ACCURACY STUDY OF DIGITAL RESTITUTION PRODUCED FROM SCANNED 1/40000 SCALE AERIAL PHOTOGRAPHS AT DIFFERENT RESOLUTIONS

M. Cherkaoui-O.[a], M. Rouchdi [a], J. Massiji[b], I. Solomay[b]

[a] Département de Cartographie-Photogrammétrie, Institut Agronomique et Vétérinaire Hassan II
Rabat, Maroc (m.cherkaoui@iav.ac.ma)

[b] Ingénieurs au secteur privé

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RESUME :

La photogrammétrie a connu une évolution croissante passant par les procédés analogique, semi- analytique et analytique qui étaient bien développés durant la deuxième moitié du siècle précédent. Vers la fin du même siècle le procédé numérique qui est devenu possible avec l'augmentation des performances et la miniaturisation du matériel informatique ainsi que le développement de logiciels appropriés. Si le matériel informatique est devenu accessible à toutes les petites et moyennes entreprises topographiques, ces derniers ont du mal à acquérir une caméra numérique ou un scanner photogrammétrique nécessaires pour la production d'image photographique. Cependant, il existe sur le marché des scanners de moyennes résolutions, mais l'inquiétude réside au niveau de la précision des résultats à obtenir. Pour cela, cette étude a été réalisée pour tester les performances d'un scanner de bureau (EPSON de format A3) avec 4 résolutions différentes (300, 400, 600 et 800 dpi). Les résultats de la restitution obtenus à partir des photographies au 1/40 000 numérisées avec ces résolutions ont montré que les normes de la cartographie topographique à l'échelle du 1/50 000 et inférieure sont satisfaites avec une résolution de 800 dpi.

ABSTRACT:

For a decade, photogrammetry has known an important investment in infrastructure and equipment. Getting accurate coordinates from aerial photographs relies on long and difficult operations. Photogrammetric tasks need, also, that one should have enough knowledge about the optical, mechanical and digital systems used. Due to the rapid development of software and the high performance of hardware, digital photogrammetric procedures become widely used. Furthermore, the market offers, presently, a large variety of computers and scanners at low prices. Hence, most professionals in the cartographic field show interest in integrating the new technology in production tasks. However, they are in doubt of the product accuracy that will result using this technology. The main purpose of this research was to evaluate the accuracy of a digital restitution generated from two couples of aerial photographs at scale of 1/40 000(one couple covers a flat terrain and the other one a rudged terrain) scanned at three resolutions (400, 600 and 800 dpi) using a desktop A3 scanner. The analysis of results accuracy showed that topographic mapping at scale of 1/50 000 and lower is possible using a desktop A3 scanner and a resolution of 800 dpi.

1. INTRODUCTION

Photogrammetry has been always a synonyme of an important investment and reserved for only some specialists. It is true that the used matierial ether analogic or analitic is in general impressive. Ggetting acurate coordinates from photographic images needs elaborated methods and good knowledge about mecanics, optics and computer science based techniques. The use, progressively, of video sensors since 1975, the increase in preformance of micro-computers, has introduced a new field which is digital photogrammetry or video-grammetry (Egels, 1998). Since then, it has been a matter of digital image processing instead of direct manipulation of aerial photographies. Theses techniques have several consequances conséquences on photogrammetric restitution procedures (Duperet, 2001).

- An important decrease in price of video-restitution instruments which were brought to replace analytical stereo-restitution instruments ;
- The management of digital image is less costly than the technology which is necessary for controling the silver negative displacement in terms of micron ;
- The democratisation of restitution instruments has made the photogrammetric technique affordable to some structures such as PME, PMI and research laboratories.
- The possibility of research development for the purpose of procedures automatisation.

Howver a problem persists : the possibility of acquiring, by all professionals, performant and costly material which satisfies the needs of topographic cartography (high resolution digital camera or a photogrammetric scanner. Thus, the idea was to test medium resolution scanner to produce digital images for which the restitution result will be confronted to a number of points determined by GPS.

