STEREOSCOPIC ACCURACY

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ABSTRACT:

In the generation of photogrammetric products with large terrain coverage (Orthophoto, DTMs) some crucial issues like the application of DG / ISO procedures, the management of high amounts of data or the efficiency of automatic measurement (matching) arise. Nevertheless, in spite of the acknowledged progress in this matter, there are still some other relevant tasks - like the map plotting - that still require a great deal of work and that still are far away from a complete automatic flow. In order to analyze the stereoscopic accuracy (both horizontal and vertical), a measuring test has been performed with different image scales (GSD of 7.5 – 10 cm, 45 – 50 cm). These measures have been realized with digital workstations (Digi3D) and analytical plotters (LeicaSD2000). We have worked with a large number of stereoplotter operators from both public and private companies. We have analyzed the planimetric accuracy which depends on the image scale and also the height accuracy which depends on the image scale and also on the base / height ratio.

1. INTRODUCTION

While working with an analog camera, the relation between the map scale, the image scale and the flying height is well determined. While working with a digital camera we usually establish the relation with the analog image scale through the pixel format projection on the ground (ground sample distance – GSD). There are some drawbacks in this approach. For a 15 or 20 µm scanning resolution of the analog image we can get different GSDs for the same image/map scale rate. Besides this, comparing this GSD with the GSD related to digital cameras (such as DMC, with 12 µm pixel size and UltraCamD, with 9 µm pixel size) we get a significant variation in the image scales depending on the camera we choose.

There are not many references on stereoscopic accuracy attainable with large format digital cameras. For the DMC camera from Z/I some reports have been presented. (Dörstel, 2003; Alamús et al, 2005). As long as the UltracamD camera from Vexcel is concerned no data is available in this matter. This paper presents some experiments and results with this camera.

2. MATERIALS AND METHODS

2.1 Flights

The flights used to carry along the stereoscopic measurements by stereoplotter operators are:

- *Laguna de Duero*: two flights with large image scale, that support the comparison between analogic camera (LD_AE, Leica RC30, *c* = 153,42 mm) and digital camera (LD_D, UltracamD, UltracamD, *c* = 101,4 mm). Besides this, in this flight the original aerial photographs were observed by means of an analytical stereoplotter with an analogical optic system (LD_AA).
- *Mansilla de las Mulas*: a flight with a large scale obtained with a digital camera (MM_D, UltracamD, *c* = 101.4 mm).
- *Arauzo*: two flights with small image scale to compare between the analogical camera (AR_AE, Leica RC30, *c* = 153,42 mm) and the digital camera (AR_D, UltracamD, *c* = 101,4 mm).

Name of the Flight	m_b	*px* (µm)	*GSD* (m)	*B* (m)	*H* (m)
LD_AE	5,000	20	0.100	450	767
LD_D	8,333	9	0.075	225	845
MM_D	11,111	9	0.100	300	1,125
AR_AA	30,000	15	0.450	2,686	4,600
AR_D	55,555	9	0.500	1,500	5,633

Table 1. Data from the different images used. m_b: image scale factor; px: image pixel size; GSD: Ground Sample Distance; B: Base; H: Flying height above terrain. All the stereoscopic models have an overlap of about 60%.

2.2 Methods

2.2.1 Experiment design: The variance of the estimation of a mean is σ2/n. If we want to identify differences between two series we may diminish σ2, leading to the concept of group, or increase n, leading to the concept of repeating the experiment. It is important to distinguish between repeating an observation and repeating the experiment. If two measures are realized one after the other we attain an observation repeated twice but not a repeated experiment. The reason is that, in practice, the variation between two consecutive measurements is lower than the variation between separated observations. Consequently, it is desirable to realize the complete experiment and to repeat it afterwards. In this way we may avoid an underestimation of variability.

The only warranty against the *learning* effect and some other similar effects that may occur in every experiment is to randomize all the factors under control, e.g. to control the order in which operators work. In this way we may eliminate unpredictable bias, correlation among observations, misinterpreting differences between cameras or the learning effect in the operator.
To compare the accuracy between two cameras it is necessary to have them working under similar conditions. If a factor such as the operator ability is probably conditioning the camera accuracy there are two possible options: to use only one stereoplotter operator with both cameras (*classic design*) or to use several operators with both (*factorial design*). The classic design exhibits the following drawbacks: a lack of generalization, as the use of a single operator does not permit to apply the results to a bigger sample, inefficiency if there exists experimental variability, wrong results if there is interaction among the variables. These disadvantages in the traditional procedure become advantages in the factorial design. As long as the variable levels are exchanged in every possible combination, an estimation of interaction can be achieved and when there exists an experimental design error it is easier to asses its effects.

