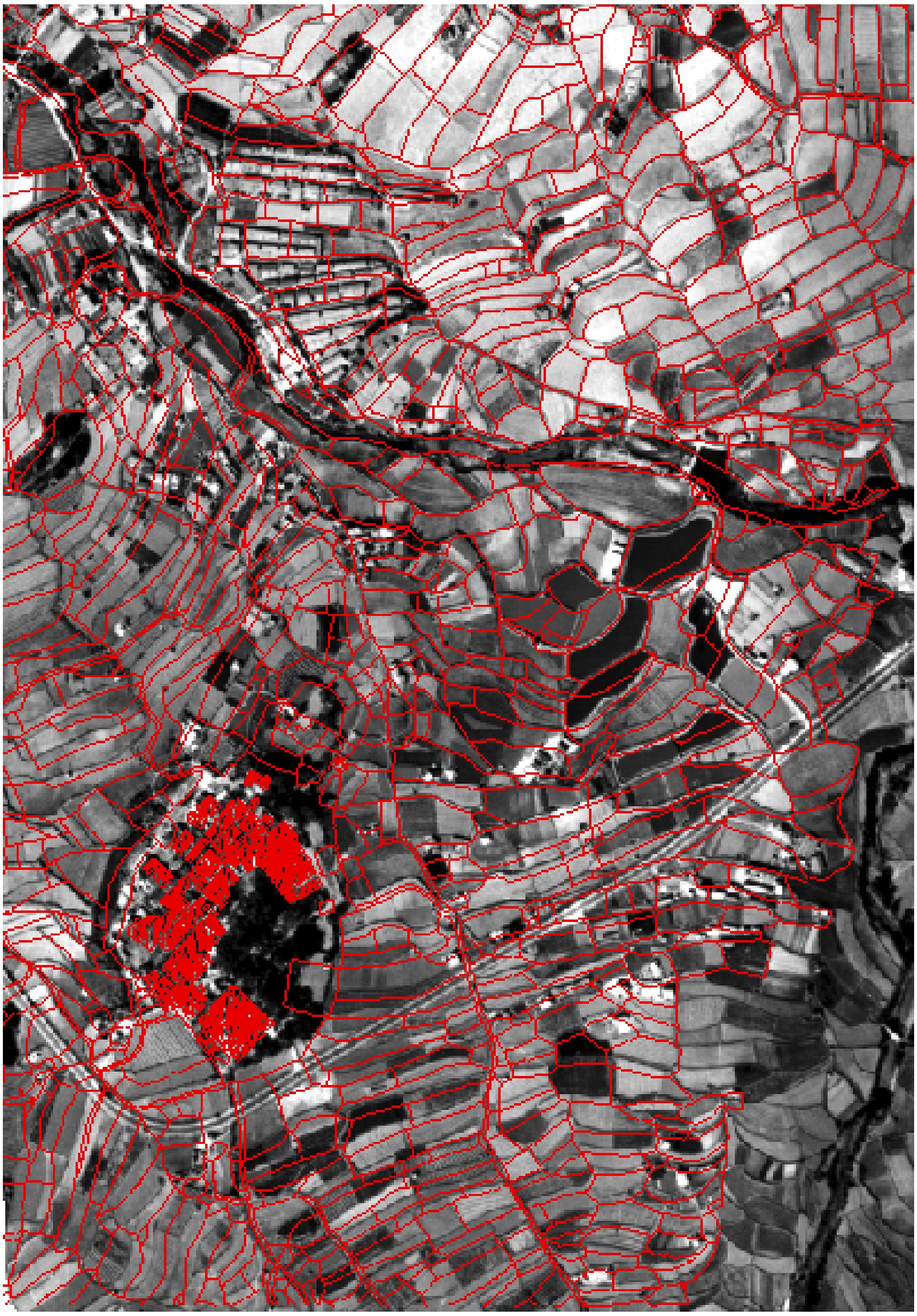

Figure 11 overlaying DD sheet with orthophoto in scheme 2

Table 3 lists accuracy statistic of two schemes.

Table 3 accuracy statistic comparison (unit: metre)

No.	X direction error			Y direction error			RMS
	maximum	Minimum	RMS	maximum	minimum	RMS	
Scheme1	12.0	0.7	7.2	4.9	0.1	2.2	7.5
Scheme2	9.0	0.0	3.7	6.9	0.3	2.6	4.5

4. CONCLUSIONS

The difference between scheme 1 and scheme 2 is the position of control points. According to the experiment results, some conclusions can be draw:

- The DD sheet has a localized error pattern;
- Distribution of control points has effect on geo-referencing results;
- The interpolation results of the scheme 1 gave a result of 2m and scheme 2 of 3m; and
- The extrapolation results are not recommended.

Further tests and comparisons on the controls points from KGPS field observations and from previous detailed plans are to be carried out. At this stage, it is still cogent to say that the correlation between the 1963 orthophoto and DD images is an improved and satisfactory means of determining lot boundaries in the New Territories.

REFERENCES

Leung et al (2008). The Reality Versus the Legality of the Demarcation District Sheets, Surveying & Built Environment, The Hong Kong Institute of Surveyors, pp26-37.

Linder, W. (2003). Digital photogrammetry: theory and applications. Berlin: Springer.

Jensen, J.R. (2005). Introductory digital image processing: a remote sensing perspective (third edition), America: Pearson education.

Tang, C. and Zhang, R. (2008). Agricultural lot boundary re-establishment using old aerial photograph and KGPS survey, Journal of Geospatial Engineering, Vol.10, pp. 1-11.

BIOGRAPHICAL NOTES

Conrad is a land surveyor who has served years as the national delegate to Commission 7 of FIG. He is a council member of the Land Surveying Division, the Hong Kong Institute of Surveyors, and has served in various statutory and government advisory institutions in Hong Kong. His research interests are in the leasehold land boundary system and its improvement.

CONTACTS

Dr. Conrad TANG
Department of Land Surveying and Geo-Informatics,
The Hong Kong Polytechnic University
HJ706, Department of Land Surveying and Geo-Informatics,
The Hong Kong Polytechnic University, Kowloon
Hong Kong SAR, PRC
Tel. +852 – 2766 5963
Fax + 852 – 2330 2994
Email: lstang@inet.polyu.edu.hk
Web site: http://www.lsgi.polyu.edu.hk/staff/Conrad.Tang/index.htm

ACKNOWLEDGEMENT

This work described in this paper was substantially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No. PolyU B-Q13C)