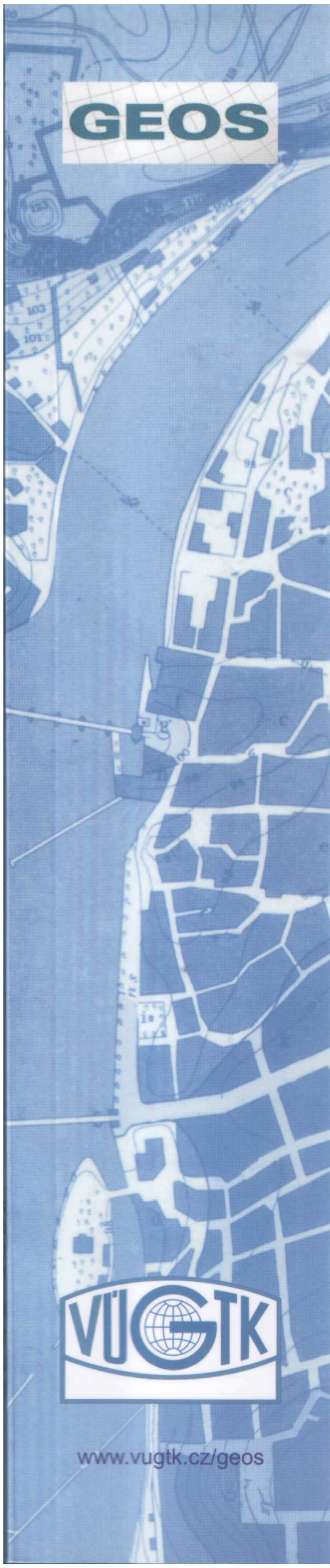

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Research Institute of Geodesy, Topography and Cartography

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3rd International Conference
and
3rd International Trade Fair
of Geodesy, Cartography, Navigation and Geoinformatics

GEOS 2008

Conference Proceedings

Prague, 27th – 28th February 2008

Milan Talich (Ed.)

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EVALUATING A LOW COST PHOTOGRAMMETRY METHOD WITH 3D LASERSCANNING

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Abstract

The aim of this paper is to evaluate the results obtained with the application of a low cost photogrametric method to architectural surveying. The development is part of a PhD research project. The referred method was developed and implemented using Autolisp Language Programming for AutoCAD and was tested on surveying façades and exterior boundaries (plan) of a well geometrically defined building. This building is a Renascentist XVIth century church. The method will be described and explained and the study case will be presented as well the obtained results.

Then, the results will be compared to a 3D laserscanning surveying of the same building. This surveying was performed with a Leica Scanner. Assuming 3D laserscanning as an accurate surveying method for the global geometry of the building, façade and plan drawings obtained from this data will be the base for comparison. This is a low cost method and is accessible to non experts in surveying as, in general, architects are and can provide reliable data for some architectural applications that do not evolve structural changes in buildings. It can also be used as a complementary method for other surveying methods both in professional or academic context.

