Digital Photogrammetry for Land Registration in Developing Countries

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SUMMARY

While photogrammetry has been extensively used for topographic mapping, it has contributed less to cadastral surveying. In optimal circumstances, for example where land enclosed with well-marked hedges or walls, the photographs may be able to supply all the field detail needed for the cadastre. On the other hand, the legal boundaries of parcels cannot be determined from the photographs without extensive checking on the ground. Nevertheless photogrammetry can be as accurate as and significantly cheaper than ground survey.

For decades, however, the method of the photogrammetric cadastral survey has been queried (p. WILLIAMSON:1983, Peter F. Dale/FAO:1995, Gottfried Konecny:1997, Kari Mikkonen:1998, Prabhakar Mishra:2001, Wijayawardana:2002). Specially, Gottfried Konecny:1997, 'Potential of GIS in the GULF-Region' put toward alternatives for the collection of cadastral data, so called 'photo-adjudication', using photogrammetry in the developing countries. And also, Wijayawardana:2002, 'Contribution of digital photogrammetry for cadastral surveys' offered the identification of land parcel boundaries using digital photogrammetric method.

This paper, especially in Azerbaijan and Morocco, describes the adjudication process of land registration using photogrammetric method and field survey, and proposes appropriate methodology for cadastre in mainland and the developing countries

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1. INTRODUCTION

At simple level, cadastral surveys are concerned with setting out and recording the turning-points or corners along property boundaries. A variety of techniques may be used, each having its own inherent accuracy and cost. The necessary and sufficient accuracy that is needed for any survey depends on the purposes for which that survey is conducted. Almost all generally known techniques in surveying can be employed for the purpose of cadastral survey. These include both field survey techniques and photogrammetry. (United Nations. Land administration in the UNECE region development trends and main principles. New York and Geneva. 2005)

While photogrammetry has been extensively used for topographic mapping, it has contributed less to cadastral surveying. Photogrammetric methods are in the cadastral context, mass production techniques that are only cost-effective if sufficient boundary points or lines need to be measured and also ideally suited to the compilation of base maps and to the recording of physical features of the landscape that are visible from the air. In optimal circumstances, for example where there are rice lands with embankments around their edge, terraced hill lands or land enclosed with well-marked hedges or walls, the photographs may be able to supply all the field detail needed for the cadastre.

On the other hand, the legal boundaries of parcels cannot be determined from the photographs without extensive checking on the ground. Generally more work will be required to supplement the photographs in the case of cadastral maps than in the case of most topographical mapping. In all cadastral surveys undertaken by photogrammetry there is a need for follow-up ground surveys to check the actual location of legal boundaries that may not be visible on the photography or may have been wrongly identified. (Food and Agriculture Organization of the United Nations, 1995)

In the developing countries, for example, an effective and inexpensive means to create a cadastre is to produce large scale orthophotos and have the neighbors agree on the identified and pricked boundary locations in the images by their signature in the so called "photo-adjudication process".

This paper describes identification of land parcel boundaries using digital photogrammetric method. Then parcel boundary can be extracted by on Digital Photogrammetric Workstation (DPW) as through line map compilation procedure. However, the major problem is to collect information, which covered, by obstacles such as trees, buildings, eaves etc. To overcome this, survey team with Total Station and GPS and related orthophoto, should go to the field. For the comparison of photogrammetric result with field survey, field survey team measured every parcel boundary within test field as a reference data.

2. ABSHERON PENINSULA, ZIRA SETTLEMENT TEST FIELD

Now only 20% of the territory of Republic of Azerbaijan is covered by cadastre maps after the land reform was completed in 2004. To establish a unified real estate cadastre to cover the whole territory of Azerbaijan (both urban and rural) is a challenging task. It should be achieved by using high-resolution orthophotos and additional field measurements to improve the quality of the digital cadastre map. Financial and technological support along with international assistances are crucial for improving the current situation. (United Nations Economic Commission for Europe, 2007)

The project for 'Improvement of the Land Cadastral System in Azerbaijan' is one of KOICA's ODA (Official Development Assistance) projects in Azerbaijan for encouraging the land registration and Zira settlement, Absheron Peninsula which was selected as a test field.

