Photogrammetric Techniques for Cadastral Map Renewal

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Key words: Cadastral Maps, Photogrammetry, Orthophoto, Registration Transformation Functions, Data Fusion.

SUMMARY

Cadastral mapping in Jordan started the early thirties, about eighty years after the introducing of first land registers by the Ottoman Empire. First cadastral maps were produced in scales 1:20000 and 1:10000 and later on other scales were used such as 1:5000, and 1:2500. At that time very low precision of the initial field surveys was used to meet the user requirements, but such precision is completely unacceptable at present due to the rapid increase of the land value, as well as the user requirements and the opportunities given by the current technology. The Department of Lands and Survey in Jordan recognizes the problem of low accuracy where physical reality on the ground doesn't match with the existing maps, this situation in no way can meet or satisfy the needs of the future development. In addition to the low precision of the original maps, the mismatch between these maps and its diversity from ground truth is due to several other reasons; First: the image registration errors which can be considered as a critical stage that largely depend on the nature of the terrain (flat, hilly,…etc.) and the validity of transformation function used in the study area. Second: the various geographic coordinate systems and the projection parameters associated with the maps in addition to the way that each projection is defined and implemented. Other factors can be summarized as: digitizing errors, scanning errors, and finally the lack of ground truth that can fairly represent the reality with high accuracy taking into consideration the cost associated with such requirement.

This paper represents an alternative solution for cadastral maps renewal based on photogrammetric techniques and possibility for extraction of features to be added to the cadastral map from different overlaid sources such as scanned old maps, satellite images, aerial orthophoto graphs, digital terrain models and field surveys. Qualitative and quantitative evaluations of the factors that lead to the mismatch between different sources of data were also discussed. Different suggestion for registration, integration and mosaicing of this data has been established based on photogrammetric techniques. Such procedure is made in a way that guarantees better representation and understanding of the real world. Moreover, different transformation functions (2D-similirty, affine and projective) are tested so that different data source can match regardless of the cause of the mismatch.

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1. INTRODUCTION

Cadastral mapping in Jordan started the early 30-es, about 70-80 years after the introducing of first land registers by the Ottoman Empire. Lands Department was created by unifying the Surveying Department, Treasury Land Department, and Department of Land Registration, under the supervision of English officials. First cadastral maps were produced in scales 1:20000 and 1:10000 and later on other scales were used such as 1:5000, 1:2500 and 1:1250. In the past decades, different methods were used for mapping such as chain surveying, plan table method and tachometry where the use of modern technologies and instruments started in the late 80s in the form of Total Station and Global Positioning Systems.

Initial field surveys which conducted to meet the user requirement, at that time, has very low precision and characterized by poor quality, however such precision and quality is completely unacceptable at present time due to significant increase in land value. The sequence generations of ownerships and redistribution of parcels to larger number of people is directly related to the size of a parcel where initial mapping parcels (low Precision) are inherited and respectfully subdivided into many small parcels where half meter is not negligible anymore. Moreover, parcel in many areas are subject to public concern or included into urban zones where high precision is required. The fact that present requirements cannot be met with the existing precision leaded to a joint project of renewal of cadastre carried on by the Department of Lands and Survey (DLS) with the technical support of German Agency for Technical Cooperation (GTZ).

This paper represents an alternative solution for cadastral maps renewal based on photogrammetric techniques and possibility for extraction of features to be added to the cadastral map from different overlaid sources such as scanned old maps, satellite images, aerial orthophotos, digital terrain models and field surveys. Ortho-rectification, registration and integration of these data have been established where validity of different transformation functions were considered. The suggested solution is made in a way that guarantees better representation and understanding of the real words.

Next section overview the status and history of cadastre in Jordan which include renewal of cadastre project in Jordan (transformations of the existing hard copy maps, Renewal of the geodetic network and transformation of old Palestine Grid coordinate system) and Legal status of cadastral boundaries in Jordan. Section 3 describes the diversity of data (satellite and aerial images, scanned and vector maps and field survey). The methodology, data processing and results, which include the field survey, orthophoto-generation, rectification of satellite images, registration of the scanned cadastral maps and re-projection of existing vector data are presented in section 4. Finally, section 5 includes conclusions and future work.