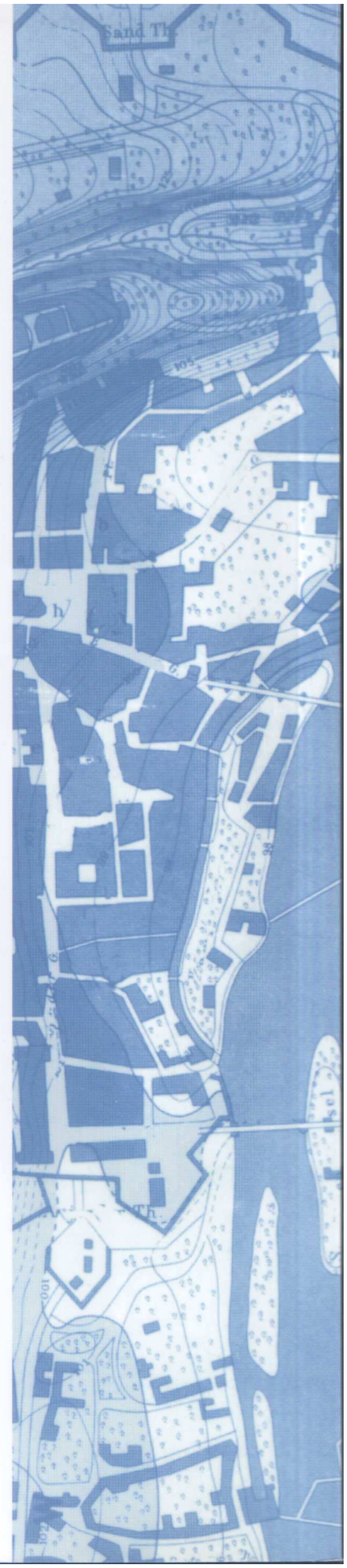
VYHODNOCENÍ FOTOGRAMMETRICKÉ METODY S NÍZKÝMI NÁKLADY A TROJROZMĚRNÝM LASEROVÝM SKENOVÁNÍM

Abstrakt

Cílem tohoto článku je vyhodnotit výsledky získané užitím nízkonákladových fotogrammetrických metod pro zaměřování architektury. Vývoj je součástí projektu pro získání titulu PhD. Předkládaná metoda byla vyvinuta a zavedena při užití programování v jazyce Autolisp pro AutoCAD a ověřena při zaměřování fasád a vnějších hranic (rovin) dobře geometricky definované stavby. Touto budovou je renesanční kostel z 16. století. Metoda se popisuje a vysvětluje a studijní případ předkládá včetně získaných výsledků.

Potom se výsledky porovnají s trojrozměrným zaměřením pomocí laserového skenování téže budovy. Toto měření se uskutečnilo pomocí skeneru Leica. Za předpokladu, že trojrozměrné laserové skenování je přesná měřická metoda pro celkovou geometrii budovy, pak fasáda a rovinné kresby získané z těchto údajů budou podkladem pro srovnávání.

Je to nízkonákladová metoda a dostupná i neodborníkům v zeměměřictví, jimiž jsou obvykle architekti a může poskytnout spolehlivé údaje pro některé architektonické aplikace nevyžadující strukturální změny budov. Lze ji též užít jako doplňkovou metodu k dalším měřickým postupům v souvislostech profesních a akademických.



A cut from Professor Karel Kořistka's famous altimetric plan of Prague of 1858 was used for the cover of this volume (text omitted).