2.2.2 Measures: For every point and operator, the standard deviation in XY, S_{xy}, is obtained and also the standard deviation in Z, S_z. These are the parameters to be analyzed and are considered to express the accuracy of the stereoscopic measures, both planimetric and in heights. It is not aimed to asses the global accuracy of a photogrammetric product but the accuracy related with the stereoscopic model (Kraus, 1993). The point stereoscopic measurements have been done in this order: first point, second point and so force until the last point to complete one cycle. No point has been observed n times in a consecutive fashion. To achieve n measurements of the same point, the cycle has been repeated n times. Each operator has realized 3 cycles at the beginning of the day and 3 cycles again at midday, to avoid tiredness in his performance, the repeatability in measurements and the so called learning effect. In this way we have 6 measurements per point and operator for a total of 13 operators from public and private companies. This stereoplotter operators are daily engaged in purely stereoscopic photogrammetric procedures (stereoplotting, editing DTMs) and have an experience that ranges from 10 years (high) to 5 years (medium) and to 1-2 years (low). In any case the minimum experience to achieve significant results has been considered to be one year.
Due to the modular composition of large format digital cameras (DMC and UltraCamD) we have considered relevant to perform a geometric analysis based on the distribution of the points across the stereoscopic surface. Consequently, the points have been distributed in nine zones of the stereoscopic model. On each of these nine zones, at least one of the three following types of points have been measured. Three types of points have been established and have been used depending on the image scale and the urban or countryside nature of the environment: well defined points on the terrain; easy urban points (roofs) and difficult urban points (ground points close to buildings).

2.2.3 Elements of comparison

2.2.3.1 Theoretical accuracy in XY: The accuracy in XY, planimetric accuracy, σ_{xy}, is determined through the image scale factor, m_b, and the image measurement accuracy, σ_i:

$$\sigma_{xy} = \sigma_i * m_b \tag{1}$$

The image measurement accuracy, σ_i, is about ± 6μm (Kraus, 1993). It may be expressed as a function of the image pixel size, *px*, as a fraction of it (*px/k*). This value, *k*, may be considered as an indicator of the image measurement accuracy. In addition, the product of the image pixel size and the image scale factor provides the terrain pixel size, *GSD*:

$$\begin{aligned} &\sigma_i = \frac{px}{k} \Rightarrow \sigma_{xy} = \frac{px}{k} * m_b \\ &GSD = px * m_b \Rightarrow \sigma_{xy} = \frac{GSD}{k} \end{aligned} \tag{2}$$

After establishing the planimetric standard deviation, S_{xy}, from a series of experimental measurements, it is possible to obtain the correspondent image standard deviation, S_i. And from the comparison of S_i and *px*, we can obtain the value of *k*, that could be a good parameter to compare between different cameras performances as it is not affected by scale.

$$\begin{aligned} &S_{xy} = S_i * m_b \Rightarrow S_i = \frac{S_{xy}}{m_b} \\ &S_i = \frac{px}{k} \Rightarrow k = \frac{px}{S_i} \end{aligned} \tag{3}$$

It is important to note that in this paper we are working with two terms that may be misunderstood: accuracy, σ, and standard deviation, *S*. The first one expresses theoretical accuracy and it is determined by the correspondent theoretical equation. The second is the empirical standard deviation and it is determined by the measurements.

2.2.3.2 Theoretical accuracy in Z: The accuracy in Z, σ_z, depends on the horizontal parallax accuracy, σ_{Px}, the image scale factor, m_b, and the ratio between flying height and flying base, *H/B* (Kraus, 1993):

$$\sigma_z = \sigma_{Px} * m_b * \frac{H}{B} \tag{4}$$

Nevertheless σ_z also can be set as function of the distance between camera and object, in this case, flying height above mean terrain, as a 0.06 $^0/_{00}H$ or a 0.08 $^0/_{00}H$ depending on the camera used (Kraus, 1993).
The accuracy in the horizontal parallax measurement can be substituted by the accuracy in the image point measurement, σ_i. Even more, the ratio flying height / flying base can be substituted by the ratio principal distance (focal length / image base, *c/b*). So:

$$\sigma_z = \sigma_i * m_b * \frac{c}{b} \tag{5}$$

As before, we can express σ_i as a function of the image pixel size, *px*, and the Ground Sample Distance, *GSD*:

$$\begin{aligned} \sigma_i = \frac{px}{k} \Rightarrow \sigma_z = \frac{px}{k} * m_b * \frac{c}{b} \\ GSD = px * m_b \Rightarrow \sigma_z = \frac{GSD}{k} * \frac{c}{b} \end{aligned} \tag{6}$$

The image base, *b*, is a function of the along strip overlap and along strip image size. The ratio *c/b* affects the accuracy in Z. The higher is this value, the worse is the accuracy in Z.

