DIGITAL STEREO PLOTTING WITHOUT 3D VISION: AN EFFECTIVE WAY IN THE ARCHITECTURAL PHOTOGRAMMETRY

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ABSTRACT

The present scientific and technological development of the computer tools propitiates the evolution of the metric photography plotting, in such a way that the accessibility to the subject is easier for the professionals.

In this research, we tackle the comparison between the digital stereo plotting with and without 3D vision, considering the first an effective choice within the architectural metric photography field.

With the purpose of demonstrating the effectiveness of digital method, we have designed a statistical experiment. It consists on the obtaining of the mean and the variance results of the plotting common errors through the information given by a sample.

The research is structured as follows: (1) Sampling method selection and obtaining of the number of points to observe; (2) Descriptive analysis of the restored points and study of the data distribution; (3) Statistic inference survey - we check the average errors by means of the paired samples method, which improves the comparison accuracy; (4) Comparison of the average errors dispersion.

With a 95% reliability, the analysis of the results determines that: (1) Working with both plotting methods, the average error of the x and y coordinates is similar. The average error of the z coordinate is minor if we work with the digital plotting method; (2) It exists inequality between the variances: Dealing with the digital program, x and z coordinates have less standard deviation. Working with both studies systems, y coordinates standard deviation result the same.

All the arguments set out here lead to the conclusion that: the digital stereo plotting precision improves the analytical plotting provided that the distances between the object and the camera are the customarily used in architectural photogrammetry.

Brief Historical Introduction to the San Vicente Ferrer Chapel.

The facade of the San Vicente Ferrer Chapel is gothic, but not the dome, which was later build, during the baroque period.

All through the 17thc., different buildings were leaned against the facades of the four chapels placed on the Miguelete Street, they had such uses as housing, warehouses or archives. Other spanish cathedrals also suffered this process.

At the beginning of the 18th c., a restoration design of the Miguelete Street was executed. The plan consisted on roofing each gothic arch of the four chapels and the leaned buildings with an ornamental cover (a face), only leaving the domes in full view.

Throughout the present 20th c. and with the purpose of retrieving the gothic art of the cathedral, these faces were destroyed. This made the facades completely visible.

Main Aim of the Project.

Our first aim would be the photogrammetric survey of the San Vicente Ferrer lateral chapel facade.

Although previous to the first one, our second aim would consist on the selection of the most adequate photogrammetric plotting to this survey. We have to be capable to rigorously analyse all the possibilities the market equipments offer. Is the entire on offer possibilities real? And, which of the equipments are the most adequate in our case?

With regard to the increasing influence of the informatics in the photogrammetric field, we consider so interesting the analysis of two main points: (1) In what cases are the informatic applications valid, and (2) if they are always available.

The analysis of the methods is possible starting from these data:

1- Error forecast in terrestrial photogrammetry. The user of the computer program is unfamiliar with the employed mathematical development and the fitting of data in the coordinates calculus. But regarding the data this method requires and the parameters it obtains, the user can intuit the mathematical development and fitting of data.

2- Statistical analysis of the results of each of the photogrammetric plotting methods. Regarding the impossibility to analyse the mathematical process we mentioned above, we conclude with an assessment starting from a statistical comparison of errors. The employed statistical method is useful in the study of the metric validity of the digital photogrammetry plotting systems we find on the market, without break in continuity.

We compare two different analytical restorers:

a) Analytical restorer with support of his own and quality recognised by its results. High price. A referent in data comparison. Main characteristics:
   - Metric camera without radial distortion.
   - Two negatives needed.
   - High-resolution photography emulsion.
   - 3D vision of the model.
   - Order of the analytical process: internal, relative, and absolute orientation.
   - Low error forecast.

b) Digital analytical restorer. It works as a PC program. Customary price; it reduces the cost of the photogrammetric survey. Characteristics:
   - Half-metric camera. It implies radial distortion.
   - Three scanned photographs needed. The resolution of the images is limited by the resolution of the scanner, and it is always lower to the resolution of the photographic image.
   - Two negatives needed.
   - High resolution photography emulsion.
   - 3D vision of the model.
   - Order of the analytical process: internal, relative, and absolute orientation.
   - Low error forecast.

