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Review

Two photogrammetric methods for measuring flat elements in buildings under construction

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Abstract

Usually, determining the dimensions of flat surfaces in buildings under construction, such as window cavities and façade coating materials, are done by direct measuring methods using tapes and plummets. Sometimes these methods suppose a slow and highly risky work for operators. This research proposes the substitution of these procedures by indirect methods based on close range photogrammetry and laser distance measurement. First, we show the design, construction and calibration of a system composed by a digital camera and a lasermeter mounted on a support with multiple turning positions. Next, two different façade element measuring methodologies are shown. The first method is based on taking a single photograph and measuring the distance to the object. The second one is based on taking three photographs and three distances measured at three different calibrated positions. Finally the accuracy of each methodology is analyzed and the pros and cons of each one are shown.

Keywords: Close range photogrammetry; Laser; Calibration; Façade

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1. Introduction

Direct methods are commonly used to measure elements in the construction field, where operators have to move within buildings under construction, leaning out from windows and climbing roofs in order to hang tapes and plummets. The substitution of these methods by indirect ones based on close range photogrammetry will allow us to eliminate any contact with the object and minimize the risks that operators are exposed to. It will also increase measuring precision, reduce time used and eliminate coarse errors, like mistakes when writing down a measurement. Besides, it will be possible to create a digital record of the photographed objects.

Now, in order to really be accepted in this field, these methods must be of low cost, and accessible to people that do not have any knowledge of photogrammetry and topography. Low cost close range photogrammetry has been under study for the last few years by researchers that have in mind to close the gap between photogrammetry and non specialized users. It is mainly based on the use of low cost digital cameras and the elimination of methods and topographic equipment for ground control points measurement. Architecture and cultural heritage conservation examples where these methods have been used can be found in [1,15,16].

Works based on a single photograph without any ground control points have been used to determine the inner orientation parameters and the orientation angles by tracing parallel and perpendicular lines from other objects [20]. In order to obtain the camera inner orientation parameters [18], a similar treatment through a photographic shot of an unknown scale introducing a distance in the space object have been also done. These methodologies make it possible to construct 3D models using a single photogrammetric image with geometrical restrictions based on geometric relationships among straight lines such as coplanarity, parallelism, perpendicularity, symmetry and distance [9]. Works based on several photographs are more frequent in the construction field. Building structural analysis stage that show a clear collapse risk have been evaluated through these methods [14] or by the measuring and study of distortions on bridges [8,11] where close range photogrammetry has also been applied to.

Apart from these conventional methodologies, we can find investigations where different information acquisition systems are combined. We basically point out research based on multi-image photogrammetry using mounted cameras over a calibrated base or through compositions of images obtained through movement [2], based on laser scanning techniques with independent digital photogrammetry [3] or combined in single system [13], or other methods based on tacheometers with integrated camera [22], among others. Within the robotic field, an automatic laser-based system was developed to measure the internal profiles of structures, using a laser pointer source on a rotating optical device fixed on to a laser measurement meter, with a notebook computer that controls the lasermeter and the rotating device to estimate the scanned profile shape and to determine the resulting cross-section area [4]. Close range photogrammetry and laser measurement, applied jointly in a way that their axes are parallel, were used to determine the flat surface dimensions on the rectangular advertisement panels [6].

In this paper two different measuring methodologies based on a system formed by a digital camera and a handheld lasermeter, both mounted on a calibrated support in different turning positions of the laser, were proposed to determine the dimensions of one or more elements contained in a façade. The benefits of each methodology and the comparison of both of them are shown.

2. Design and construction of the measuring support

The support system for the measuring equipment we make reference to in this article has been designed considering the different situations that can pop up on the daily routine for which the device has been conceived for. The system characteristics must be as follow:

a) Physical requirements:
   1. Must be able to be used with or without a tripod.
   2. Must be small and light for easy handling.
   3. Must provide a rigid link between the photographic camera and the lasermeter, avoiding looseness.
   4. The camera and the lasermeter must be easily and quickly mounted and dismounted without the need of re-calibration.

b) Technical requirements:
   1. Must be valid for every type of cameras and lasermeters.
   2. Must allow connection with peripheral equipment (for example, a personal digital assistant).
   3. The camera and the lasermeter must be able to adopt different relative positions, allowing the exact repeatability. Horizontal and vertical movement must be provided, in order to overcome any type of obstacles in the data gathering process. The movement must be quick and precise, without using any tools.
   4. The maximum turning angles of the lasermeter must be such that the laser pointer will be visible in the picture. In our particular case, with a 60 ^{g} angular opening camera and a 15 cm base support, the maximum turning angles calculated were 37 ^{g} and 30 ^{g} from the left and right to the central position, respectively.