Camera	c (mm)	Image width (mm)	b (mm)	c/b
Analogic	150	220	88	1.705
DMC	120	92	36.8	3.261
UltraCamD	100	67.5	27	3.704

Table 2.- Ratios *c/b* of some aerial photogrammetric cameras provided a 60% overlap along flight line.

A comparison between accuracies leads to a comparison between different cameras:

$$\frac{(\sigma_z)_D}{(\sigma_z)_A} = \frac{\left(\frac{GSD}{n} * \frac{c}{b}\right)_D}{\left(\frac{GSD}{n} * \frac{c}{b}\right)_A} = \frac{\left(\frac{1}{n} * \frac{c}{b}\right)_D}{\left(\frac{1}{n} * \frac{c}{b}\right)_A} \tag{7}$$

The ratios *c/b* are known for a certain camera once the end overlap has been established. In principle we assume that *k*, our accuracy indicator is the same for both types of cameras, analogic and digital. The comparison should be undertaken through stereoscopic measurements on images from similar flying surveys, i.e. with similar *GSD* In this way, we can determine empirically the standard deviation of a series of measurements in Z of a digital camera (S_{zD}) and of an analogic camera (S_{zA}), evaluate its ratio and compare it with the ratio of the theoretical accuracies (σ_{zD}/σ_{zA}):

$$\frac{\sigma_{zD}}{\sigma_{zA}} \neq \frac{S_{zD}}{S_{zA}} \Rightarrow k_D \neq k_A \tag{8}$$

Since the ratios *c/b* are known for both cameras, if the differences in the ratios are significant we can conclude that the parameter *k* for both of them are significantly different (the higher value of *k*, the better accuracy).

2.2.3.3 Relationship between planimetric and height accuracy: The quotient between the planimetric and the height standard deviations, S_{xy}/S_z, by itself is not meaningful, but if it is compared with the quotient *B/H*, we get the relation between the planimetric and height accuracies since this ratio, theoretically, equals one.

$$\frac{S_{xy}/S_z}{B/H} \tag{9}$$

3. RESULTS AND DISCUSSION

3.1 Large scale flights

In the stereoscopic model called LD_AE, 46 points have been observed. These measurements were done by five different operators, trough two series with three cycles each. The five operators were distributed as follows: two highly experienced, one in the medium range and two with short experience.

Operator	S_{xy} (m)	S_z (m)	Number of observations
1	0.013	0.025	274
2	0.018	0.042	276
3	0.012	0.030	268
4	0.020	0.033	276
5	0.018	0.030	275
Balance	0.016	0.032	1,369

Table 3.- Standard deviations obtained in the flying survey LD_AE.

The same operators measured the same points on digital images from the flyight LD_D:

Operator	S_{xy} (m)	S_z (m)	Number of observations
1	0.014	0.042	274
2	0.018	0.070	274
3	0.011	0.048	275
4	0.019	0.063	276
5	0.017	0.053	273
Resumen	0.016	0.055	1,372

Table 4.- Standard deviations obtained in the flying survey LD_D

3.1.1 Comparison LD_D vs LD_AE: The ratio between the standard deviations S_{xy} of the two fligths is one (0.016/0.016), so no significant differences in planimetry can be appreciate. The ratio between the standard deviations in Z is 1.719 (0.055/0.032) while the theoretical ratio between the correspondent accuracies is:

$$\frac{(\sigma_z)_{LD\_D}}{(\sigma_z)_{LD\_AE}} = \frac{\left(\frac{0{,}075m}{k} * \frac{101.4mm}{27mm}\right)_{LD\_D}}{\left(\frac{0{,}100m}{k} * \frac{153.42mm}{88mm}\right)_{LD\_AE}} = 1.616 * \frac{k_{LD\_AE}}{k_{LD\_D}} \tag{10}$$