Statistic Model Formulation.

According to the order and development method requirements of this science, we design a statistical experiment.

The infinite points of the facade would constitute the population. The continuous random variables are: Xp, Yp, Zp, Xc, Yc, and Zc (variables to compare).

As it is logically deduced by the equations that follow, the first three variables in a way represent the error we find in measuring the coordinates of the points by photogrammetry plotting. We say "in a way", because we do not know the real value of the x, y and z coordinates of each point.

$$Xp = Xclas - Xplan$$
$$Yp = Yclas - Yplan$$
$$Zp = Zclas - Zplan$$

Clas: meaning the coordinate obtained by classic plotting, and Plan: obtained by analytical plotting with the Planicomp-C100 restorer.

The variables corresponding to the digital method are:

$$Xc = Xclas - Xcdw$$
$$Yc = Yclas - Ycdw$$
$$Zc = Zclas - Zcdw$$

Cdw: the coordinate obtained by digital stereo plotting with the Rollei Metric CDW program.

Method of the Statistical Experiment.

These are the steps followed in our analysis:

1. Calculus of the sample size.
2. Samples taking. Measurement of the x, y, and z of the control points coordinates with both 2D and 3D plotting methods and by classic topography.
3. Study of the data normality.
4. Comparison between the typical deviation of the errors made in x, y, and z coordinates.
5. Study of the medium errors by an analysis of the paired data.
6. Analysis and conclusions of the former results.

1. Sampling. Regarding the sampling of probabilities, we find different methods: simple random, stratified o by conglomerates. Although the methods, which better, fit according to our study are the simple random and the stratified sampling. We choose the simple random sampling (SAS) because: a) The sample differences between the stratum are direct function of the distance between the selected point and the objective of the camera (starting from the formula of the error forecast in terrestrial photogrammetry). We almost take into consideration all the representative differences, including minimal surface but excepting the high section of the chapel dome; b) By the application of the SAS, and studying the obtained results (they require 43 points as a minimum), and establishing the anomalous data, we take 49 points of the population.

2. **Data obtaining: fulcrum and checkpoints.** In the plotting we studied 9 fulcrum by direct intersection with the Topcon Total Station GTS-303. After this, we measure the x, y, and z coordinates of the 49 required checkpoints by:

- Classic topography method, by direct intersection.
- Analytical restitution by Planicomp C-100.
- Analytical restitution by Rollei Metric program.

3. **Data normality.** In order to know if a sample fits into a typified normal to successfully make the statistical inference, we have employed:

- The sampling parameters, which make reference to the form of each of the six studied variables distribution: standard symmetry and kurtosis coefficients; last one useful when we need to know if there is a high lacking of data proportion on the extremes. Sampling form parameters affirm that the generated variables are normal, because their values belong to the [+2, -2] interval.
- Although it would be enough to prove the normality by means of the sampling parameters, we have drawn the graphs of the six variables in normal probabilistic paper.

The values of the continuous random variables: Xp, Yp, Xc, Yc, and Zc, are approximately situated along a straight line, as the five probabilistic paper graphs of the following pages show. With that, we can assert that there is normality within their distributions.

Although the Zp = Zclas - Zplan variable continues being a normal distribution, it shows anomalous data. They are not irregularly high or low values, separated from the straight line in the right top and the left bottom of it.

The n size of sample to the Zp variable is 38 points, that is the reason why we can discard a maximum of 11 points that are deviant from the straight line. When we repeat the probabilistic diagram, we observe that the Zp variable fits into a normal distribution.