For the support design, CAD SolidWorks [19] was used, that allows the evaluation of the element assembly, movement viability, and final weigh and appearance. Fig. 1 shows the 3D model done with this program, and the basic elements are indicated.

Once the support was designed, steel was selected as the base material to build the support body in order to guarantee that the system does not deform and the soundness of the calibration and measuring method developed, apart from its ease to be mechanized. All this at the expense of sacrificing the final weight of the equipment, for which at its final development light material with the same consistency will be used.

So that the implemented methodologies work correctly, it is indispensable that no movement is present in the system while gathering the data. To do so, the data of the measured distance and the photograph taken must be done in a simultaneous way. This has been solved through a Bluetooth transceptor and the

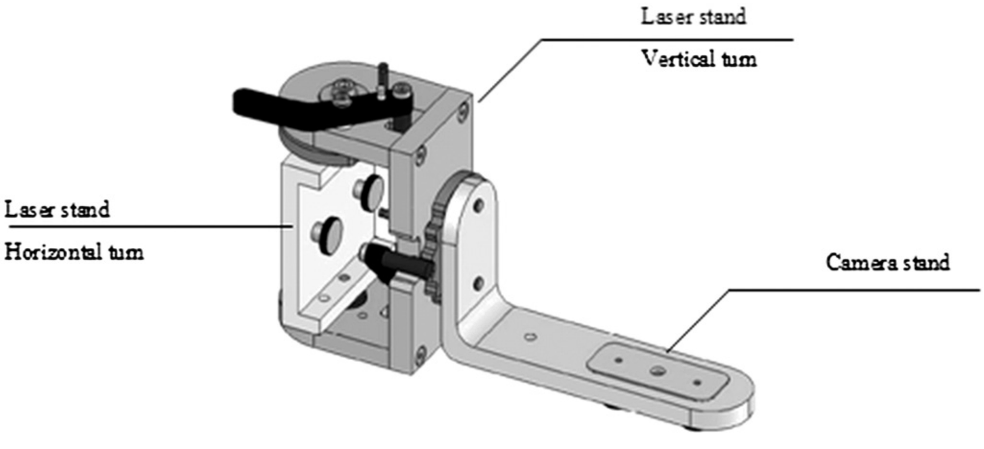

Fig. 1. Support 3D design.

connection to the system through a PDA, where the measured distance is stored, as it is shown in the scheme in Fig. 2.

3. Equipment calibration

The designed system is formed by two information capturing devices: a digital photographic camera and a handheld lasermeter. The digital camera captures the geometry of the object and the lasermeter captures the distance from the system to the object. The calibration of laser based compound systems must determine the relative position between the devices that form it, so it is essential that both devices should be previously calibrated independently. The camera calibration is done through conventional techniques based on multiple shots taken from different positions over a calibrated grid [17]. It is advisable to have the camera calibrated regularly, approximately every six months, with the purpose of verifying the stability of the parameters, on which the precision in the calibration of the system depends directly. The lasermeter, on the other hand, should be recalibrated it in shorter periods of time, since it uses mechanical elements and as a result of the conditions in which foreseeable it will be used. The calibration of the laser will be done by the company that distributes it, in their laboratories, in accordance with the terms indicated by them. It is necessary to calibrate it at each turning position of the lasermeter in order to measure objects with the designed system, which implies the determination of the following parameters:

1. The relative position between the laser measuring source point and the camera optical center, defined by vector L (X_L-X_o, Y_L-Y_o, Z_L-Z_o).
2. The angular components between the camera optical axis and the measuring axis of the laser, defined by a unitary vector U(U_X, U_Y, U_Z).

The procedure used consists of taking several photographic shots with a fixed camera on a moving object (Fig. 3). The calibration sequence and the calculations of the calibration parameters are indicated as follows:

1. The reference system is fixed on the camera, assigning coordinates (0,0,0) to the principal point and null turns to the