2. OVERVIEW

Existing status of the cadastre, which inherited very low precision of the initial field surveys, became completely unacceptable due to decreasing of the parcel area and rapid increase of the land value. Moreover, many areas are subject to public concern, or included into urban zones where better precision is required. A joint project for renewal of cadastre was carried on by the Jordanian Department of Lands and Survey (DLS) with the technical support of GTZ. The main objective of such project is to study different methods that can lead faster access to land related information, better quality-better positional and temporal precision, wide range of information and better security of the ownership.

2.1 Renewal of Cadastre Project in Jordan

The project (Heckmann B. 2003) consists of the following (Figure 1):

– Transformations of the existing hard copy maps (about 10000) in digital vector format and their edge matching. This phase of the project was completely finished by 2002.

– Renewal of the geodetic network. Precise GPS surveying was used to tie the old geodetic network of the DLS to the geodetic network of the Royal Jordanian Geographic Center (RJGC). In this way, each observed control point with original coordinates in Palestine Grid coordinate system was provided new pair of accurate coordinates in Jordan Transverse Mercator (JTM) coordinate system. (Reference for JTM) The two pairs of coordinates were used to obtain transformation parameters between the two systems. For this purpose the area of the Kingdom was divided into zones 5x5 km. Two types of 2D-transformations were considered at the time (Limmert, 2001): Helmert and Affine. The transformation parameters were used to transform the rest of the control points (points that were not observed) to JTM and also for future transformation of the cadastral maps (originally in Palestine Grid Projection) to JTM.

– Transformation of the digital cadastral maps from the old Palestine Grid coordinate system to JTM. This phase is currently under execution. In general the transformation is based on the parameters extracted for each zone, based on the Palestine Grid and JTM coordinates of the control points, mentioned in the previous section.

– Partial resurveying: This concept was adopted as the best appropriate method for Jordan based on the following considerations; the limited budget, which does not permit full resurveying and the time consuming nature of the full resurveying.

It has to be mentioned that accuracy standards were adopted for field procedures in order to insure the quality of the final results. In this domain photogrammetric methods were suggested for comparison between the converted JTM cadastral maps and ground truth (Heckmann, 2003), however photogrammetry was not used neither for check nor for extraction of new features to be added to the cadastral maps at the time.