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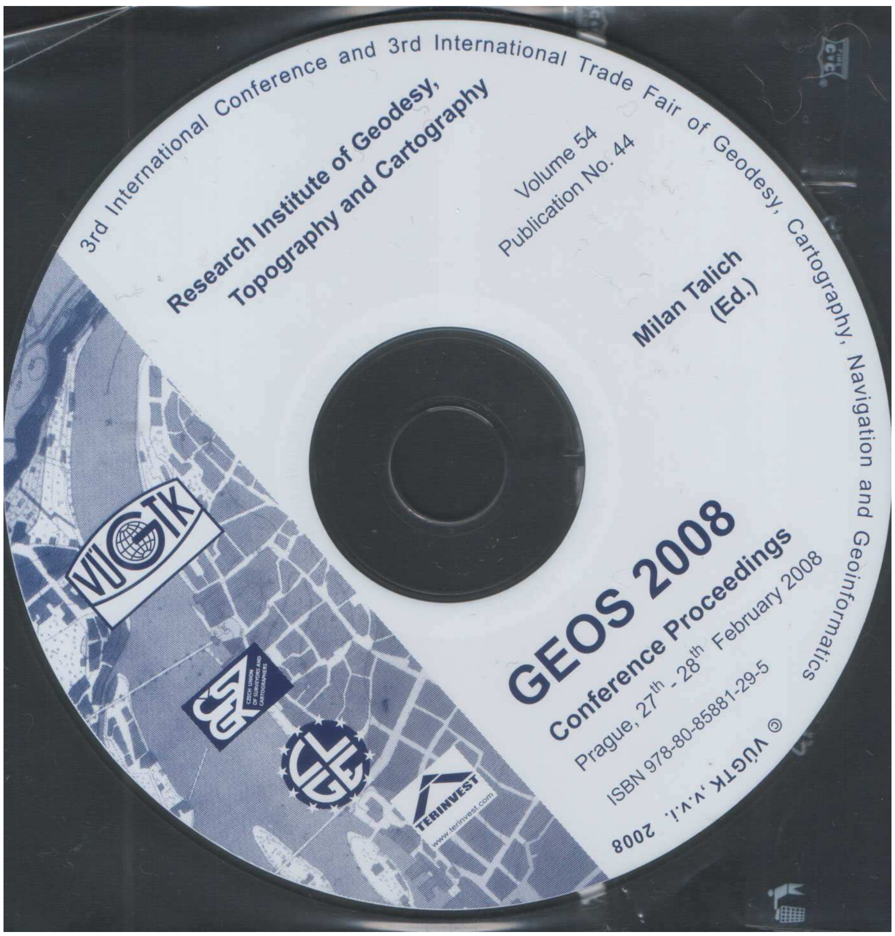
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Vážení čtenáři,

opět se vám dostává do rukou sborník z mezinárodní konference geodézie, kartografie, navigace a geoinformatiky, tentokráte **GEOS 2008,** konané pod heslem „**Naše profese v Evropě bez hranic**" a pod záštitou náčelníka Geografické služby AČR plk. Ing. Pavla Skály.

Konference GEOS 2008 si klade za cíl stejně jako v předchozích letech podchytit novinky a vývojové trendy ve všech specializacích našeho oboru. Vzhledem k většímu rozšíření schengenského prostoru koncem loňského roku, bylo zvoleno právě motto, které více reflektuje tuto novou situaci v Evropě. Konference se tak věnuje nejen již tradičním tématům, jako jsou geoinformace a GIS, kartografie a mapová tvorba, navigační systémy a služby založené na lokaci, geodetické základy a geodetické práce, katastr nemovitostí, fotogrammetrie a dálkový průzkum. Ale zaměřuje svou pozornost také na oblasti pohybu zeměměřičů v evropském prostoru, uznávání kvalifikací pro výkon zeměměřických činností, požadavky na vzdělávání zeměměřičů a zajišťování kvality zeměměřických prací.

V roce 2008 je konference oproti předchozím letům vyjímečná v tom, že bezprostředně předchází zasedání valného shromáždění Rady evropských zeměměřičů (CLGE), které se koná v Praze v následujících dvou dnech. Motto konference je navíc velice blízké i tématům, kterým se CLGE dlouhodobě věnuje.

Kromě zmíněného zasedání valného shromáždění CLGE probíhá ještě souběžně s konferencí v Praze ve dnech 28. 2. až 1. 3. též 3. mezinárodní veletrh geodézie, kartografie, navigace a geoinformatiky GEOS, který také stojí za shlédnutí.

Únor 2008

Milan Talich
odborný garant konference

Dear reader,

this year again you receive in your hands proceedings from the International Conference of Geodesy, Cartography, Navigation and Geoinformatics **GEOS 2008** held under the motto „**Our profession in Europe without Barriers“** and under auspices of the Chief of the Geographic Service of the Army of the Czech Republic colonel Ing. Pavel Skála.

The main task of conference GEOS 2008 is, similarly to the previous years, to follow news and development trends in all specializations of our field. Regarding the enlargement of Schengen territory at the end of 2007, we decided to choose the above mentioned motto as it reflects this new situation in Europe. Therefore the conference focuses not only on traditional subjects, e.g. geoinformatics and GIS, cartography and mapping, navigation systems and services based on location, basic geodetic control and geodetic work, cadastre of real estate, photogrammetry and remote sensing, but also on the scope of surveyors´ movement within the territory of Europe, recognizing qualifications and education requirements for land surveyors and controlling the quality of land surveying.