The Absheron Peninsula is one of the most important region for strategic reasons in Azerbaijan. It is famous with being one of the main oil field areas in the world. Recently raising economical value through BTC (Baku–Tbilisi–Ceyhan) pipe line, there are several oil fields active in Absheron Peninsula. The area has a flat topography, in some parts with steep and rugged terrain. Baku, the capital of Azerbaijan is located center of the peninsula, there are some agricultural lands and barren field in the inner part of the Peninsula. Figure 1 shows the Landsat TM imagery of the test field taken in May 2004. Zira test field is located in the end of Absheron Peninsula, and also selected Working area1 and Working area2 for regional differences. (Figure 2).

Working area1 these areas are an residential area generally straight, uniform walls and distinctly demarcated, while working area2 these area are an old town which has narrow and winding road relatively indistinctly demarcated. The area is an residential area similar to Working area1 covers 8 ㎢, which accounts for 80% of the total test field area. And the remaining 20% were covered the old town.

Figure 1: Landsat TM image of Absheron Peninsula.

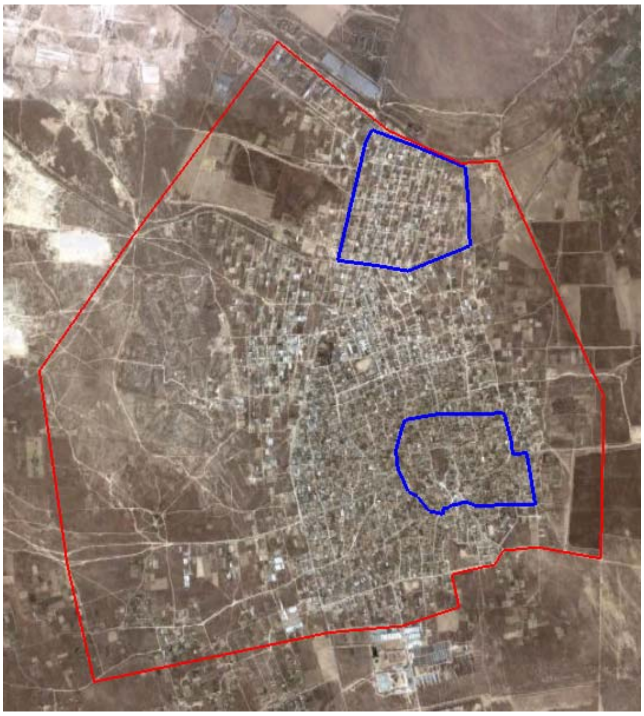

Figure 2: Zira Study Area

(Working Area1: upper, Working Area2: lower)

3. PHOTOGRAMMETRY PROCEDURES

3.1 Ground Control process

The whole test field covers nearly 3.3x3.3km area with nearly flat. For this project totally 40 GCP points have been planned to be constructed. However even though the point #20 was constructed earlier, the GPS survey of this point was not completed due to its place being in the military forbidden zone. Therefore totally 39 points were able to be surveyed by GPS.

GPS surveys were referenced from the control points of PIRALLAHI and BURUN, which are in the national geodetic coordinate system. Based on these two reference points all other 39 GCP points have been surveyed with dual frequency GPS transceivers in concurrent sessions. All GCPs were pre-signalized using white paints in order to be identified in aerial images.

On the day of May 4th, 2010; GPS surveys were completed with 6 Leica 1200 series and 2 Leica 500 series dual frequancy GPS transceivers. GPS Surveys of GCPs carried out in a network sessions of about 45 to 60 minutes of simultaneous static GPS surveys. Observation period has been determined according to the maximum baseline length in each session. Every session has two common points in order to tie two sessions to each other. Then these sessions were tied to the primary reference stations wherever it is possible. Elevation Mask was set to 10 degrees and data was collected in 15 seconds recording interval. Survey results have been processed using Leica GeoOffice software with an accuracy of about 1~2cm.