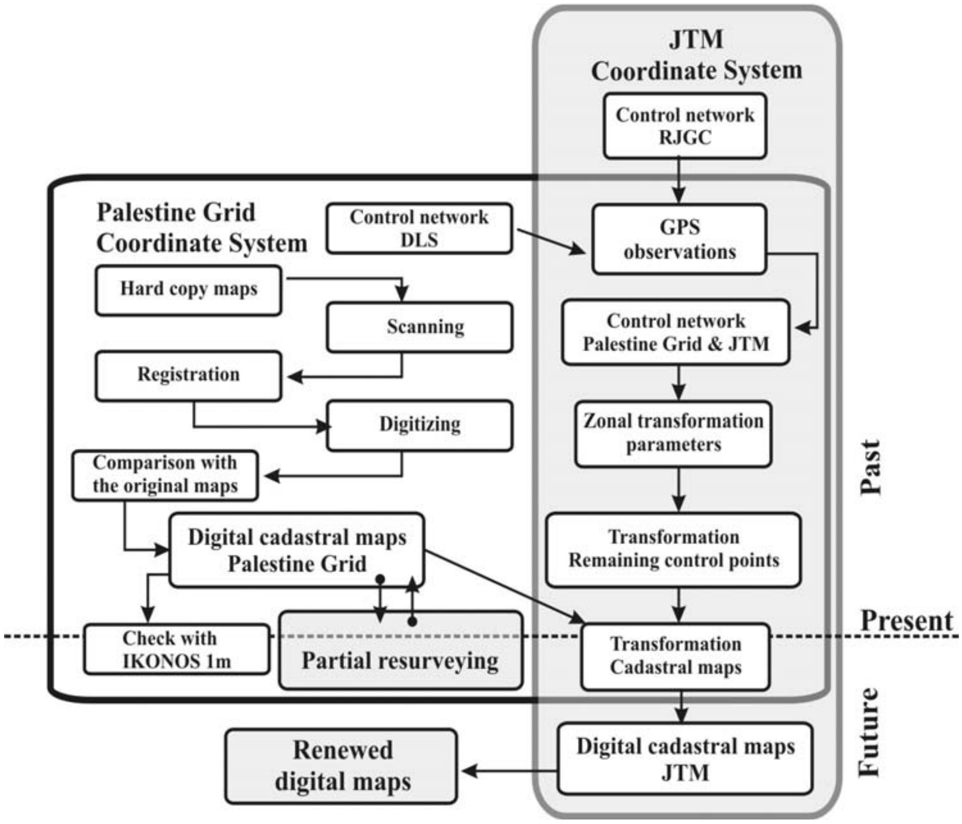

Figure 1: Renewal of Cadastre in Jordan.

2.2 Legal Status of Cadastral Boundaries in Jordan:

Establishment of cadastre in Jordan is now complete in about 95% of the kingdom's territory. During the establishment cadastral boundaries are demarcated after adjudication process is finished and agreement about the boundaries is reached. The demarcation (initial and reestablishment) is done using iron pegs that can be and very often are easily removed and destroyed. It also can be easily confused with pegs, used for other purposes, for example to support newly planted trees. The boundary demarcation with iron pegs is already considered as insufficient (Kubisch, 2003) and new marks are suggested.

After the conversion of the hard-copy cadastral maps into digital form and their edge matching the boundary corners (settlement points) still have graphical accuracy, which is even reduced by the errors introduced due to scanning, image registration, and edge-matching transformations. Although the users are provided with these coordinates from digital source but graphical precision, DLS does not guarantee their correctness. In order to avoid litigations between neighbors caused by such false accuracy DLS accompanies this kind of coordinates with official statement that they can be used for orientation only.

The on-going partial resurveying project improves the positional quality of the boundary points from graphical to numerical, but only in sporadic manner. Boundary reestablishment is required each time a transaction takes place and technical quality parameters are set for this purpose. After the digital cadastral map (or part of it) is updated with new high precision field survey the correctness of the included boundary corners is completely guaranteed. Figure 2 represents the degree of guarantee of the cadastral boundaries according to their type.

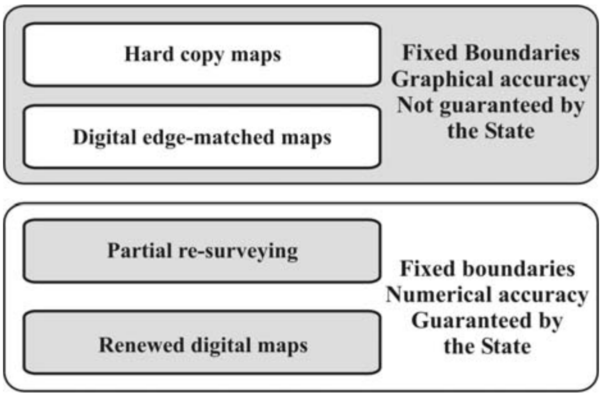

Figure 2: Legal status of the cadastral boundaries in Jordan

3. DATA SOURCES AND DIVERSITY

One of the major problems that exist for many years in Jordan is the fact that wide range of data is available with different scales, accuracy and coordinate systems, in hard copy or digital forms therefore data fusion of these data is not an easy task. The data sources used in this research are samples of a wide range of data, which include scanned hard copy cadastral maps, GPS field survey, satellite and aerial images and existing maps in vector format (Figure 3):