In comparison with previous years, conference GEOS 2008 is exceptional as it is held immediately before the General Assembly Meeting of the Council of European Geodetic Surveyors (CLGE) that takes place in Prague in the following two days. In addition, the conference motto is very close to the subjects that are of long-term interest of CLGE.

Besides the above mentioned General Assembly Meeting of CLGE, at the same time as the conference, the 3rd International Fair of Geodesy, Cartography, Navigation and Geoinformatics GEOS (that is worth seeing as well) takes place in Prague from 28 February to 1 March 2008.

February 2008

Milan Talich
Professional Warranter of the Conference

Contents / Obsah

Cadastre of Real Estate / Katastr nemovitostí

Cadastre of Real Estate, Photogrammetry and Remote Sensing / Katastr nemovitostí, Fotogrammetrie a dálkový průzkum

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The aim of this paper is to evaluate the results obtained with the application of a low cost photogrametric method to architectural surveying. The development is part of a PhD research project. The referred method was developed and implemented using Autolisp Language Programming for AutoCAD and was tested on surveying façades and exterior boundaries (plan) of a well geometrically defined building. This building is a Renaissant XVIth century church. The method will be described and explained and the study case will be presented as well as the obtained results.

Then, the results will be compared to a 3D laser scanning surveying of the same building. This surveying was performed with a Z+F Scanner Imager 5006. Assuming 3D laser scanning as an accurate surveying method for the global geometry of the building, façade and plan drawings obtained from this data will be the base for comparison.

This is a low cost method and is accessible to non experts in surveying as in general architects are and can provide reliable data for some architectural applications that do not evolve structural changes in buildings. It can also be used as a complementary method for other surveying methods both in professional or academic context.

1 Introduction

To building surveying, for architectural purposes, many strategies may be adopted. Some are more practical and rapid and others are slower. Some may require experts and other don't. We must always consider de adequacy of the chosen strategy with surveying purpose.

The method here presented that can be defined as an elementary photogrammetric method can be applied to the survey of buildings with approximately contiguous plane façades. Its operative base consists on three steps: a) drawing rectification, b) angle determination between façades, and c) angle registration. All these steps take place within AutoCAD working environment on drawings produced over inserted images. It is required that one vertical and one horizontal measurement be taken from each façade. In practice only one vertical measurement is needed over the entire exterior of the building.

First step consists on the rectification of vectorial drawing, rather than image, produced over one or more inserted pictures of the façade.

Second and third steps consist on producing, with a minimum effort in field work, the plan of the exterior boundary of the building. This is applicable when the building presents multiple contiguous façades. This may me of interest if we don't have access to the interior of the building and its boundary presents convex angles. Third step is done manually.

It is not intended to defend the efficiency of this method with respect to others, but to point out that it can be used as a complement of other surveying methods.

To make this set of procedures operative it was programmed two routines in AutoLisp.

2 Drawing rectification

As it was referred, first step of the method consists on drawing rectification. This corresponds to a projective transformation that can de defined as follows:

$$X_u = \frac{e_1 x_n + f_1 y_n + g_1}{e_0 x_n + f_0 y_n + 1}$$

$$Y_u = \frac{e_2 x_n + f_2 y_n + g_2}{e_0 x_n + f_0 y_n + 1}$$

Where:

X_u and Y_u are the coordinates of the unknown point P_u,

x_n and y_n are the coordinates of the known point P_n corresponding to the unknown point P_u,

e_0, e_1, e_2, f_0, f_1, f_2, g_1, g_2 are the eight parameters of the projective transformation.

It is known that four P_n points and the corresponding four P_u points are required to determine the eight parameters of the projective transformation. In practice this means that a minimum of to measurements must be done: height and width.