3.2 Flight and Aerotriangulation

Initially the aerial data collection has been planned for between 15th of April to 15th of May, however due to bad weather conditions and flight permission delay from Azerbaijan aviation authorities it was delayed to end of May. The test field was finally flown on 1st of June. The flight has been initially planned for 3200 feet altitude, however the flight control tower gave the permission for only 4000 feet, the reason for that was the 3200 feet altitude is used for incoming air traffic. Due to this altitude difference aerial data collection took place with following values:

GSD=10 cm, Forward Overlap = %70 and Side Overlap = %45
(Planned GSD = 8cm, Forward Overlap = %60 and Side Overlap = %30)

Aircraft Flight time	Cessna 402B / TC-CAY 1hr 30min
Aerial Camera Focal Length Size of pixel	DiMAC WIDE+ 80.3767.mm 6.8 micron x 6.8 micron Pixels
GSD(altitude) Overlap	10.32cm(altitude 1220m /4000feet) Forward =70%, Side =45%
Num of Exposures and Strips	281 /11

Table 1. Table 1 Flight Specifications

During aerial data collection, GPS in the plane has worked concurrently with the GPS transceiver on the GCP point #13 for DGPS process, the GPS observations were done with 1 second intervals.

Aerial triangulation measurements were made in Image Station Automatic Triangulation Software (Zeiss-Intergraph) adjusted bundle block adjustment. In the first adjustment process all GCP points were included into the adjustment and exterior orientations of photos have been calculated. In the second adjustment process, 14 of those 39 GCP points have been taken as check points. At the end of the aerial triangulation adjustment process, coordinates of these 14 check points have been calculated. The overall accuracy of aerial triangulation was satisfied at general accuracy with RMSE x= RMSE y=0.03m, RMSE z=0.06m and sigma naught =1.838 micron.

3.3 Cadastral Feature Stereocompilation

As a result of photogrammetric aerial triangulation, exterior orientations of aerial images have been calculated (Xo, Yo, Zo, Omega, Phi, Kapa). Stereo models have been created using these EO values. Stereo interpretation has been done in Image Station Stereo Display (ISSD) software of Zeiss- Intergraph and Leica Photogrammetric Suite(LPS) digital photogrammetric systems.

In this project the map which stereocompiled every cadastral features in test field defines as a draft cadastral map. Cadastral features, for example, firstly terrestrial structure demarcating the parcel similar to building, brick fence, common fence and wall, hedge. Second, a ridge or farming edge in the field dividing boundary. Third, terrestrial features concerning cadastral boundary assigned by Azerbaijan cadastral authorities.

During the stereocompilation the details of cadastral features fall below the trees have been marked with yellow circles in order to be re-surveyed with geodetic field work with GPS. At the end of stereocompilation, draft parcel boundary map, topographic map, DEM, TIN and manual contour map (with 50 cm intervals) were produced.

The details fall below the trees which were come across during the stereo interpretation were completed with field surveys. Missing information for those details also completed such as building name, street name, school name, river name, neighborhood-village name. All missing details have been surveyed with total station. Acquired text information and survey results have been merged with the map in the edit workstations.

Figure 3 : Topographic map(Left) and Draft Cadastral map(Right)

4. COMPARISON OF DRAFT CADASTRAL MAP WITH REFERENCE MAP

For the comparison of draft cadastral map with field survey, field survey team measured every parcel boundary within test field as a reference map.

Draft cadastral map of stereocompilated cadastral features in test field were compared and superimposed with field survey results for each working area. (Fig. 4a and 4b)