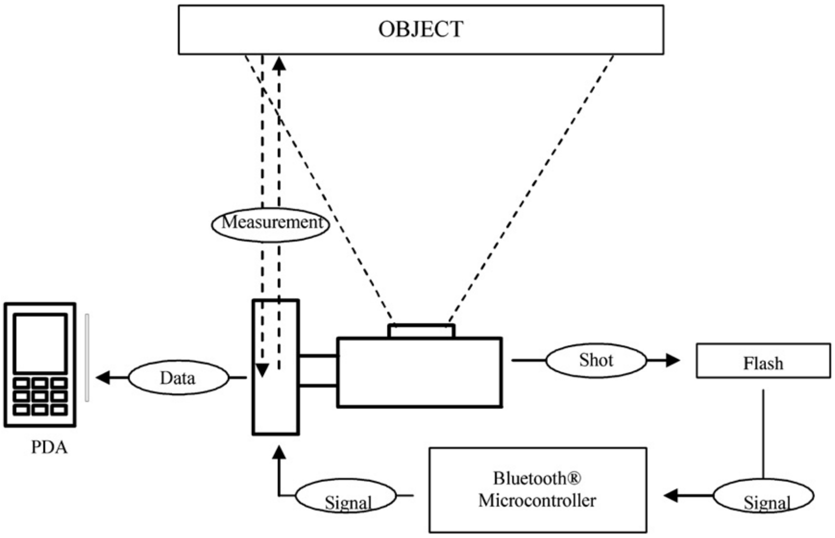

Fig. 2. PDA-camera communication system.

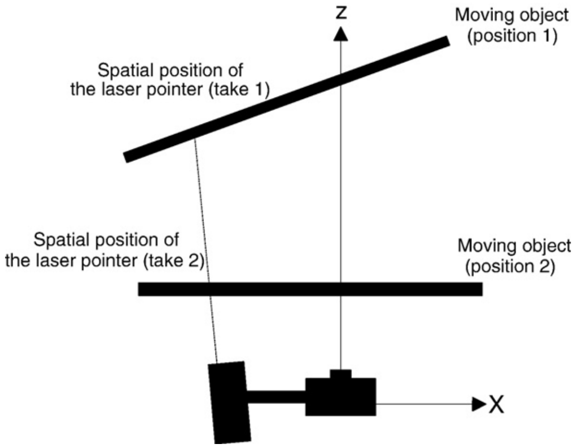

Fig. 3. System calibration process.

image plane. That way, the laser pointer coordinates in the space object for each taken shot can be calculated by applying the colinearity condition [21] as follows:

$$X_{PL}^{(i)} = Z_{PL}^{(i)} \frac{y_{PL}^{(i)}}{-c} \tag{1}$$

$$Y_{PL}^{(i)} = Z_{PL}^{(i)} \frac{y_{PL}^{(i)}}{-c} \tag{2}$$

where:

$(X_{PL}^{(i)},Y_{PL}^{(i)},Z_{PL}^{(i)})$ object coordinates of the laser pointer
$(x_{PL}^{(i)},y_{PL}^{(i)},-c)$ laser pointer photocoordinates

2. The laser measurements origin determination and its direction vector are given by the expression:

$$\begin{pmatrix} X_L \\ Y_L \\ Z_L \end{pmatrix} = \begin{pmatrix} X_{PL}^{(i)} \\ Y_{PL}^{(i)} \\ Z_{PL}^{(i)} \end{pmatrix} - Dm_L^{(i)} \begin{pmatrix} U_X \\ U_Y \\ U_Z \end{pmatrix} \tag{3}$$

where,

$Dm_L^{(i)}$ is the measured distance by the laser on each position. The resulting unknowns in each shot are the laser measurement origin coordinates (X_L, Y_L, Z_L), their direction vector $U(U_X, U_Y, U_Z)$, and the coordinate $Z_{PL}^{(i)}$.

3. Substituting Eqs. (1) and (2) in (3), and developing the equation system for three or more laser pointer space positions, an estimation of the unknown values and its precision is obtained by using the least square method [12].

4. Object dimension determination

The dimensions of the photographed elements, in both methods, are determined from the coordinates in the object space of the points that define the border, in such a way that the absolute orientation is not necessary in any case when determining such magnitudes through the differences between the relative coordinates.

4.1. Methodology based on 1 photograph and 1 object distance

The method used to determine such coordinates is based on the external orientation of the image plane through parallel and perpendicular lines visible in the photograph [9], by restricting the turn calculations, through determining the vanishing line in the image space, to only two.

The placing of vanishing points that define the vanishing line can be done correctly using the object to be measured or any other element that will comply with such restrictions and it is placed in the same plane, and even over elements that while being out of our measuring plane are parallel to it [5].