Let P_i $(i = \{1,2,3,4\})$, of coordinates X_i and Y_i, and P'_i $(i = \{1,2,3,4\})$, of coordinates x_i and y_i, be corresponding points under the projective transformation. The points P'_i are associated with the points P_n, of coordinates x_n and y_n, of the figure ff that are to be transformed into the points P_u, of coordinates X_u and Y_u, of the figure FF.

If three of the eight coordinates of the points P_i are equal to 0, and three of the eight coordinates of the points P'_i are equal to 0, then the eight projective parameters are easy to calculate.

In general this condition is not in principle fulfilled.

In order to perform the projective transformation fulfilling this condition a set of other transformations must be carried out:

a) A translation according to the vector $\overrightarrow{P_4 O}$ is applied to the points P_i $(i = \{1,2,3,4\})$, of coordinates X_i and Y_i, in order to get the points P_{it}, of coordinates X_{it} and Y_{it}, according to the following expressions:

$$X_{it} = X_i - X_4$$

$$Y_{it} = Y_i - Y_4$$

b) A translation according to the vector $\overrightarrow{P'_1 O}$ is applied to the points P'_i $(i = \{1,2,3,4\})$, of coordinates x_i and y_i, and to the points P_n, of coordinates x_n and y_n, of the figure ff, in order to get the points P'_{it}, of coordinates x_{it} and y_{it}, and the points P_{nt}, of coordinates x_{nt} and y_{nt}, of the figure ff_t, according to the following expressions:

$$x_{it} = x_i - x_1$$

$$y_{it} = y_i - y_1$$

$$x_{nt} = x_n - x_1$$

$$y_{nt} = y_n - y_1$$

c) A rotation is applied to the points P_{it} centred in the origin in order to align the vector $\overrightarrow{P_{4t}P_{3t}}$ with xx axis, getting the points P_{itr} of coordinates X_{itr} and Y_{itr}, according to the following expressions:

$$X_{itr} = X_{it}\cos\alpha + Y_{it}\sin\alpha$$

$$Y_{itr} = -X_{it}\sin\alpha + Y_{it}\cos\alpha$$

Where:

$$\cos\alpha = \frac{X_{3t}}{\left|\sqrt{X_{3t}^2 + Y_{3t}^2}\right|}$$

$$\sin\alpha = -\frac{Y_{3t}}{\left|\sqrt{X_{3t}^2 + Y_{3t}^2}\right|}$$

d) A rotation is applied to the points P'_{it} and to the points P_{nt} of the figure ff_t, centred in the origin in order to align the vector $\overrightarrow{P'_{1t}P'_{2t}}$ with the axis xx, getting the points P'_{itr} of coordinates x_{itr} and y_{itr} and the points P_{ntr}, of the figure ff_{tr}, of coordinates x_{ntr} and y_{ntr}, according to the following expressions:

$$x_{itr} = x_{it}\cos\beta + y_{it}\sin\beta$$

$$y_{itr} = -x_{it}\sin\beta + y_{it}\cos\beta$$

$$x_{ntr} = x_{nt}\cos\alpha + y_{nt}\sin\beta$$

$$y_{ntr} = -x_{nt}\sin\beta + y_{nt}\cos\beta$$

Where:

$$\cos\beta = \frac{x_{2t}}{\left|\sqrt{x_{2t}^2 + y_{2t}^2}\right|}$$

$$\sin\beta = -\frac{y_{2t}}{\left|\sqrt{x_{2t}^2 + y_{2t}^2}\right|}$$

e) After these transformations we have four points P_{itr} and four corresponding points P'_{itr} under an auxiliary projective transformation. The eight parameters of this projective transformation, e'_0, e'_1, e'_2, f'_0, f'_1, f'_2, g'_1, g'_2 can be easily calculated:

