USE OF VOLUMETRIC TARGETS TO IMPROVE ACCURACY IN ARCHITECTURAL PHOTOGRAMMETRY AT LOW COST

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ABSTRACT

The measuring of traditional architectural elements in the rural environment has a range of special characteristics. Generally, the emplacement of these elements is not the most favourable circunstance for photogrammetry measuring, owing to the existence of handicaps of different nature, which make difficult the vision of the object. For this reason, its necessary to use every available tools that allow us to improve the 3D construction models generated by means of architectural photogrammetry techniques at low cost.

A delicate matter when it comes to generating the 3D model through photographs, is the signposting of points. The more accurate is this, the more accurate will be the 3D model through photographs, is the signposting of points. The more accurate is this, the more accurate will be the 3D model created.

With the aim of improving the emplacement of these points through the digital photogrammetry software, we have developed two types of targests that make easier this task. As they´re volumetric targets their visual location is given and moreover it indicates us the emplacement of the structure point we´re going to mark. This characteristic makes posible the vision of the targets and, therefore, we can mark points in serveral photographs, what brings more reliability to the 3D photogrammetric model created.

1. INTRODUCTION

The terrestrial or close range photogrammetry at low cost is a hig potential tool for the measuring of heritage elements in the rural traditional architecture. It´s a quick technique, easy to use, which involves low cost and gives us enough accuracy for this goal.

There are frequently problems at the moment of realizing 3D models of the photographed elements at the time of signposting the reference points. Generally, those are difficult to identify and we can´t guarantee an accurate sigposting.

Another habitual problem is the scarce number of photographs where we can see each point. This is due to the nature of the photographed object and often to the difficulty in photographing it from the most adequate position.

The problems we described previously have led us to develop elements that allow us to locate the points to sigpost easily and as accurate as posible. We´ve developed a volumetric targets sistem that permit us to locate and sigpost points easily and accurately.

The 3D targets we have developed have two different shapes. One of them has a conical shape and others have an spherical shape. The ones which are conical allow us to mark points while the spherical don´t give us this possibility. What these spherical targets permit is to create aditional points in a great number of photographs, which confer stability to the 3D model created.

We have done a contrast with the aim of knowing the behaviour of the analyzed targets and the improvement their use provides the 3D model created. The contrast is realized on a traditional rural construction, which is representative of the difficulties we have to deal with in the country when we use photogrammetry techniques at low cost.

Once we get the datas through photogrammetry techniques at low cost, they´re contrasted with those we got by means of a reference equipment (total station). This makes possible the calculation of errors and their estatistical treatment, in order to determine which target brings more accuracy to the 3D model created through Architectural Photogrammetric Techniques alt low cost.

1.1 Procedure summary

Documentation and design of the experiment.
Choice of a significant construction of the working conditions in the county.
Configuration of the different architectonic photogrammetry equipments.
Signposting of the points on the construction to determine the coordinates.
Measuring and determination of coordinates with the reference method, total station.
Construction of the volumetric targets. Optimization of the fastening sistems.
Calibration of the photographic cameras.
Trials of the country work. Placing of the targets, photographing and unleading of datas.
Country work. Photogrammetic procedure. Photographs-taking with different equipments.
Working office. Acquiring of the 3D model of the construction with each equipment by means of an especific software.
Acquiring of the coordinates of every points.
Determination of the errors in independent distances.
Statistical processing.
Results acquiring and conclusions.

2. EXPERIMENT DESCRIPTION

2.1 Material

The equipment must be as accurate as posible at the moment of realizing planes to scale of rural construction. It´s very important that the components are low-cost, so the low-cost equipment will give rise to a major functionig and technique difussion.

REFERENCE EQUIPMENT

It´s not part of the photogrammetry equipment, it provides us with the necessary reference measurement for the accuracy contrast.

TOTAL STATION TOPCON GPT-6005 Measurement accuracy of ± (3 mm + 2 ppm) in measurements with prism and ± (5 mm + 2 ppm) in measurements without prism. Angular accuracy (standard deviation based on norm DIN 18723) 5” (1,5 mgon). Minimun lecture in the angular measurement 1”/5” (0.2/mgon). Measurement without prism from 3 to 150 metres. Minimun registration of the measurement in fine mode 1mm/0.2mm. Circular prism with metallic support. Toptrans program v 1.5.1. of data transmission.