First step in establishing the external orientation consists on determining the rotation angles α and μ (Fig. 4) by placing the image plane parallel to the object plane. The rotation angles are given by the following equations if A and B (Fig. 4) are the two vanishing points, with image coordinates (x_a, y_a) and (x_b, y_b), respectively, obtained by the intersection from the image parallel straight lines in the object space:

$$\alpha = \arctan \frac{x_a - x_b}{y_a - y_b} \tag{4}$$

$$\mu = \arctan \frac{c}{d} \tag{5}$$

Where c is the focal distance of the camera and d the distance between the main point and the vanishing line in the image space, where the value is given by the following expression:

$$d = \frac{|y_a x_b - y_b x_a|}{\sqrt{(x_b - x_a)^2 + (y_b - y_a)^2}} \tag{6}$$

Knowing the spatial position of the image, a system of coordinates customized to our purposes in order to apply the colinearity condition and to obtain coordinates of any point in the object space is defined. In order to achieve this we will place the coordinate system in the optical center of the camera, in a way that X and Y axis are parallel to the plane that contains the object. The defined colinearity results in:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = k(R_\alpha)(R_\mu) \begin{pmatrix} x \\ y \\ -c \end{pmatrix} \tag{7}$$

where:

(X, Y, Z) The coordinates of any given point in the object space
$(x, y, -c)$ the photocoordinates of the point in the image space
k The scale coefficient
(R_α) α angle rotation matrix
(R_μ) μ angle rotation matrix

In order to determine k, it is necessary to supply the lasermeter with the same α and μ rotation angles that the camera

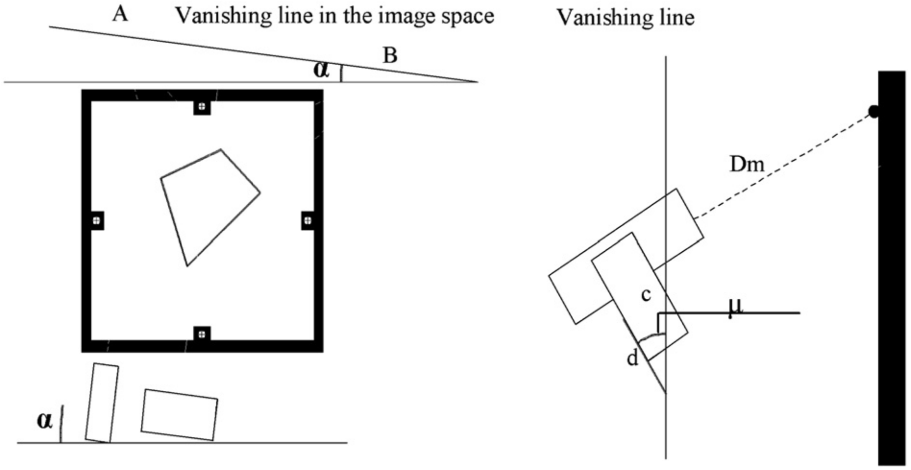

Fig. 4. External orientation using the vanishing line.

has undergone, in a way that both will have the same parameters. The coordinates of the laser pointer over the object are obtained according to the following expression:

$$\begin{pmatrix} X_{PL} \\ Y_{PL} \\ Z_{PL} \end{pmatrix} = (R)\left[\begin{pmatrix} X_L \\ Y_L \\ Z_L \end{pmatrix} + Dm\begin{pmatrix} U_X \\ U_Y \\ U_Z \end{pmatrix}\right] \tag{8}$$

where:

(X_{PL}, Y_{PL}, Z_{PL}) laser pointer coordinates
$(R)=(R_\alpha)(R_\mu)$ rotation matrix
(X_L, Y_L, Z_L) lasermeter center coordinates
D_m distance measured by the lasermeter
(U_X, U_Y, U_Z) laser direction vector

Developing Eq. (8) for coordinate Z^1_{PL} scale factor k is calculated using the third row of the Eq. (7):

$$k = \frac{Z_{PL}}{m_{31}x_{PL} + m_{32}y_{PL}m_{33}c} \tag{9}$$

4.2. Methodology based on 3 photographs and 3 object distances

The used method consists on taking three photographic shots in the same position and three laser distances at different calibrated positions. The designed support must guarantee the absence of movements of the camera when moving the lasermeter positions, in such a way that the three images must be taken from the same spot, so it should be enough to take a unique photographic shot. However, it is convenient to carry out the rectification of the image trio [7] to obtain a unique image plane, assuring the absence of movement due to external elements to the support. The procedure will consist on the rectification of two of the photograms to the position of the other one, taken as fixed and with null turns, through the photocoordinates of common points in the three images, not taking into account the differential translations the support could transmit to the lasermeter on the data gathering. Such transformation among photograms is given by the expression:

$$\begin{bmatrix} x_i' \\ y_i' \\ c \end{bmatrix} = K*[R]*\begin{bmatrix} x_i'' \\ y_i'' \\ c \end{bmatrix} + \begin{bmatrix} d_x \\ d_y \\ d_z \end{bmatrix} \tag{10}$$

where,

$(x_i', y_i'$, c) point i photocoordinates in shot 1
$(x_i'', y_i''$, c) point i photocoordinates in shot 2
$[R]$ rotation matrix between both photograms $K \approx 1$
(d_x, d_y, d_z) CDP differential translations considered null