$$g'_1 = X_{1tr}$$

$$g'_2 = Y_{1tr}$$

$$f'_2 = \frac{Y_{1tr}x_{4tr} - Y_{1tr}x_{3tr}}{x_{3tr}y_{4tr} - y_{3tr}x_{4tr}}$$

$$e'_2 = \frac{Y_{1tr} y_{3tr} - Y_{1tr} y_{4tr}}{x_{3tr} y_{4tr} - y_{3tr} x_{4tr}}$$

$$e'_1 = \frac{e'_2 X_{2tr}}{Y_{2tr}} + \frac{X_{2tr}(Y_{1tr} - Y_{2tr})}{x_{2tr} Y_{2tr}} - \frac{X_{1tr} - X_{2tr}}{x_{2tr}}$$

$$f'_1 = -\frac{e'_1 x_{4tr} + X_{1tr}}{y_{4tr}}$$

$$e'_0 = \frac{e'_2}{Y_{2tr}} + \frac{Y_{1tr} - Y_{2tr}}{x_{2tr} Y_{2tr}}$$

$$f'_0 = \frac{e'_1 x_{3tr} + f'_1 y_{3tr} + X_{1tr} - e'_0 x_{3tr} X_{3tr} - X_{3tr}}{y_{3tr} X_{3tr}}$$

f) Now a projective transformation can be applied to the points P_{ntr}, of coordinates x_{ntr} and y_{ntr}, of the figure ff_{tr}, in order to get the corresponding points points P_{utr} , of coordinates X_{utr} and Y_{utr}, of the figure FF_{tr}, according to the following expressions:

$$X_{utr} = \frac{e'_1 x_{ntr} + f'_1 y_{ntr} + g'_1}{e'_0 x_{ntr} + f'_0 y_{ntr} + 1}$$

$$Y_{utr} = \frac{e'_2 x_{ntr} + f'_2 y_{ntr} + g'_2}{e'_0 x_{ntr} + f'_0 y_{ntr} + 1}$$

g) A rotation is applied to the points P_{utr}, of coordinates X_{utr} and Y_{utr}, of the figure FF_{tr}, centred in the origin and symmetric to the one applied in c), getting the points P_{ut}, of coordinates X_{ut} and Y_{ut}, of the figure FF_t, according to the following expressions:

$$X_{ut} = X_{utr}\cos(-\alpha) + Y_{utr}\sin(-\alpha)$$

$$Y_{ut} = -X_{utr}\sin(-\alpha) + Y_{utr}\cos(-\alpha)$$

Where:

$$\cos(-\alpha) = \cos\alpha = \frac{X_{3t}}{\left|\sqrt{X_{3t}^2 + Y_{3t}^2}\right|}$$

$$\sin(-\alpha) = -\sin\alpha = \frac{Y_{3t}}{\left|\sqrt{X_{3t}^2 + Y_{3t}^2}\right|}$$

h) Finally, a translation is applied to the points P_{ut}, of coordinates X_{ut} and Y_{ut}, of the figure FF_t, according to the vector $\overrightarrow{OP_4}$, getting the points P_u, of coordinates X_u and Y_u, of the figure FF , corresponding to the points of the initial figure ff , according to the following expressions:

$$X_u = X_{ut} + X_4$$

$$Y_u = Y_{ut} + Y_4$$

3 Angle determination between façades

In order to perform this operation, photograph must be taken horizontally and a minimum of three measurements must be carried out *in-sittu*, V_C, D_e and D_d. To simplify the process it is supposed that a rectangle corresponding to the measurements taken can be drawn over the image in each façade as shown in fig. 1. Then, by selecting the segments V_C, V_e e V_d in the picture and the segments $V_{C'}$, D_e and D_d drawn apart , angle between both façades can be calculated.