Figure 1. TOPCON GPT-6005

PHOTOGRAPHIC CAMERAS

WERLISA PX1310 Digital photographic camera of low-range. Object lens f = 9,00 mm focal distance (equivalent to 37 mm in a camera format of 35 mm), CCD of1.300.000 effective pixels. Resolutions between 1280x1024 and 640x480 píxels, with three compression modes.

Figure 2. WERLISA PX1310

HEWLETT-PACKARD Photosmart 735C. Digital photographic camera of medium range. Object lens: Optical zoom 3X f value : panoramic mode f:2,6 mm to f:4,9 mm in telephoto lens mode f:5,0 a f:9,0mm of focal distance (equivalent to 38 mm – 114 mm in a camera format of de 35 mm), CCD of 3.200.000 effective pixels. Resolutions between 2048x1536 and 640x480 pixels, with three compression modes.

Figure 3.HEWLETT-PACKARD Photosmart 735C

OLYMPUS Camedia C5060 Digital photographic camera of high-rante. Object lens: Optical zoom 4X. F value in panoramic mode f:2,8 mm to f:4,8 mm in telephoto lens mode f:4,8 a f:8,0mm of focal distance (equivalent to 27 mm – 110 mm in a camera format of 35 mm), CCD of 5.100.000 Píxels. Resolutions between 3264x2448 and 640x480 píxels, with three compression modes.

Figure 4. OLYMPUS Camedia C5060

VOLUMETRIC TARGETS

Spherical Targets. Hollow plastic spheres, with bright colours and with a diameter of 45mm in the equatorial section.

Conical Targets. Pasteboard paper cones with bright colours and with an inside angle of 60º.

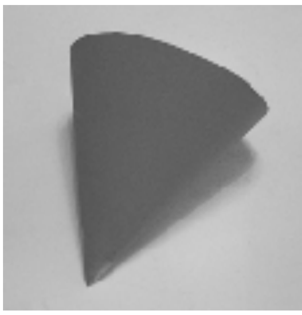

Figure 5.Conic Target

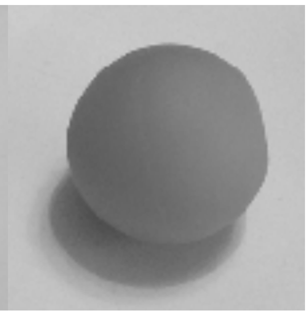

Figure 6. Spherical Target

Natural Targets. This kind of targets are singular elements of the construction that are easily recognizable and allow us to signpost. This type of target let us work without placing any aditional element on the objet to measure.

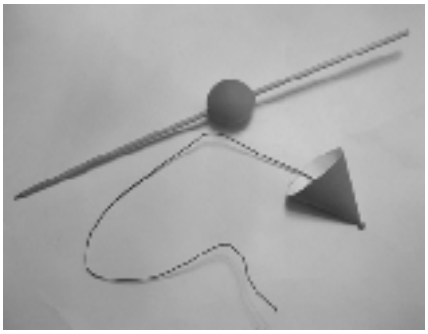

Figure 7. Volumetric targets

PRECISION TARGETS

Targets with subpixel bearing. Paper targets with circular graph in black colour to supply a high contrast. The computer preogram detects the centre of this targets in an automatic way with an accuracy of 1/20 of píxel.

Figure 8. Targets with subpixel bearing

SOFTWARE

PhotoModeler 5 Pro® (Eos Systems Inc)
AutoCad ®2.005 (Autodesk)
Microsoft® Office
Adobe Photoshop® 6
SPSS® 12 for Windows
Toptrans v 1.5.1.
TopCal ® 21, versión 1.12.28

An essential factor is the type of construccion where we apply this methodology. The traditional rural constructions are usually situated in places where the access, the lighting and the visuals are not optimun. Moreover, they usually have an irregular geometry and a difficulty in acciding to some of their elements. Therefore, a representative construction of the problems we approached previously was selected, with the aim of doing the contrast of accuracies in real conditions, that is to say in working conditions in the country.