If we compare the empirical and the theoretical results we get $k_{LD\_AE} = 1.06 * k_{LD\_D}$. We obtain the conclusion that the variation in the accuracies of the analogic and the digital camera are very slight.
Are this empirical data significant? We think they are because they include five operators with different but enough experience, measuring the same points in images that come from an analogic and a digital camera. Besides this, the points are distributed in the overall stereoscopic surface according to nine zones and with the three types of points in each zone.
Is the difference meaningful? The *relative relief* is the quotient between the differences in heights in a certain zone and the flying height above the mean terrain surface *(ΔH/H)*. In our case, due to the different flying heights, we obtain a ratio between the relative relieves of both cases of:

$$\frac{\left(\Delta H / H\right)_{LD\_AE}}{\left(\Delta H / H\right)_{LD\_D}} = 1{,}10 \qquad (11)$$

This figure could help to explain the differences between the height accuracies but these differences are too little to achieve meaningful conclusions.
Nevertheless there are two considerations that we must still do. The first is related with the selection of the points to be measured. To obtain the same *GSD* with the analogic and the digital camera, it becomes necessary to use several models of the digital camera to cover the same terrain surface that the analogic camera covers. For this reason, the distribution of the points to be analyzed is defined over a unique stereomodel of the analogic camera and this results on a coverage of several models of the digital camera

Type of Point	S_{xy} (m)	S_z (m)
T	0.014	0.017
E_A	0.015	0.014
D_U	0.024	0.017

Table 5.- Standard deviations obtained from the flight LD_AE, with different types of points T: Terrain; E_A: Easy Urban; D_U: Difficult Urban.

Type of Point	S_{xy} (m)	S_z (m)
T	0.029	0.052
E_A	0.033	0.050
D_U	0.042	0.074

Table 6.- Standard deviations obtained from the flight LD_D, with different types of points T: Terrain; E_A: Easy Urban; D_U: Difficult Urban.

The second consideration is related with the type of points. In case of the points placed at the base of buildings the accuracy in Z is clearly worse than the accuracy for the other two type of points. And in the case of the digital camera, the result is even worse. This could be due to the fact that the points were selected close to the buildings on the image from the analogic camera. The different geometry through the different digital models besides the shorter focal length (that leads to larger occlusions) can possibly explain this behaviour.
These two considerations make us think that that the height measurements on the images from the digital cameras are not as good as the measurements on the images from the analogic camera. At least, these mesaurements are not done under the same conditions.
We may ask now what about if the scanning process would have been done with a 15μm pixel size instead of the actual 20μm pixel size? In this case the terrain pixel size would have been of 0.075m., thus equalling the digital flight *GSD*. In consequence, the theoretical accuracies ratio would have been:

$$\frac{(\sigma_z)_{LD\_D}}{(\sigma_z)_{LD\_AA}} = \frac{\left(\frac{0{,}075m}{k} * \frac{101.4mm}{27mm}\right)_{LD\_D}}{\left(\frac{0{,}075m}{k} * \frac{153.42mm}{88mm}\right)_{LD\_AA}} = 2.155 * \frac{k_{LD\_AA}}{k_{LD\_D}} \qquad (12)$$

This new figure 2.155 is larger than the later one, 1.616, about a 33%. If we would have had our five operators measuring the images from the analogic camera under these conditions, would have we got results a 33% better? Some authors think that the best image pixel size for a scanning process is 15μm (Boniface, 1996).
We did not scanned the aerial photographs with a 15 μm pixel size but we carried along observations on the same points on the original analogic film with the analytical plotter Leica SD2000 with four other operators. This is the flying survey LD_AA.

Operator	S_{xy} (m)	S_z (m)	Number of observations
1	0.012	0.021	275
2	0.019	0.031	269
3	0.012	0.020	276
4	0.011	0.027	274
Balance	0.014	0.025	1,094

Table 7.- Standard deviations obtained from the flight LD_AA

3.1.2 Comparison LD_AE vs LD_AA: The ratio of accuracies in XY exhibits worse results for the digital image (with 20 μm pixel size) compared with the analogic photograph of about 14% (0.016/0.014). If we admit a linear behaviour in this part of the relationship accuracy / scanning pixel size this suggest that the best scanning pixel size should be 20/1.14 = 17.5 μm.
The ratio of accuracies in Z shows that with the 20 μm pixel size scanned image we obtain results that are a 28% worse (0.032/0.025) than with the original analogic photographs. According to this, and if we attribute all the difference to the different scanning pixel size, the best scanning pixel size would have been 20/1.28 = 15.6 μm (In this case, the ratio *c/b* is the same because the camera and flying geometry are the same).
These results seem to point at the fact that we would have achieved better accuracy if we would have scanned the photographs with a 15μm pixel size. With this, the terrain pixel

size would have been the same as the one of digital camera flight (0.075 m).