2. MATERIAL AND METHODS

2.1. Used material

The material used in this study is composed of :

1. A computer with the following caracteristics :
    - Speed 800 MHz ;
    - SDRAM 128 Mb ;
    - Graphic card Labs Oxygen de 32 Mb ;
    - Screen ADI 21 inchs with a maximal resolution of 1920x1200 pixels ;
    - Fast bus ;
    - 3D measuring device ;
    - Hard disk of 10 Gb.
2. A flat scanner EPSON GT 12 000 with the following caracteristics
    - Black and white with a photoelectric device : color CCD array ;
    - Effective resolution : 9760 dots per 13760 pixels at 800 Dpi ;
    - Digitizing resolution : 50 Dpi to 3200 Dpi per interpolation ;
    - Color separation : RGB color filters on CCD array.
3. 3D display system (Nu Vision Model # 60GX) composed of crystal liquid focusing glasses.
4. Digital photogrammetric software VirtuoZo integrating the following modules :
    - Aérotriangulation ;
    - DTM derivation ;
    - Orthophos production ;
    - Digital restitution either using IGS module or Bentley micro-station software. The latest is the one used in this study.
5. Two stereoscopiques couples covering two different zones, one flat area and a rough muntainous area (Table 1.).
6. Three GPS receivers (ASHTECH).

Area	Photos scale	Date	Average level diffrence (m)	Topography
Al Hoceima	1/40000	February 2000	300	Rough terrain
Sidi Slimane	1/40000	May 1991	10	Flat

Table 1. Used couples caracteristics

2.2 Methodology

The purpose of this research is the study digital restitution accuracy for the needs of topographic mapping at scale of 1/50 000 and lower.
Taking into account that the available maximal scanner resolution is 800 dpi and that the dimension 30 µm is acceptable in the majority of aerotriangulation tasks, DTM, orthophotos orthographies, etc... (Kasser, 2001), the selected resolutions for this study are : 300, 400, 600 et 800 dpi. After scanning the photographs at the above resolutions, the results were converted from TIFF format to the VirtuoZo software format. The general followed methodology during this research is provided by the flowchart of figure 1.

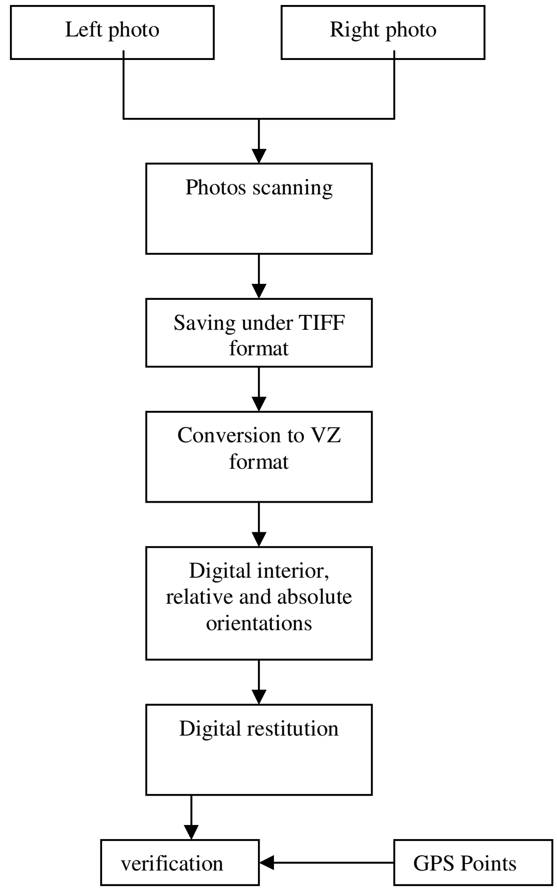

Figure 1 : Flowchart of the methodology

2.3 Used formulas

Due to the fact that coordinates are obtained from the process which integrates scanning, interior, relative and absolute orientations and restitution, their accuracy depends on mesearing tasks and consequently on the dimension of the pixel. This latest is a function of geometric resolution and photographs scale. In this context, we present the used formulas for the purpose of computing the theoric accuracies :
- Pointing error on the scanner coordinates is about half pixel. It is given as follows :

$$\sigma_x = \sigma_y = t/2 \qquad (1)$$

where t the pixel dimension

- Relative orientation is realized automatically by means of images correlation. Its accuracy depends on the number of measured points by correlation and on the pixel dimension L'orientation relative. Hence the formula is :

$$K \times t \qquad (2)$$

Where K is the ratio between the Root Mean Square Error (RMSE) and the pixel dimension (0.2 < K < 1.5)

- For the two used couples, control points were determined by aerotraingulation based on classic stereopreparation. The accuray, in planimetry and altimetry, of points determined by stereopreparation is estimated about ± 20 cm and the one by aerotriangulation is about ±60 cm. Thus, the corresponding formula may be given:

$$\sigma_a(m) = \left[\frac{n_1 x 0.20^2 + n_2 x 0.60^2}{(n_1+n_2)} \right]^{1/2} \quad (3)$$

n_1 is the number of control points obtained by stereopreparation and n_2 those obtained by aerotriangulation.