Once the photogram 2 rotation matrix $[R]$ in reference to photogram 1 has been determined, the object coordinates of the laser pointer 2 has been applied such turns as if they really were in photogram 1, will be recalculated.

$$\begin{bmatrix} X_{PL}^{(2)'} \\ Y_{PL}^{(2)'} \\ Z_{PL}^{(2)'} \end{bmatrix} = [R]*\begin{bmatrix} X_{PL}^{(2)} \\ Y_{PL}^{(2)} \\ Z_{PL}^{(2)} \end{bmatrix} = [R]*\left(\begin{bmatrix} X_L \\ Y_L \\ Z_L \end{bmatrix} + Dm_L^{(2)}\begin{bmatrix} U_x \\ U_y \\ U_z \end{bmatrix}\right) \tag{11}$$

where,

$(X_{PL}^{(2)}, Y_{PL}^{(2)}, Z_{PL}^{(2)})$ laser pointer object coordinates (take 2)
$(X_{PL}^{(2)'}, Y_{PL}^{(2)'}, Z_{PL}^{(2)'})$ laser pointer object coordinates turned to shot 1
$Dm_L^{(2)}$ distance measured by the laser in shot 2

Applying the same procedure to image 3 in respect to image 1, the rectified laser pointer 3 object coordinates $(X_{PL}^{(3)'}, Y_{PL}^{(3)'}, Z_{PL}^{(3)'})$ will be obtained.

The three repositioned laser pointers define the plane where the object to be measured is. The points defining the contour of that object are contained in the plane, and then obligatorily verify the expression:

$$\begin{vmatrix} X_i - X_{PL}^{(1)} & V_x & W_x \\ Y_i - Y_{PL}^{(1)} & V_y & W_y \\ Z_i - Z_{PL}^{(1)} & V_z & W_z \end{vmatrix} = 0 \tag{12}$$

where,

(V_x, V_Y, V_Z) vector formed by $(X_{PL}^{(1)}, Y_{PL}^{(1)}, Z_{PL}^{(1)})$ and $(X_{PL}^{(2)\prime}, Y_{PL}^{(2)\prime}, Z_{PL}^{(2)\prime})$
(W_x, W_y, W_z) vector formed by $(X_{PL}^{(1)}, Y_{PL}^{(1)}, Z_{PL}^{(1)})$ and $(X_{PL}^{(3)\prime}, Y_{PL}^{(3)\prime}, Z_{PL}^{(3)\prime})$
(X_i, Y_i, Z_i) vertex coordinates in the object plane

Imposing the co-linearity condition (1) and (2) to each point determining the shape of the object in photogram 1 and forcing them to comply with the belonging to the laser defined plane (12), we obtain:

$$\begin{vmatrix} Z_i \dfrac{x_i'}{-c} - X_{PL}^{(1)} & V_x & W_x \\ Z_i \dfrac{y_i'}{-c} - Y_{PL}^{(1)} & V_y & W_y \\ Z_i - Z_{PL}^{(1)} & V_z & W_z \end{vmatrix} = 0 \tag{13}$$

where,

(x'_i, y'_i, c) vertex "i" photocoordinates
Expression from Z_i is obtained by determining (X_i, Y_i) through expressions (1) and (2). The same procedure is repeated for each vertex i of the object to be measured.

5. Results

To prove the suitability of the system, a series of tests have been done using the following instruments:

1) Calibrated camera Canon EOS 10D:
    Focal distance: 20.2157 $mm \pm 0.004$
    Format: (22.5203×15.0132) mm
        $(3{,}072 \times 2{,}048)$ pixels
    Principal point: (11.1601, 7.5245) mm
    Radial distortion parameters:
        $K_1 = 2.186e{-}4\ \text{mm}^{-1} \pm 1.6e{-}6$
        $K_1 = -4.360e{-}7\ \text{mm}^{-3} \pm 1.1e{-}8$
    Decentring distortion parameters:
        $P_1 = 4.034e{-}5\ \text{mm}^{-1} \pm 2.2e{-}6$
        $P_1 = -1.726e{-}5\ \text{mm}^{-1} \pm 2.9e{-}6$
2) Lasermeter Zinder Leica Disto Plus:
    Precision: ±1.5 mm (between 0.2 and 200 m)

5.1. Calibration

The results obtained in the calibration are shown in Table 1. As it can be seen, the highest precision is obtained in the horizontal convergent position of the lasermeter. Such precision is slightly diminished in the parallel axis position, and at a greater value in the laser divergent position (this is logical, hence, the inverse intersection is supposed to be done with the smallest angles at the different positions). In any case the obtained precisions are quite satisfactory in all the calibrated turning positions, with standard deviations lower than 1 cm.