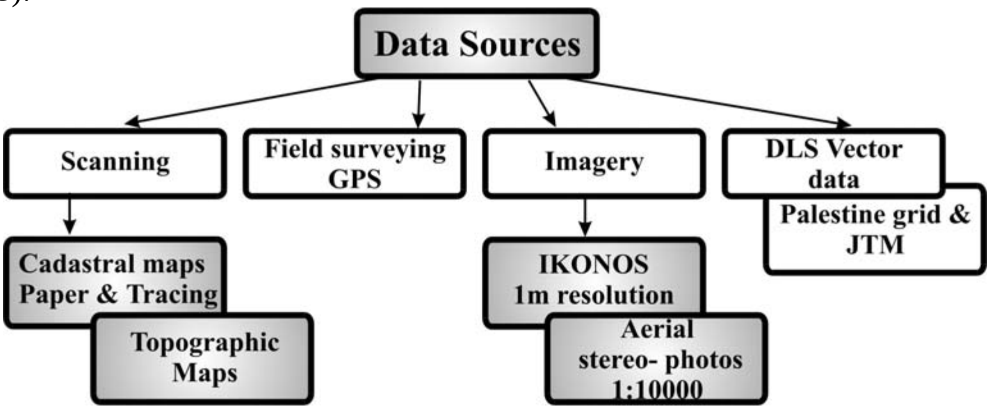

Figure 3: Data sources used in the research

– Scanned hard copy cadastral maps: The hard copy maps were provided by DLS in two forms: original paper maps (Figure 4) in scale 1:2500 and reproductions of original maps obtained by photo-copying process. All cadastral maps are in Palestine Grid projection. The scanning was performed with 400 dpi resolution.

Figure 4: Original Cadastral Map

– Satellite imagery: IKONOS panchromatic image with 1m resolution, this image was captured in 2002.

– Aerial Stereo Photographs: Six aerial digital photographs, provided by the Royal Jordanian Geographic Center (RJGC) covered the project area in scale of 1:10000 and 0.2m ground resolution. These photographs, taken with RC 30 aerial camera with nine inch format, 60% overlap and 30% side-lap. There images were arranged in a block of two strips and three columns (Figure 5).

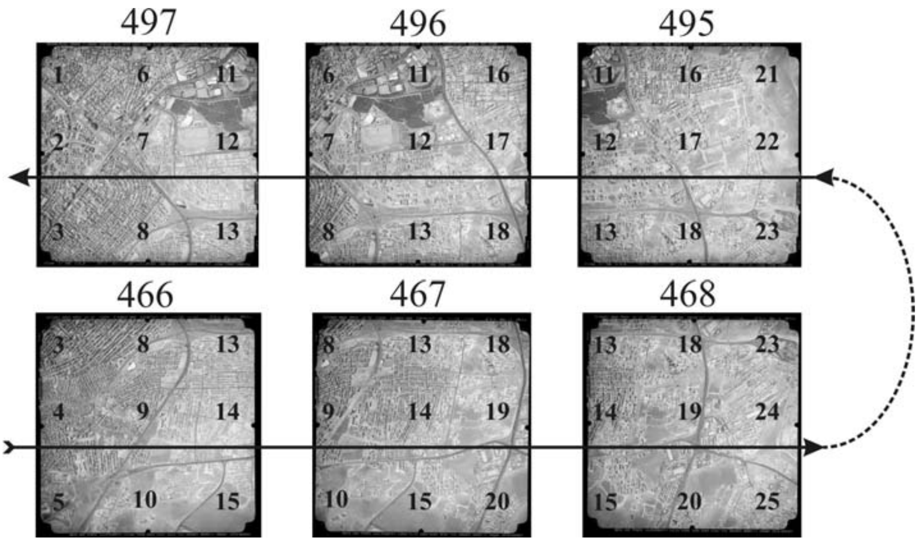

Figure 5: Aerial photographs and distribution of control points

– Field Survey: GPS field survey was carried with Leica 530 dual frequency receivers. The field survey provided control points with precise coordinates, and vector data (such as boundaries, street edges) that are used for comparison with ground truth.