- The planimetric error on terrain coordinates depends on the pixel dimension and the scale of negative. This one is given by :

$$\sigma_p = (\sigma_x^2+\sigma_y^2)^{1/2} = \sqrt{2} \text{ x } \frac{t}{2} \text{ x Ec} \quad (4)$$

Where t is the pixel dimension and Ec the scale number .

- The altimetric average error depends mainly on the pixel dimension, the scale of the negative and on the ratio base – height (B/Z). It is given by the simplified formula which follows :

$$\sigma_Z = \sqrt{2} \text{ x Ec } \frac{t}{2} \text{ x } \frac{Z}{B} \quad (5)$$

Where Z represents the diffeérence (H-h) between the altitude of perspective center (H) and the point of interest (h).

- The accuracy of absolute orientation depends on altimetric and planimetric acuracy of scanner coordinates and the accuracy of control points. Hence, the planimetric accuracy is given by :

$$\sigma_P = (\sigma_p^2 + \sigma_a^2)^{1/2}$$

And the altimetric accuracy is given by :

$$\sigma_Z = (\sigma_z^2 + \sigma_a^2)^{1/2}$$

3. EXPERIMENTAL STUDY

3.1 Case of AL Hoceima couple

3.1.1 Interior orientation

Table 2 shows that the calculated pointing error, either for left or right photo is less than the theoric error which is half pixel. Hence, measures can be juged as acceptables for the continuation of the process.

Resolution (dpi)		300	400	600	800
Pixel dimension (µm)		85	64	42	32
Pointing error (µm)	Left photo	**36**	**19.92**	**14.76**	**9.44**
	Right photo	**21**	**18.67**	**8**	**5**
Theoric pointing error		42	32	21	16

Table 2 : Interior orientation results

3.1.2 Relative orientation

Table 3 shows that, generally, the differences are less than half pixel. We can also notice an enhancement of relative orientation with increasing resolution. Consequently, the process can be continued and goes to the absolute orientation.

RÉSOLUTION (dpi)	300	400	600	800
Taille du pixel (µm)	85	64	42	32
σ_r (µm)	49	17	10	6
K	0.57	0.26	0.24	0.19

Table 3. Relative orientation results

3.13 Absolute orientation

Table 4 provides absolute orientation results that is planimetric RMSE (mxy) and altimetric (mz) calculated for the different resolutions. Moreover, this table provides also the corresponding theoric accuracies in planimetry (σ_P) and in altimetry (σ_Z). By analizing these results, we can notice that, for any used resolution, the planimetric RMSE is out of tolerance. However, for the altimetry, we can notice that the errors are aceptables for 300 and 400 dpi resolutions but not for those of 600 and 800 dpi. This result may be due to the terrain topography and vegetation cover which may have an effect on features identification. We can notice also accuracy enhancement with increasing resolution.

Resolution (dpi)	300	400	600	800
mxy (m)	4.259	3.129	1.865	1.830
σ_P (m)	2.448	1.863	1.2936	1.021
mz (m)	2.905	2.398	1.931	1.817
σ_Z (m)	3.618	2.727	1.855	1.245

Table 4. Absolute orienation results

The obtained results urged us to use the resolutions of 600 and 800 dpi Sidi Slimane couple. These results are discussed next.

3.2 Case of Sidi Slimane couple

3.2.1 Interior orienation

Table 5 shows that the calculated pointing error, either for left or right photo is less than the theoric error which is half pixel. Hence, measures can be juged as acceptables for the continuation of the process.