Please, note that the observation system is different in this case (including the stereoscopic vision system). In addition, these observation series have been done with different operators. Maybe part of the differences found between the series is due to these variables that have remained out of the designer control.

3.1.3 Comparison LD_D vs LD_AA: In the last chapter we have point the fact that perhaps it have been desirable a 15μm scanning pixel size provided that the differences in accuracies are directly related to the differences in the scanning pixel size. We think that the global average values of the different flights are comparable even knowing that there are differences in the operators and in the measuring instrument.

The ratio of accuracies in XY is about a 14% (0.016/0.014) better in the analogic flight. The theoretical ratio of accuracies in Z, supposing the same *GSD* in both flights is of 2.155, while the empirical ratio, found through the tests is of 2.200 (0.055/0.025), almost the same.

3.1.4 The large scale flight MM_D: As stated before, due to the conditions of the point selection for the experiment and due to the type of points, it is not possible to achieve definitive conclusions. In consequence, some further experiments were developed with another digital flight, with another set of points and with a *GSD* (0.100 m). equal to the one of the analogic flight, scanned with a resolution of 20 μm. In this case, only points of the Terrain type were observed with three points on each of the nine stereomodel zones. Thus, the total number of points were 27. The operators were four: two highly experienced; one, medium and one, low.

Operator	S_{xy} (m)	S_z (m)	Number of observations
1	0.016	0.053	162
2	0.018	0.046	162
3	0.022	0.062	162
4	0.016	0.044	162
Balance	0.018	0.051	648

Table 8.- Standard deviations obtained from the flight MM_D.

Comparing the MM_D and the LD_AE flights, with the same GSDs, the difference in accuracies in XY is about a 13% (0.018/0.016), worse for the digital flight. The ratio between the empirical standard deviations in Z is 1.594 (0.051/0.032), while the theoretical ratio is 2.155. This results in $k_{MM\_D} = 1.35 * k_{LD\_AE}$, i.e., a 35% better with the digital camera than with the analogic camera.

If we compare MM_D with LD_AA, the difference in XY accuracies is of a 28% (0.018/0.014) and if we compare the ratios of observed standard deviations in Z, 2.040 (0.051/0.025) with the ratios of the theoretical ones, 2.155, $k_{MM\_D} = 1.06 * k_{LD\_AA}$ we find it is almost the same.

3.1.5 Full comparison: The different values of S_i and of *px* are not comparable among them. But the different values of the accuracy indicators, *k*, are comparable. The values of LD_AA and of MM_D are very similar. The worse value of LD_D could be due to the conditions of the point selection and its types. As for the value of LD_AE, the best of them, maybe is due to the 20 μm pixel size. As stated before, this figure may not be the ideal one to determine adequately the parameter *k*.

	LD_AE	LD_AA	LD_D	MM_D
S_i (μm)	3.20	2.80	1.92	1.62
px (μm)	20	15	9	9
k	6.25	5.36	4.69	5.56
S_{xy}/GSD	0.16	0.19	0.21	0.18
S_z/H	$4.17 * 10^{-5}$	$3.26 * 10^{-5}$	$6.51 * 10^{-5}$	$4.53 * 10^{-5}$
$\frac{S_{xy}/S_z}{B/H}$	0.85	0.95	1.09	1.32

Table 9.- Figures from the four large scale flights analyzed. S_i: standard deviation obtained from the image measurements; *px*: image pixel size; *k*: accuracy indicator, obtained from S_i, *px* and the image scale factor, m_b; S_{xy}/GSD: ratio between planimetric accuracy and *GSD*; S_z/H: ratio between height accuracy and flying height; $(S_{xy}/S_z)/(B/H)$: quotient between the planimetric and height empirical standard deviations ratio and the planimetric and height theoretical accuracy ratios. Note that it has been assumed that the *px* of LD_AA, the analogic flight observed with the analytical stereoplotter, is 15μm.

The different values of S_{xy}/GSD are similar for all the flights. The values of S_z/H in the case of the analogic camera flights are in the range of $3\text{-}4 * 10^{-5}$, while in the case of the digital camera flights are in the range $4.5\text{-}6.5 * 10^{-5}$. For the two analogic flights the values $(S_{xy}/S_z)/(B/H)$ express better planimetric standard deviation than height standard deviation while in the case of the digital flights, this parameter expresses the inverse, worse planimetric standard deviation than height standard deviation.