– Vector Data: Digital cadastral maps in vector format were obtained from DLS in both Palestine Grid and JTM projections.

4. METHODOLOGY AND DATA PROCESSING

Regarding the methodology applied by DLS several factors have to be considered; firstly, the topography of the area was not taken into consideration throughout the transformations processes due to unavailability of topographic data. Therefore, only affine transformation was used in the project, regardless to the nature of the terrain. Secondly, the registered scanned images were compared only with the original hard copy maps, again due to of the lack of data (satellite images, aerial photos, etc) at that time. Moreover the quality (precision, distribution and source) of the control points is not always sufficient. Finally, the comparison with ground truth (field surveying) is carried out in sporadic manner, which affects the consistency of the accuracy analyses. In this paper the previously mentioned factors are considered, where different transformations functions were tested with regard to the nature of the relief in the area, satellite images, aerial stereo-photos, and precise GPS field surveying are used to generate ground truth model (Orthophoto and high resolution Digital Elevation Model (DTM)), which can be used for checking and updating of existing cadastral maps.

4.1 Field Survey

All points were surveyed with GPS relatively to two control stations, whose coordinates were determined with respect to two stations of International Terrestrial Reference Frame (ITRF) in Nicosia and Ramon, where the achieved accuracy is 0.15m. Two methods (Figure 6) of field GPS survey were used:

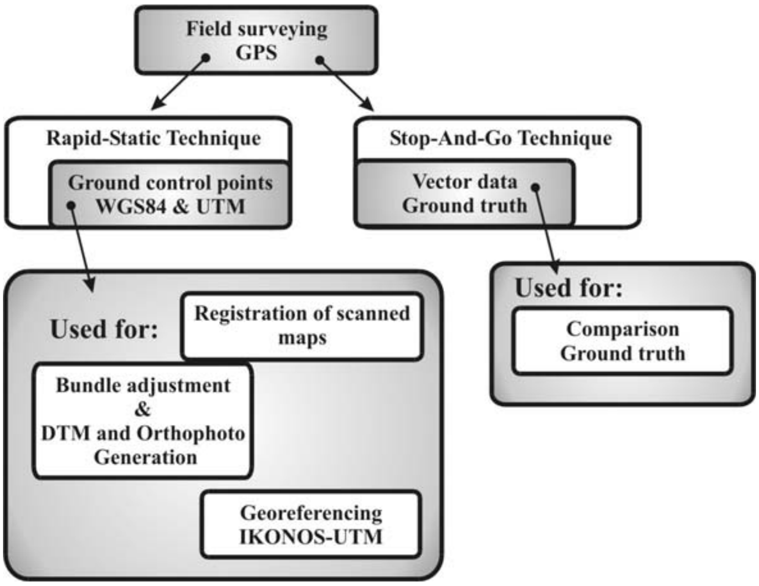

Figure 6: GPS Techniques and their use

– Rapid-Static technique with about 15-20 minutes observation time at each point. This technique was applied for determination coordinates of 25 control points, used for image and aerial photos processing.

– Stop-and-Go technique, applied for determination of the coordinates of about 250 check-points and vector data collection. The check points and vector data are used, as mentioned in the previous section, for comparison with ground truth.

For all check points millimeter accuracy was achieved with respect to the two main stations. WGS84 coordinates of all control points were projected to standard UTM Zone 36 coordinates system which was selected as coordinate system for the final results.

4.2 Aerial Stereo Images

Processing of aerial photos (Figure 7) includes the standard procedures of inner, relative and absolute orientation. Table 1 represents a sample of the exterior orientation parameters and their precision. The generated stereo model was checked using a set of well distributed check points. The RMS based on the differences between ground and model coordinates of those points was found to be 0.335m.