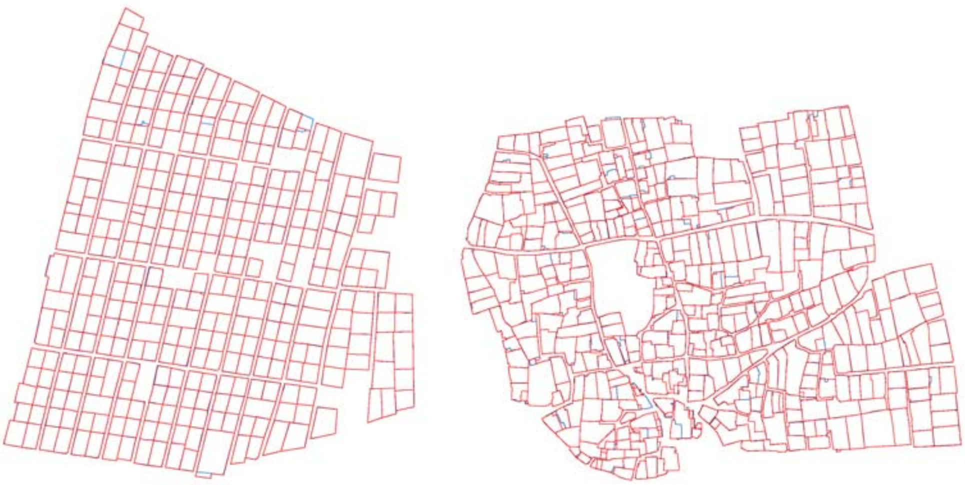

Figure 4: Superimposed of draft cadastral map of working area 1 (a) and working area 2 (b) with field survey result (Red: Field survey, blue: Photogrammetry)

Classification	Working Area 1		Working Area 2	
	Boundary point	**Parcel**	**Boundary point**	**Parcel**
Field Survey (GPS, T/S)	876 points	328 parcels	3,548 points	425 parcels
Photogrammetry (draft cadastral map)	3,272 points	323 parcels	6,190 points	386 parcels
Coincidence rate	96%	89%	82%	71%
Regional Character	newly built residential area make up generally straight, uniform walls and distinctly demarcated		old town narrow and winding road relatively indistinctly demarcated	

Table 2 Comparison of survey result with working area 1 and 2

First, the reason the draft cadastral map has more boundary points than field survey is because photogrammetry drew more detail than field in case of curved wall or winding road. In land registration process shall be erased the unnecessary boundary points.

The analysis showed that draft cadastral map boundary points in working area1 mostly coincided with field survey results, but working area2 relatively shows lower coincidence rate. Also, draft cadastral map parcels in working area1 mostly coincided with field survey results for 97% within a 2% parcel-area difference, and working area2 poorly coincided with field survey results for 71%. The reason is the regional character which each working area has.

classification	**Working Area 1**		**Working Area 2**	
Accuracy	$RMSE_x$	$RMSE_y$	$RMSE_x$	$RMSE_y$
	0.12cm	0.14cm	0.19cm	0.21cm

Table 3 Comparison of RMSE with working area 1 and 2

Also, draft cadastral map boundary points in working area1 mostly coincided with field survey results, when blunder eliminated, shows RMSEx = 0.12m, RMSEy = 0.14m and working area2 shows RMSEx = 0.19m, RMSEy = 0.21m. This shows draft cadastral map in this project conformed to the ASPRS Standard for planimetric feature coordinate accuracy requirement for tatget scale 1/1,000 as limiting RMSEx or RMSEy 0.25m.

5. CONCLUSION

This paper describes identification of land parcel boundaries using digital photogrammetric method. Then parcel boundary can be extracted by on Digital Photogrammetric Workstation (DPW) as through line map compilation procedure. For the comparison of photogrammetric result with field survey, field survey team measured every parcel boundary within test field as a reference data. The results are as follows:

Parcels of draft cadastral map in working area1 coincided with field survey results for 97%, while working area2 coincided with field survey results for 71%, within a 2% parcel-area difference

The reason is the regional character which each working area has. Working area1 newly built residential area makes up generally straight, uniform walls and distinctly demarcated. On the contrary, working area2 which old town area makes up narrow and winding road and wall relatively indistinctly demarcated

In this analysis, the identification of land parcel boundaries using digital photogrammetric method would be the most reasonable way to register the land in Azerbaijan where sub-urban area or newly developed residential area similar to working area1 consisting 80% in Zira testfield. The region where some part of old town or indistinctly demarcated similar to working area2 suggests the land registration method through the field survey with GPS or T/S.

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BIOGRAPHICAL NOTES

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Mr. Ahn has a Master's Degree from Geoinformatic Engineering at the Inha University.
He was previously Technical Advisor of the Morocco Cadastral Support Program 2007 – 2008 supporting the land registration with photogrammetric method.
Now he is also take part in Azerbaijan Land Registration project.

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