Equipmet	Camera	Volumetric Target
1	OLYMPUS	Natural
2	Camedia	Conic
3	C5060	Spherical
4	HP	Natural
5	Photosmart	Conic
6	735C	Spherical
7	WERLISA	Natural
8	PX1310	Conic
9		Spherical

Figure 9. Equipments configuration

2.2 Experimental procedures and methods.

We find faced with the necessity of knowing which combination of elements, which we can dispose of for the configuration of the photogrammetry equipment, give us more accuracy at the moment of working out planes to scale of the constructions that are subject matter of the study.

For all this, a test with the country and office procedure is developed in such a way that let us to get the already-established goal.

The first step of the test consists of determining the material we dispose, with the determinant that is must be low-cost. There are elements that are common to every equipments. Tose are the computer program of the photogrammetric modelling and the subpixel marking targets used for the points over the accuracy will be contrasted. Those elements are considered as steady factors.

We have realized the contrast with cameras of different ranges with the aim of knowing the sensibility of this element integrated with the volumetric targets as opposed to the accuracy.

The test is always submitted to the difficulties that appear in the country, that is to say working in real conditions.

We need to know the point coordinates of the construction obtained with all the equipments we´re going to analyze. We nean by equipment the combination of edge targets and photographic camera, because the facade targets are common for all the equipments.

To realice the accuracy contrast it´s necessary to have a reference measurement, which gives us measurements as close as posible to the real dimension. The reference measurement is obtained by means of a measurement with an total station of the selected construction for the study.

Figure 10. Selected Construction

When taking the points we care about those are the same for all the equipments, included the reference one. For all this a set of marks are realized in an indelible way. The situation of these points is established in an aleatory way, with the aim of satisfying the randomnes principle of the experiments desing rules. Areventive measure an excess pints is generated to avoid shortages of number of dates for statistical treatmet. 15 points are taken by facade and 4 by edge as a minimun. In this way we have available a number of answers enough to guarantee a hig reliability grade in this treatment.

As we try to check the configuration that gives us the closest measurements to the real ones, we need to compare the results obtained with architectonic photgrammetry with those we obtained with the method we call "reference method", the total station.

To contrast the accuracy according to the volumetric target used we employ the points aforementiened previously marked on the facade of the construction.

To determine the position of these elements we use a type of target which is automatically recognized by the employed software with an accuracy of 1/20 pixel. This is the kind of target called subpixel marking target that works with high accuracy.

We create the 3D model with wolumetric targets and we determine the points coordinates of the facade identified with subpixel marking targets. Those are the ones we use for the accuracy contrast.

With the aim of making the most of the performance qualities of each photgraphic camera, tests of each machine are realized to determine the configuration of the different variables that give the best contrast and the better visiblility of the targets. Once the photographs have been taken and unloaded in the computer equipment we can start the processing with the photgrammetric software with this one, the coordinates of every point are determined and a 3D model is generated and scaled with the photographs that have been taken with each equipment.

In the measurement with electronic theodolite realized in this study a closed polygonal was realized, independente or local. Independent or local because both the leaving and the arrival of the itinerary is realized in the same point, which is called origin, which permits the determination of errors in itself. The itinerary or polygonal was defined based on the angular lectures (horizontal and vertical), on the distances (geometrical) and on the altitudes of the device and prism in each stations.

Once we´ve established the itinerary it´s necessary to measure the points from the bases or stations that are part of the aforementioned itinerary. In the point measurement distances were not registered, only angles were measured. The points were located without prism. For this reason, it´s necessary to apply the intersection direc method to determine their coordinates.

We work with distances between points, not with coordinates, with the aim of avoiding moving the major accuracy values towards a determined direction. The task with coordinates requires the use of a spatial system of common reference. As the coordinates generated with the adduced datas with each equipment are different, at the moment of creating the reference system it´s only possible to make coincide one of the 3 axes of the coordinates, and we´ve to adjust the position of the other 2. For this reason, depending on the adjusted axis, the method will be more accurate in one direction than in another one. This is what have led us to work in a more objective way and to emplo distance in our analysis.

For the determination of distances points are taken on the facades 2 by 2 in an aleatory way and distance is found out between them. Those points will be same for every configuration of the photogrammetry and reference equipment.

The aleatory variable answer used in this statistical analysis ys the error in independents distances between targets. It´s done like that to guarantee the aleatoryzation priciple of the experiments design and for requests of statistical treatment.

It´s understood by error the remoteness of the closer measurement to the real, this is the one given by the reference method, the total station.