On the other hand, the distance to the object is a determinant factor of the angular field of the system. In short distances, the angular field for the divergent lasermeter position is outstandingly reduced, the exactly opposite happens for the convergent case. As such distance increases, the opposite occurs. However, the convergent position covers, in any case, a greater angular field than the one for the camera, while the divergent position reaches such value, in the best of the cases, at infinite object distance.

So, taking both factors into consideration, the results show a better adjustment and a greater range of options in the lasermeter convergent position.

It is to be highlighted from the test done in the system calibration, in the first place, the mechanical and dimensional stability shown by the system, proving that the variations in the results done through repeated studies during several sessions, in the different positions studied, are insignificant. Such result reinforces the initial hypothesis in the use of heavy materials of great sturdiness, as it verifies the reliability of the mechanisms used for the fitting of the positions at different turns.

In the same way, it can be stated that the mechanical adjustment solutions of the different elements are satisfactory, a conclusion that can be reached through repeating the former process after mounting and dismounting the camera, and the lasermeter, in repeated occasions, which shows that the support fit solutions adopted avoid any recalibration of the system, ensuring the exact position.

Finally, the results obtained using the second measuring methodology have verified the existing independence between the camera and the lasermeter due to the support, that isolate both elements from relative movements when one of them varies.

5.2. Methodology based on 1 photograph and 1 object distance

The best results with this methodology were obtained when the camera axis is not perpendicular to the wall plane, in a way that it is easier to define the vanishing lines.

Table 1
Calibration results of the set camera-lasermeter. Units are meters

Value	Vertical downwards parallel	Vertical upwards parallel	Horizontal divergent	Horizontal parallel	Horizontal convergent
$X_L - X_0$	-0.2142 ± 0.00479	-0.2059 ± 0.00860	-0.1640 ± 0.00694	-0.2111 ± 0.00059	-0.2352 ± 0.00017
$Y_L - Y_0$	$+0.0221 \pm 0.0052$	-0.0229 ± 0.00976	$+0.0003 \pm 0.00034$	-0.0001 ± 0.00017	-0.0012 ± 0.00010
$Z_L - Z_0$	$+0.1344 \pm 0.0090$	$+0.1451 \pm 0.01281$	$+0.1733 \pm 0.01319$	$+0.1169 \pm 0.00140$	$+0.14742 \pm 0.0012$
U_x	-0.0207 ± 0.00165	-0.0418 ± 0.00206	-0.3921 ± 0.00009	-0.0335 ± 0.00012	$+0.3611 \pm 0.00005$
U_y	-0.4084 ± 0.00082	$+0.39173 \pm 0.00100$	$+0.01090 \pm 0.00004$	$+0.0193 \pm 0.00008$	$+0.0023 \pm 0.00004$

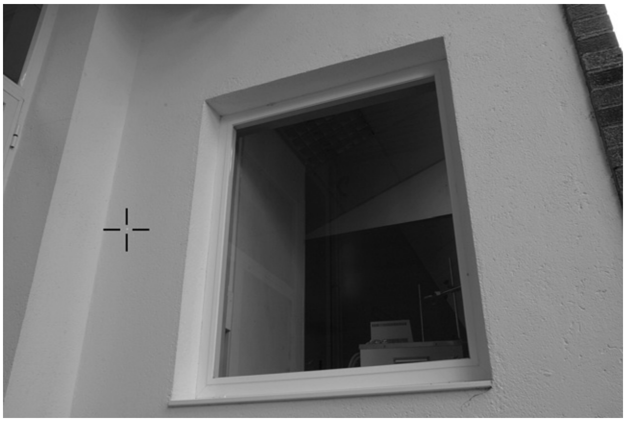

Fig. 5. Photograph of a window where the laser pointer is marked with line segments.

Once the image is set (Fig. 5), the four corners of the window are marked over the image and their coordinates calculated, then the two dimensions of the window (height and width) are calculated.

For a determined relative position and distance between the camera and the window, the measurements vary slightly depending on the two pairs of parallel lines used to determine the vanishing points. In Fig. 6 the cumulative frequency distribution of the absolute error is shown (obtained comparing the window measurements with the ones obtained with the proposed system for a unique photograph taken at three meter distance from the window). A total of fifty measurements from the window were calculated (hence, fifty values of the error were obtained), each one corresponding to a vanishing line obtained starting from two pairs of parallel lines. As it can be seen, ninety percent of the errors are less than 5 mm, that form a relative error of 0.6% (the window measures 88 cm × 80 cm).