3.2 Small scale flights

In the so called AR_AE flight, a series of points distributed along the nine stereomodel zones, were measured. In each of these zones three points were measured which gives a total amount of 27 points. These points were observed by four different operators in two series of three cycles each. All the points were of the Terrain type. These four operators are distributed as follows: two with large experience, one with medium experience and one with little experience.

Operator	S_{xy} (m)	S_z (m)	Number of observations
1	0.093	0.132	162
2	0.093	0.125	162
3	0.104	0.214	161
4	0.084	0.119	162
Balance	0.094	0.148	647

Table 10.- Standard deviations obtained with the flight AR_AE.

The digital flight AR_D was observed by the same group of operators that measured the very same points than in the analogic flight AR_AE.

Operator	S_{xy} (m)	S_z (m)	Number of observations
1	0.124	0.228	162
2	0.086	0.221	161
3	0.145	0.311	162
4	0.110	0.229	162
Balance	0.116	0.247	647

Table 11.- Standard deviations obtained with the flight AR_D.

3.2.1 Comparison between AR_D vs AR_AE: If we compare the accuracies it may be noticed that the ratio between the standard deviations in XY, is a 23% (0.116/0.094) worse in the case of the digital camera, even though the difference between the *GSDs* is only of 11 % (0.500/0.450). In spite of the fact that the problematic bad defined points have been eliminated, maybe the selection of points on the analogic stereomodel is "improving" the accuracies obtained in this case. In addition, with this small scales, we must consider the bigger uncertainty related with the identification of the point at the countryside (Kraus, 1993).
The ratio between the empirical Standard deviations in Z is 1.669 (0.247/0.148), while the ratio between the theoretical accuracies is 2.393. This implies that $k_{AR\_D} = 1.43 * k_{AR\_AE}$.

$$\frac{(\sigma_z)_{AR\_D}}{(\sigma_z)_{AR\_AE}} = \frac{\left(\frac{0{,}500m}{k} * \frac{101.4mm}{27mm}\right)_{AR\_D}}{\left(\frac{0{,}450m}{k} * \frac{153.42mm}{88mm}\right)_{AR\_AE}} = 2.393 * \frac{k_{AR\_AE}}{k_{AR\_D}} \tag{13}$$

We reach the conclusion that the accuracy in Z is much better in the case of the digital camera than in the case of the analogic one, about a 43%. The variation between the relative relieves of both flights is about 22%, and can hardly explain the percentage found.

	AR_A	AR_D
S_i (μm)	3.13	2.09
px (μm)	15	9
k	4.79	4.31
S_{xy}/GSD	0,21	0,23
S_z/H	$3.22 * 10^{-5}$	$4.38 * 10^{-5}$
$\frac{S_{xy}/S_z}{B/H}$	1.09	1.76

Table 12.- Data from the two small image scale flights.

The ratio S_{xy}/GSD is quite similar in both flights (0.21 and 0.23). The height ratios S_z/H show some larger differences but not too much ($3.22 * 10^{-5}$ and $4.38 * 10^{-5}$). The quotient $(S_{xy}/S_z)/(B/H)$ establishes that in both cases the planimetric standard deviation is worse than the height standard deviation but in the case of the digital camera this difference is more acute.

Is interesting to note, for the same operator, the differences among the different flights. The flights LD_AE y LD_D were observed by the same operators and the flights MM_D, AR_AE, y AR_D were observed by the same operators. The flight LD_AA has been observed by other tour operators, and these have not repeated the measurements.

4. CONCLUSIONS

In all the flights that have been used, we have analyzed the influence of a set of variables on the accuracies in XY and in Z. These variables are: the distribution of points on the model, the operators and their experience, the type of points. In every case it has been found that these variables do not influence the variation in the accuracy in XY between the analogic camera and the digital camera. Besides this, and except the type of points, they neither explain the variation in the accuracy in Z.

We find that the indicator k, as the image pixel fraction, is a good element for comparison. From the data obtained, we can say that this indicator shows better results for the analogic camera for all the flights. We can also say that this number is worse for higher flying flights, no matter the type of camera used.

The values of the ratio $(S_{xy}/S_z)/(B/H)$ express that the flights with the analogic camera offer rather better results in planimetry than in heights while in the case of the digital camera flights, the result is inverse: the planimetric accuracy is worse than the height accuracy.

The empirical conclusion we get is that the negative impact caused by the worse ratio *B/H* from the digital camera flights is smaller as the flying height becomes larger.

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