Table **1.1**	$X_{t.clásica} - X_{rest.Planic.}$	$Y_{t.clásica} - Y_{rest.Planic.}$	$Z_{t.clásica} - Z_{rest.Planic}$
Sampling mean m´´	**0.0094551** m	**0.00566122** m	**-0.00803** m
Sampling variance s^2	**0.000451569** m^2	**0.00045793** m^2	**0.000117775** m^2

Table **1.2**	$X_{t.clásica} - X_{rest.CDW}$	$Y_{t.clásica} - Y_{rest.CDW}$	$Z_{t.clásica} - Z_{rest.CDW}$
Sampling mean m´´	**0.00397347** m	**-0.000534693** m	**0.00168397** m
Sampling variance s^2	**0.000218948** m^2	**0.000388385** m^2	**0.000546267** ^{2}

4. **Comparing data dispersion.**

With the purpose of inferring population data from the sampling data, we use the F distribution by Snedecor. This distribution is used in practices, when comparing the variability caused by different operative conditions.

We compare the continuous random variables variances defined by both 2D and 3D analytical plotting.

By the statgraphic 1, we obtain the statistical summary of the data that appears on the 1.1 and 1.2 tables.

Is the answer variable variance the same in the different data obtained by the comparing random variables (Null hypothesis)

$$\text{Sampling mean: } m'' = X = \Sigma \frac{X_i}{n}$$

$$\text{Sampling variance: } \sigma^{2}{}'' = s^2 = \frac{\Sigma (X_i - X)^2}{n-1}$$

That is, is it admissible $\sigma_{xp} = \sigma_{xc}$, can we admit admissible $\sigma_{yp} = \sigma_{yc}$. Each of these equalities represents one null hypothesis (H0).

In order to determine if the previous hypothesis are or not admissible, we must consider the probability distribution associated to the sampling of the standard population.

From the sampling we calculate the following quotient:

$$\frac{s_1^2/\sigma_1^2}{s_2^2/\sigma_2^2} \approx F_{n1-1,\, n2-1}$$

n is the size if the sample taken out from the i population. Right population implies that

$$\frac{s_1^2}{s_2^2} \approx F_{n1-1,\, n2-1}$$

But, if H_0 is wrong

$$\frac{s_1^2}{s_2^2} > o < F_{n1-1,\, n2-1}$$

Means comparison results:

From the listing of the statistical statgraphics it can be deduced that

a) There is no variances equality between Xp and Xc variables, where the second variance is minor.
b) Variance equality between Yp and Yc variables.
c) No variance equality between Zp and Zc, being minor the first variance.

Considering α =0.05, as a first risk element, it implies a 95% reliable interval within the results.

5. Comparing paired data.

With the purpose of comparing the means of the studied variables and in order to assure in a population level if they can be considered similar or if they differ, we apply the probability t distribution by Student, which relates the difference X – m.

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We must take into account the distribution of the sampling mean calculated from the standard data in order to answer the question.

When we affirm that the analytical plotting CDW method has a similar restitution error to the Planicomp-100 (which is a null hypothesis), is the same as saying that:

$$H_0.: m_d = 0$$

When m_d means the difference between the standard error obtained by a plotting method and the standard error obtained by the second plotting method, we will obtain three null hypotheses. First difference: between standard errors of Xp and Xcdw variables; second: between the standard errors of Yp and Ycdw; and the third one: in between the standard errors of the Zp and the Zcdw.

$$m_{dx} = 0$$
$$m_{dy} = 0$$
$$m_{dz} = 0$$

If the $\bar{X}$ sampling mean differs from 0, then there will be evidence to consider H_0: m_d = 0 as admissible, now that the sampling means average coincides with the real m value, and although in this case we only have one sampling mean, we can expect that it would be near m.

On the contrary, if the $\bar{X}$ sampling mean does not little differ from 0, we would consider the null hypothesis as not acceptable, but we would consider an alternative the following hypothesis H_0: $m_d \neq 0$ In general, we affirm that:

$$\text{If } m_d = 0 \rightarrow (H_0 \text{ admissible}) \rightarrow \frac{X - m}{s/\sqrt{n}} \approx t_{n-1}$$

$$\text{And if } m_d \neq 0 \rightarrow (H_0 \text{ not admissible}) \rightarrow \frac{X - m}{s/\sqrt{n}} \geq\geq t_{n-1}$$

Variances comparison results

By the study of the results we can assert that, with a 95% reliability, the average committed error when measuring (x,y) coordinates is the same considered by both the Planicomp-100 restorer and the Rollei Metric CDW plotting program.