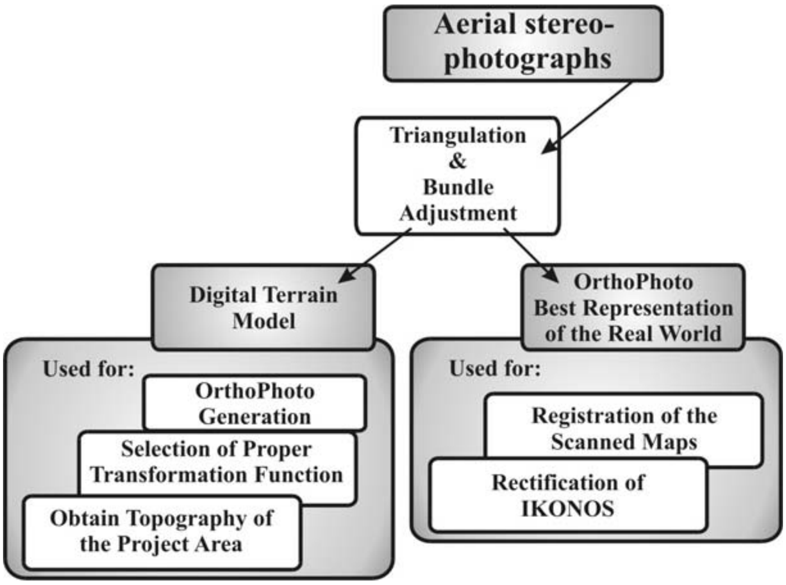

Figure 7: Processing of the aerial photographs

Image	EOP Parameters	Adjusted Value	Residual
13-497	Camera X (m)	775062.536	$-2.311*10^{-7}$
	Camera Y (m)	3541518.534	$-8.073*10^{-7}$
	Camera Z (m)	2450.111	$4.354*10^{-7}$
	Ω (degree)	0.3	$2.785*10^{-8}$
	Φ (degree)	1.2	$-5.567*10^{-9}$
	K (degree)	269.8	$1.860*10^{-9}$

Table 1: Exterior Orientation Parameters

For DTM generation, image correlation strategy was used for automatic extraction of the conjugate points. Moreover, adaptive method was used to generate a DTM with grid format, where the nature terrain (hilly, flat) was considered; Firstly a DTM file was created with 100 m post spacing to provide the whole project area with initial elevations of the terrain model where each post was edited to ground and saved. Then another DTM was built with 10 m post spacing, where improved representation of real terrain for 1:10000 photo-scales can be obtained. Finally, the consistency test between the generated DTM and collected GPS check points was carried out in order to insure of the quality of the produced DTM. The generated DTM was used mainly for orthophoto generation and selection of the proper transformation function (2D-similarity, affine and polynomial) based on the complexity of the generated terrain. The generated DTM was used for 3D visualization of the study area where the generated orthophoto dropped over DTM to show topography and details of the terrain, Figure 8.

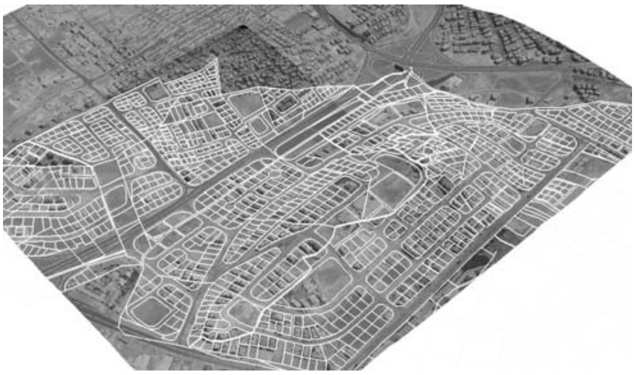

Figure 8: 3D view for cadastral boundaries overlaid with Orthophoto.

Next stage in the processing is to generate Orthophoto. Basically the orthophoto is photograph, transformed from perspective to orthogonal projection, or otherwise said, corrected for tilts and relief displacements (Wolf and Dewitt, 2000). The produced DTM was used for orthophoto generation. Regions that are not edited correctly in the DTM file appear on the orthophoto as breaks and cuts in the region. These errors were removed by manual editing of the DTM based on visual inspections. The orthophoto and DTM were finally overlaid with the vector data collected from the field (Figure 9).