From the photogrammetric modelling we obtain 52 accuracy points that give reliable information, because we underrate from the analysis every point where we suspect there had been a displacement of the target. This means we have 26 distances, therefore 26 errors by equipment for the statistical treatment.

The experiment is protected from possible strange slants as there are a high number of datas taken in a way totally independent. This experiment can be also considered balanced because the sample sizes are equal in every case.

In the beginning we work with a depth level of analysis of millimetres. This makes that in some difference of distance we get the value of "0", that is to say that with this depth level of analysis the error doesn´t exist. This phenomenon gives us problems at tht moment of the statistical treatment, because we take logarithms to homogenize the datas, and as we all know the logarithm of "0" doesn´t exist. In this way we would do away with the most accurate values of the statistical treatment.

To solve the aforementioned problem the analysis depth is increased till tenths of millimitre. With this order of magnitude we get rid of the problems with the logarithms. Althoug it could appear to be excessive to work with tenths of millimitres the treatment requires it.

We consider that we must employ the Medium Quadratic Error for a definitive classification according to the accuracy, because this variable answer has implicit two terms: the slant of each method and the variability. This makes it more complete at the moment of establishing the classification in a definitive way.

Medium Quadratic Error: $MQE = \frac{1}{N}\sum_{I=1}^{N}\left(\hat{d}_i - d\right)^2$

dî: Photogrammetry measurement.
d: Reference measurement.
N: Number of measurements.

3. EXPERIMENT RESULTS

As final result of the study a list of the different equipments is shown, indicating its accuracy in percentage value with regard to the reference measurement.

3.1 Cameras Ordering

EQUIPMENT (Olympus)	Accuracy (%)
Olympus C5060- Spherical Target	99,63
Olympus C5060- Natural Target	94,64
Olympus C5060- Conical Target	88,70

EQUIPMENT (HP)	Accuracy (%)
HP 735C- Spherical Target	99,62
HP 735C- Conical Target	99,24
HP 735C- Natural Target	91,45

EQUIPMENT (Werlisa)	Accuracy (%)
Werlisa Px 1310- Spherical Target	98,86
Werlisa Px 1310- Natural Target	98,70
Werlisa Px 1310- Conical Target	98,43

3.2 Accuracy Ordering

EQUIPMENT	Precision (%)
Olympus C5060- Spherical Target	99,63
HP 735C- Spherical Target	99,62
HP 735C- Conical Target	99,24
Werlisa Px 1310- Spherical Target	98,86
Werlisa Px 1310- Natural Target	98,70
Werlisa Px 1310- Conical Target	98,43
Olympus C5060- Natural Target	94,64
HP 735C- Natural Target	91,45
Olympus C5060- Conical Target	88,70

4. CONCLUSIONS

The accuracies contrast reveal the supremacy of the spherical targets. This is the same for any of the 3 digital cameras.

Betwen the 2 better equipments the differences are very rduced. The Olympus equipment C5060- Spherical targets, which is the better equipment, is different from the second one only in the photographic camera, the rest of the components are the same. The difference in price from one camera to another has, nowadays, a ratio of 3 to 1 in favour of the HP 735C equipment-spherical targets, therefore this equipment is more recommendable for the professional woek owing to the considerable saving that involves, whenever that bigger "grade" of accuracy doesn´t compensate the payment.

It´s really uncomfortable to work with conical targets. They require lots of care because they´ve very fragile, the placing is tedious and the location with the computer program of photogrammectric modelling has quite a lot of uncertainty and a high waste of time.

The yellow and orange targets become practically invisible in the views against the light, which makes more difficult their location.

The decisive parameter to get a high accuracy with the measurement by means of photograph, equally to the other factors, is the target. For the most favourable target, spherical target, the better is the photographic camera the more accurate will be the measurements. Ahigh range photographic camera doesn´t mean a high accuracy in photogrammetry, but it provides a high photographic quality of the documentation.

The spherical targets improve the 3D model accuracy generated by means of architectonic photogrammetry techniques at low cost. This kind of targets don´t let us signpost concrete points of the construction but we can generate aditional points that will be recognized with a high accuracy and will be seen in a great number of photographs, which will give a great stability and accuracy to the model generated. For those reasons the spherical targets should be included in every measurement with photogrammetric equipment at low cost.

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