Advantages of the paired data method

1. This method allows us to outstandingly increase the precision in the comparison; in our case, the comparison between the standard errors committed by each of the plotting methods. It is a tough test.
   The homogeneity between the experimental units makes tough the comparative analysis, and that is why we calculate the errors of each kind of plotting upon the same cathedral facade points.

2. The mdx, mdy, and mdz variables difference between the obtained error by the Planicom-100 and the one obtained by the CDW plotting program, makes no necessary to know the real value of the coordinate (and this makes more reliable the comparison, because we avoid the error we drag along when we measure the coordinates of the points with classic topography). We demonstrate the affirmation by the first of the three H0:

$$H_0 = m_{dx} = 0 = m_{xp} - m_{xc} = m_{xclas} - m_{xplan} - (m_{xclas} - m_{xcdw}) =$$
$$= -m_{xplan} + m_{xcdw} = 0$$

Conclusions.

Digital Stereo plotting without 3D vision: an effective way in the architectural photogrammetry.

In this research, we have tackled the comparison between the digital stereo plotting with and without 3D vision, considering the first an effective choice within the architectural photogrammetric field.

As a previous summary to the conclusions, we can affirm that, with the purpose of demonstrating the effectiveness of the digital method, we have designed a statistical experiment. It consisted on the obtaining of the mean and the variance results of the plotting common errors through the information given by a sample.

The research is structured as follows:
1. Sampling method selection and obtaining of the number of points to observe.
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With a 95% reliability, the analysis determines that:
1. Working with both plotting methods, the average error of the x and y coordinates is similar. The average error of the z coordinate is minor if we work with the digital plotting method.

2. It exists inequality between the variances: Dealing with the digital program, x and z coordinates have less standard deviation. Working with both studies systems, y coordinates standard deviation result the same.

3. All the arguments set out here lead to the conclusion that:

A) The standard precision of the digital stereo plotting without 3D vision improves the precision of the analytical 3D vision plotting provided that the distances between the object and the camera are the customarily employed in architectural photogrammetry.

B) The operative speed of the analaytical plotting without 3D vision can overcome the speed of the digital system without stereoscope vision, over all working with not smooth objects. Maybe the technological development of the informatics does not take a long time to overcome this restriction. On the other hand, this restriction is strongly related to the experience of the user.

C) Working with the analytical plotting without stereoscope vision we cannot restore points that are not indicated on the photographs, as it could be possible with the sculptures plotting.
   However, we think the insufficiency of the system could be remedied by the creation of a web of points that defined the curves of the level (eg: by fixing adhesive signs).

D) It is proved that both the orientation record of the analytical 3D plotting and the files of the standard deviations provided by the analytical plotting without 3D vision, fit into the reality of the committed errors. So, these data can be useful when selecting the most interesting method according to our study, especially within projects of considerable scope.

E) Despite the results do not fit into the error forecast, we indicate some justifications:
   - 3D vision plotting. The parallax error according to the act of orientation is 19 micron, which amply overcomes the predicted 5 micron for this plotter. To a large extent, this is due to the taking the pictures: the photographs are convergent and taken with a little vertical angle.

- Digital plotting 2D vision program. In order to obtain all the orientation methods, we have one more photography than the necessary, because of the demand of the software. Logically, the typical deviation of errors will be minor, and the plotting of the error points will diminish. Another justification of the digital system without 3D vision precision is that it avoids the characteristic error of the orientation in the formation of the model.

F) The accelerated development of the computer tools - as a support of both teaching and researches work- makes unavoidable its application and study on the architectural photogrammetry field. Insofar as this quick development of the techniques related to this subject woks as it is working nowadays, it would be more and more unavoidable.

G) A researching way that can completely justify the obtains results is open. By the moment, it exceeds the aspirations of our project. The following step would be to apply the lineal regression of the statistical method to factors as: the distance in between the object and the camera, the plotting of images, the distribution of the fulcrum, erc. in order to understand how so important factors have effect on the 3D vision plotting errors.

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