Resolution (dpi)		600	800
Pixel dimension (µm)		42	32
Pointing error (µm)	Left photo	6.08	4.12
	Right photo	4.47	5.39
Theoric pointing error		21	16

Table 5: Interior orientation error

3.2.2 Relative orientation

Table 6 shows that in general the differences are less than one fifth of a pixel. D'après le tableau 6, on remarque qu'en général les écarts sont inférieurs au cinquième du pixel. We can also notice an enhancement of relative orientation with increasing resolution. Consequently, the process can be continued and goes to the absolute orientation.

Resolution (dpi)	600	800
Pixel dimension (µm)	42	32
σ_r (µm)	6	5
K	0.14	0.16

Table 6. Relative orientation results

3.2.3 Absolute orientation

Table 7 provides absolute orientation results that is planimetric RMSE (mxy) and altimetric (mz) calculated for the different resolutions. Moreover, this table provides also the corresponding theoric accuracies in planimetry (σ_P) and in altimetry (σ_Z). Moreover, this table provides also the corresponding theoric accuracies in planimetry (σ_P) and in altimetry (σ_Z). By analizing these results, we can notice that, for any used resolution, the planimetric RMSE is less than the theoric error.

Resolution (dpi)	600	800
mxy (m)	0.896	0.797
σP (m)	1.342	1.082
mz (m)	0.487	0.276
σZ (m)	1.897	1.477

Table 7. Absolute orientation results

Before going to the step of restitution evaluation, we should emphasize that results for the case of Sidi Slimane sont better than those of Al Hoceima. This may be due to the terrain topography and the vegetation cover which in turn may have an effect of features identification.

3.3 Restitution evaluation

For the purpose of restitution evaluation 11 GPS points were colected for the case of Al Hoceima and 14 others for the case of Sidi Slimane. The coordinates of these points were adjusted based on known planimetric points. Furthermore, taking into consideration both resolutions : 600 and 800 dpi, the coordinates of these points were compared with their corresponding points provided by restitution. Table 8 presents the obtained average differences during this verification.

Resolution (dpi)		600	800
Al Hoceima	D_{xy} (m)	3.90	1.996
	D_z (m)	6.93	2.033
Sidi Slimane	D_{xy} (m)	3.00	1.890
	D_z (m)	2.07	2.011

Table 8. Results of restitution verification

By analizing table 8, we can notice that for the same couple, the results is enhanced from resolution 600 to 800 dpi. We can also notice that the obtained result for Sidi Slimane is better than the one for Al Hoceima. This may be due to the terrain topography which is rough in the case of al Hoceima and flat in the case of Sidi Slimane
Moreover, to conclude for the scales of maps to be produced, we have considered the tolerated differences which are used by the National Cartographic Agency in Morocco. These differences are ± 0.2mm at map scale for the case of planimetry and ± 1/3 of contour interval for the case of altimetry. Therefore for a map at scale of 1/50000, we obtain 10 m in planimetry and 3.33 in altimetry.
By taking into account these differences, those of the collected points by GPS and their corresponding points collected from restitution, we can conclude from the results of table 9 that topographic mapping at scale of 1/50 000 is possible using aerial photographs at scale of 1/40 000 and an A3 office scanner.

Resolution (dpi)	600	800	600	800
	% des points à écart ≤ 10 m		% des points à écart ≤ 3.33 m	
Al Hoceima	82%	100%	27%	91%
Sidi Slimane	100%	100%	35%	71%

Table 9. Results of restitution verification

4 Conclusions

This research has dealt with the study of accurac of digital restitution from images acquired by means of an A3 office scanner. The purpose was to see at which level can restitution results be used for topographic mapping at medium scale.accuracy Considering that the scale of photographs is 1/40 000 and the resolutions are 300 and 400 dpi, we are faced with a problem of features identification and hence the results are not acceptables. On the other hand, for the resolutions of 600 and 800 dpi, the results are better and apply to topographic maps standards at scale of 1/50 000 and lower. Thus, it is possible to conclude that an A3 office scanner with a resolution of 800 dpi is sufficient to convert photographs at scale of 1/40 000 to images for the purpose of a digital restitution. And topographic mapping at scale of 1/50 000 and lower. For a better validation of this study, it useful to undertake the same experience but using areas with variable terrain topography and a dense vegetation cover..

We also recommend to undertake similar researches using aerial photographs at scale of 1/20 000 and larger.

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