5.3. Methodology based in 3 photographs and 3 object distances

Tests run with the second methodology over the same windows and at the same distances used in the first methodology, obtained the best results when the camera axis was perpendicular to the wall plane, in a way that it was the best situation to define the rotations between the images that were be applied to the 3 points that defined the object plane (Fig. 7).

Once the plane was set, the corners of the window were marked over the image and their coordinates calculated, obtaining the two dimensions of the window (height and width).

For a determined relative position and distance between the camera and the window, the measurements slightly vary depending on the process of marking the corners due to the perspective view of the plane.

6. Method comparison

In order to determine the precision of the system in measuring plane objects, and the difference between the two methodologies, several tests were made measuring the same rectangular windows of known dimensions from different places.

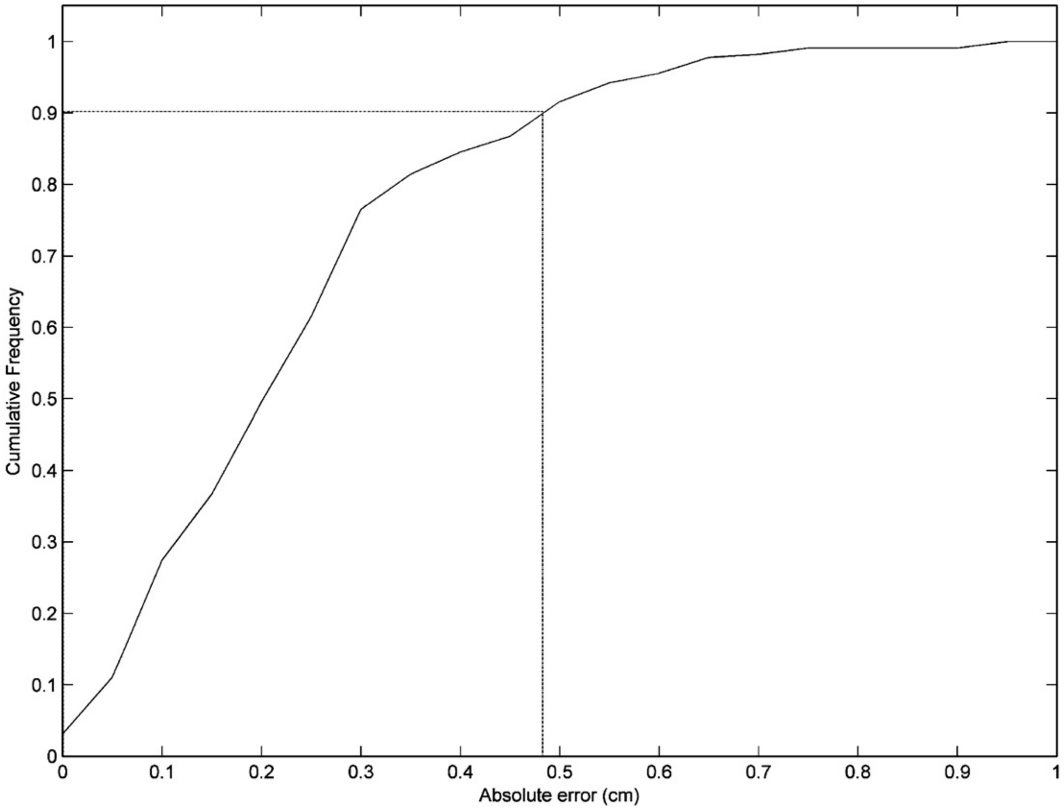

Fig. 6. Cumulative frequency of absolute errors in the panel measurement.

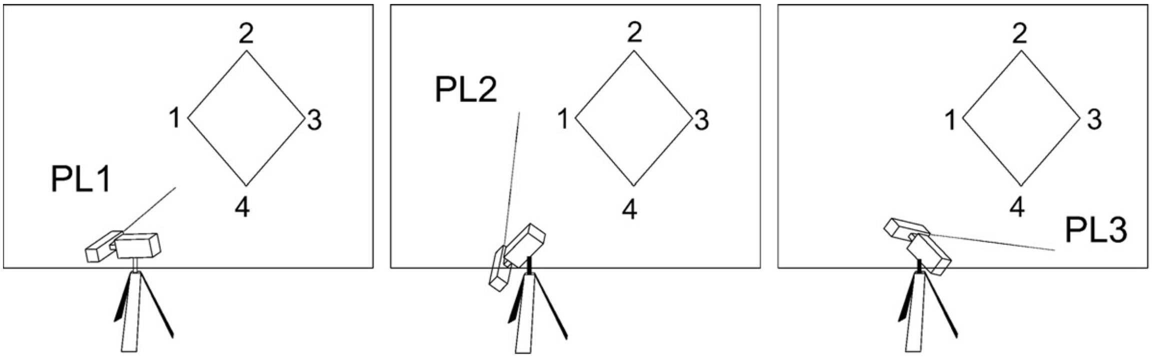

Fig. 7. Measurement method using 3 photographs and 3 laser distances.