Figure 9: Overlay of orthophoto with vector field data

4.3 Satellite Imagery

Another source of data, which provides 1 meter geometric resolution, has high coverage (6 km x 6 km) and can be used for cadastral data extraction, is IKONOS satellite image. Obvious mismatch between the provided geo-referenced IKONOS image and collected GPS vectors appeared as shown on Figure 10. Therefore well distributed points extracted from the Ortho-photo were used to correct the IKONOS image.

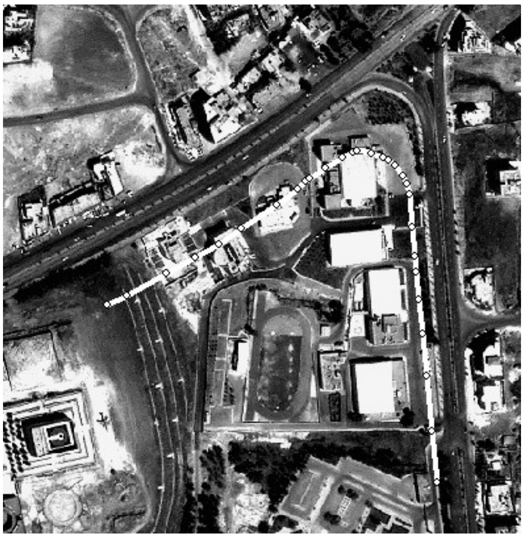

Figure 10: Overlay of IKONOS with field data before registration

The parameters of the registration transformation functions between IKONOS and Orthophoto (using 2-D similarity, affine and projective transformation functions) (Table 2) are estimated using twenty well distributed tie points, which have been manually identified in the orthophoto and IKONOS image. The variance component derived from the least squares procedure summarizes the quality of fit between the involved primitives in the registration process. Analyzing the results, one can see that the estimated variance component has improved using affine transformation when compared to that derived through 2-D similarity transformation. Considering the estimated variance component resulting from the registration of the IKONOS and Orthophoto, using a 2-D similarity transformation (7.356), it can be concluded that such a transformation function is not a valid one. However, using an affine and the projective transformation resulted in a much more reasonable RMS (6.564) and (5.996) respectively, which signifies the validity of these transformation functions.

RMS (m)	Projective Transformation	Affine Transformation	Similarity Transformation
IKONOS to Orthophoto	5.996	6.564	7.356

Table 2: RMS results of transformation of IKONOS image to Orthophoto

4.4 Scanned Hard Copy Cadastral Maps

Registration of the scanned cadastral maps and their matching with the orthophoto was the real challenge. Three types of transformation functions (similarity, affine and projective) were tested on scanned maps in hilly and flat areas. The registration was based on common points between the scanned maps (input image), orthophotos (reference image). The resultant RMS errors and comparison are given in Table 3. It can be noticed that affine transformation gives best results in flat areas while projective transformation is more adequate in hilly areas.

RMS (m)	Projective Transformation	Affine Transformation	Similarity Transformation
Hilly area	**2.13**	2.711	17.436
Flat area	5.349	**4.981**	9.607

Table 3: RMS for registration of scanned maps to orthophoto

The registered scanned map with best RMS value was compared with the field vector data collected using GPS, and orthophoto (ground truth model). Figure 11 illustrates the overlay of these data sources. These maps were used to generate a mosaic and to extract a vector layer, which represents the cadastral boundaries.

Figure 11: Overlay of best registered map with GPS field survey and Orthophoto

4.5 Vector Data

Figure 12 shows the vector data processing flow-chart. The overlay of the vector data provided by DLS with the satellite images and orthophotos required re-projection of the vector layers. Originally in undefined coordinate system, the layers passed through a process of topology building, definition of projection (both Cassinni and JTM used), then transformation to UTM zone 36 with datum WGS84 ellipsoid (Figure 12). This transformation was performed with ArcGIS software as follow: from Cassinni and JTM projections the layers were converted to geodetic coordinates, referring respectively to Clarke and ED50 (modified) ellipsoids; classical 3D transformation was used to compute geodetic coordinates on WGS84 ellipsoid, on which standard UTM zone 36 projection was applied.

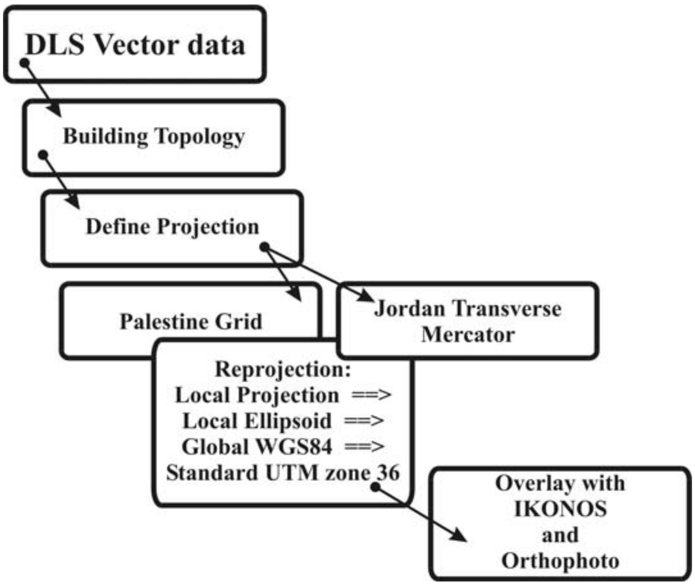

Figure 12: DLS vector data processing

While very good match between GPS check points and vector data and orthophotos and rectified IKONOS was achieved, the overlay between DLS vector data with the same layers shows larger differences (Figure 13).

Figure 13: Overlay of orthophoto with vector data (DLS-white color; GPS- dotted black)

5. CONCLUSIONS AND FUTURE WORK

This paper addressed the key issues of an efficient cadastral map renewal and data fusion methodology that can handle multi-temporal multi-source data (raster and vector). The presented approach uses the orthophoto generated from stereo pair image as the base of all available data since it represents the ground truth. Using orthophoto will save time and costs for field surveying. Then, the registration transformation function is analyzed to determine the mathematical relationship between conjugate primitives in the data to be registered. It has been established that affine transformation can be used as the registration transformation function for flat areas while projective transformation will be more appropriate for hilly areas. Moreover, 2-D similarity transformation can be used as another alternative for some applications with less demanding accuracy requirements.

An important application of orthophoto is to check the consistency between legal boundaries (cadastral map) and physical boundaries (orthophoto). Cadastral maps can be very successfully updated using orthophoto in old settlement areas where agreements between neighbors exist and the physical boundaries are obviously not changed since long time. In this case it can be assumed that the physical boundaries follow the legal ones and any systematic distortion of the digital map can be easily estimated, analyzed and reduced, applying proper transformation function.

As mentioned before changing the way of boundary demarcation has to be considered. New marks, substituting the iron pegs, can be designed regarding future application of photogrammetric methods. For example photogrammetric marks can be used on the top of the survey mark. These marks should have size, shape and color suitable to be recognized as image of the boundary corner on an aerial photograph with required precision. The photogrammetric marks can be attached to the established boundary corners in the whole area where cadastral surveying is to be performed.

Similar techniques can be used to overlay existing digital cadastral maps with Digital Surface Models (DSM), laser scanning data, close-range photogrammetry images. Looking toward future 3D cadastral models, where property rights should be associated with particular volumes in space can be built easily. DSM can provide precise positions of cadastral boundaries above the Earth's surface (high buildings, flats and apartments). Additional information can be gathered using close range photogrammetry: surface rendering for buildings and other constructions as well as natural objects may be useful for valuation, taxation purposes and expansion of virtual models.

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BIOGRAPHICAL NOTES

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