It is important to highlight the importance of the camera calibration, since it will affect the magnitude of the measurement in any of the two studied methods. Fundamentally the errors have been caused by the distortion due to the lens [10], having verified this by running tests over the equipment, the effect over the magnitudes were less than 2 mm and within the distance ranges studied in this research.

Comparing both methodologies, it is observed that the first method is simpler and faster than the second one, both, in the field data gathering and in the element measuring. The first methodology requires just a few seconds to gather the data since it uses a single shot. The second methodology, even though it is very fast, needs to be repeated 3 times, moving the laser to different positions. The reference values needed in the first case are only the ones for windows corners and the one for the laser pointer position, while on the second method, it is necessary to do the same in each of the three photograms. However, its application is more limited, since it depends on the fact that certain geometrical requirements in the image are fulfilled, requirements that are not necessary in the second method.

A determining factor in the precision of the first method can be due to wrongly signaling any of the points that define the vanishing points since it can be translated to significant errors when calculating the dimensions of the object. In such a way, that even though the set of tests done show similar precisions, the reliability of the first method is less than the one in the second method, due to this circumstance.

Another disadvantage of the first method compared to the second one is that the laser pointer needs to appear in the image, which implies the impossibility of using these methods for long distances and in surfaces where there is little contrast between the colour of the laser and the object. Not so, in the second method, where it is not necessary that the lasers appear in the image, only requiring that the laser has the measuring range.

Table 2 shows the length of the two sides of a window measured with the two proposed methods, and also with a pocket tape, including the differences between them in each case. The maximum difference in the first methodology was of 8 mm, corresponding to a relative difference less than 1.2%, at an approximated distance of 5 meters. Maximum differences with the second one were less than 0.5 cm, corresponding to a relative difference less than 0.6% at the same distance than in the other case.

7. Conclusions

In this research, a simple close range photogrammetry system has been shown in order to measure flat objects that have been thought out for its application in measuring holes in building façades, even though other applications are possible. It is an economical and easy to use system that does not require the gathering of ground control points used by topographical methods.

The calibration tests done show that the best position between the camera and the lasermeter is the convergent one, showing in any case a high dimensional and mechanical stability of the calibrated support, and with satisfactory mechanical solutions of adjustment of the different elements.

Table 2
Window measuring results in meters at mean distances

First Methodology						Second Methodology					
Real	Obs	Dif	Real	Obs	Dif	Real	Obs	Dif	Real	Obs	Dif
1.270	1.267	0.003	0.663	0.657	0.006	1.270	1.272	0.002	0.663	0.661	0.002
1.270	1.265	0.005	0.663	0.655	0.008	1.270	1.269	0.001	0.663	0.660	0.003
1.270	1.264	0.006	0.663	0.662	0.001	1.270	1.265	0.005	0.663	0.667	0.004
1.270	1.267	0.003	0.663	0.662	0.001	1.270	1.267	0.003	0.663	0.661	0.002
1.270	1.265	0.005	0.663	0.662	0.001	1.270	1.270	0.000	0.663	0.665	0.002
1.270	1.269	0.001	0.663	0.657	0.006	1.270	1.266	0.004	0.663	0.659	0.004
1.270	1.267	0.003	0.663	0.658	0.005	1.270	1.266	0.004	0.663	0.668	0.005
1.270	1.267	0.003	0.663	0.659	0.004	1.270	1.268	0.002	0.663	0.661	0.002

Differences obtained in respect to the conventional method.

The system and the measuring methods in this article have shown to be useful to measure flat elements, where adequate precisions for the building field were obtained, for short and medium distances (lower than 15 meters), reducing its precision as the distance increases, due to the laser precision and the vertexes definition of the image elements.

In the first methodology the best results were obtained with oblique shots from the object that allowed a better determination of the vanishing points. In the second one, the best results were obtained with frontal shots from the object, although oblique ones gave very good results too.

The methodology based on one shoot has shown to be simpler but of more limited use, both for its precision as for the geometrical restrictions that must be fulfilled in the image as the visibility need of the laser pointer. The second method, despite the increasing time needed for the field data gathering, has shown a higher precision and total independency from the geometrical characteristics of the image and the showing of the laser pointer in it.

Although satisfactory results were obtained in the experiments carried out, work on improving the design and the weight of the equipment as well as new measurement determination methods that imply less intervention from the user is being carried forward.

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