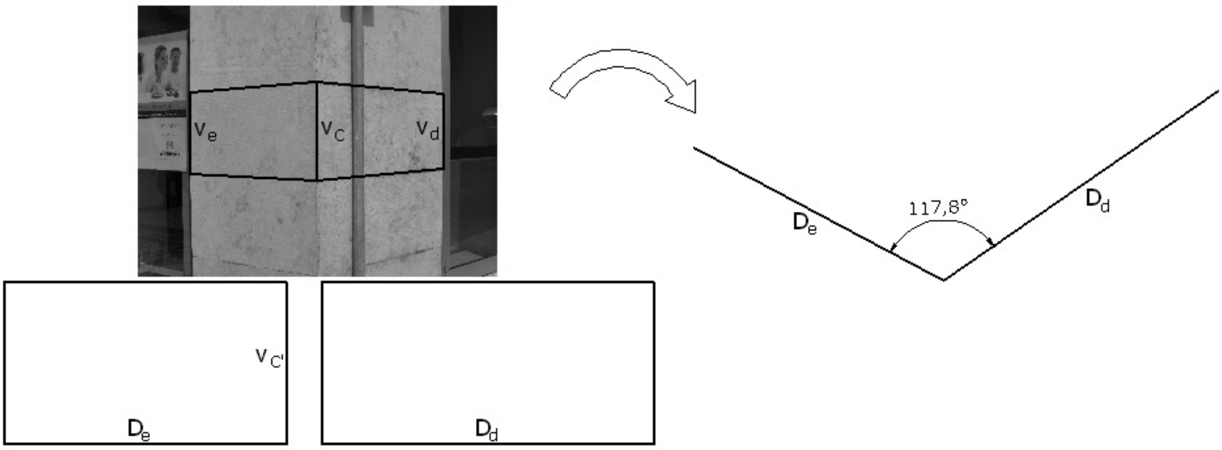

Fig. 1

This determination relies on the following.

Let us consider the right façade in fig. 1.

Let $D_d K = [OB] = R$, where K is a scale factor determined by:

$$K = \frac{V_C}{V_{C'}}$$

Let $[ON]$ be the distance, taken over the photo, between verticals V_C and V_d.

Let A be any point in the right façade (in practice this point doesn't have to be identified by the operator; it can be assumed as the crossing point between rectangle diagonals).

Let M be, in the image, the corresponding point to the point A (in practice this point doesn't has to be identified by the operator; logically it has to be the crossing point of the trapezium diagonals)

On fig. 2 xx axis corresponds to the image plan.

The angle α that right façade does with picture plan is undetermined. However it is known that the projecting rays $A.M$ and $B.N$ cross at the projection centre P as shown in fig. 2.

Let the coordinates of the points A, B, M, N and P be as follows:

$$A = (r\cos\alpha; r\sin\alpha)$$

$$B = (R\cos\alpha; R\sin\alpha)$$

$$M = (d;0)$$

$$N = (D;0)$$

$$P = (X_P; Y_P)$$

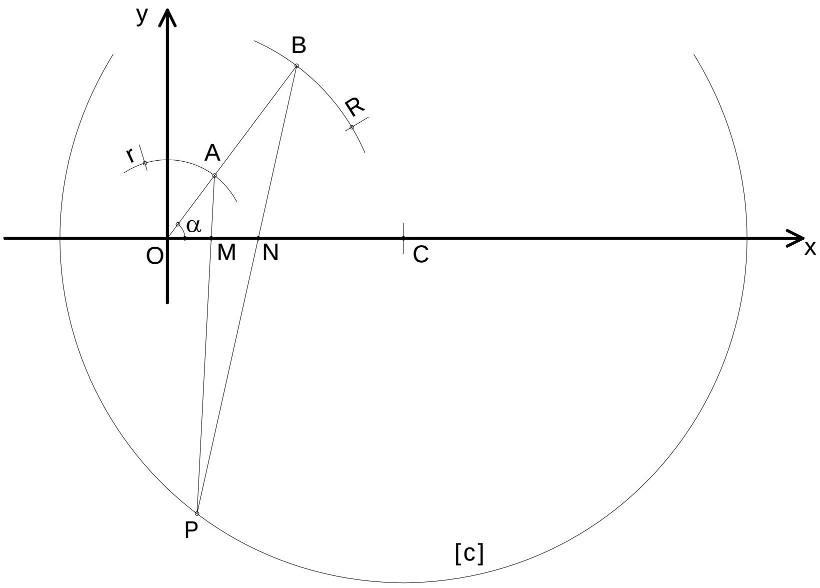

Fig. 2

The alignments $A.M.P$ e $B.N.P$ can be expressed by:

$$\begin{vmatrix} r\cos\alpha & d & X_P \\ r\sin\alpha & 0 & Y_P \\ 1 & 1 & 1 \end{vmatrix} = 0$$

$$\begin{vmatrix} R\cos\alpha & D & X_P \\ R\sin\alpha & 0 & Y_P \\ 1 & 1 & 1 \end{vmatrix} = 0$$

From this one can determine X_P e Y_P, as follows:

$$Y_P = \frac{Rr(d-D)}{Rd-rD}\sin\alpha$$

$$X_P = \frac{Rr(d-D)}{Rd-rD}\cos\alpha + \frac{Dd(R-r)}{Rd-rD}$$

These express the parametric equations of a circle $[c]$ with centre $C = \left(\frac{Dd(R-r)}{Rd-rD};0\right)$ and radius $R_{[C]} = \left|\frac{Rr(d-D)}{Rd-rD}\right|$.

Proceeding In an analogous way to the left façade one can determine a circle $[e]$ with centre E and radius $R_{[E]}$ as show in fig. 3.

The centre of projection P that allows to reconstruct simultaneously the geometry derived from the projection of both façade planes is one of the intersection points of the two circles $[c]$ and $[e]$.

Like this one can determine the angle π between both façades refered to the dimensions $D_e K$ and $D_d K$. Scale factor can then be eliminated dividing boht values with K.

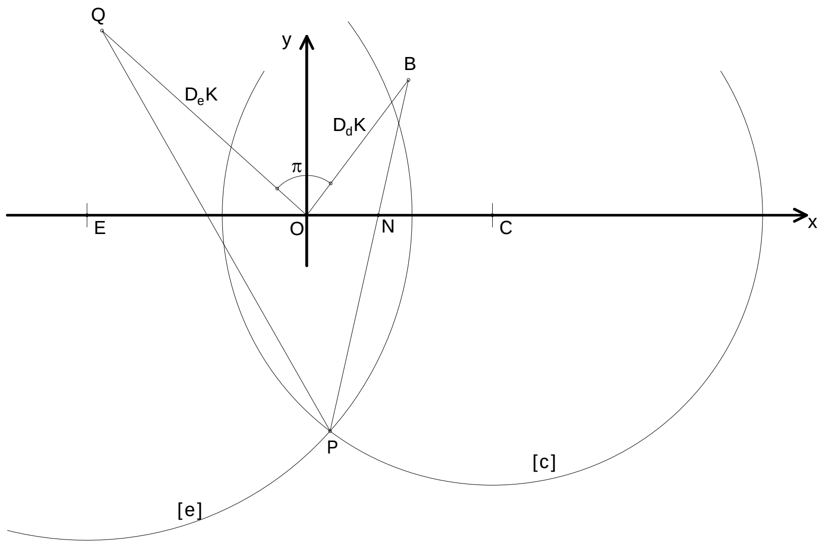

Fig. 3

4 The case study

As referred, the surveying method described was implemented with AutoLisp Programming Language for AutoCad. Then the principal façade and exterior boundary of a Renaissant XVIth century church were surveyed to test the application.

Fig. 4

To façade drawing some assumptions were made that may not be correct. It was assumed that left and right limits of the façade are vertical, and that the upper limit is horizontal. Control measures were taken with metric tape.

Fig. 4 represents façade surveying and fig. 5 represents boundary surveying.

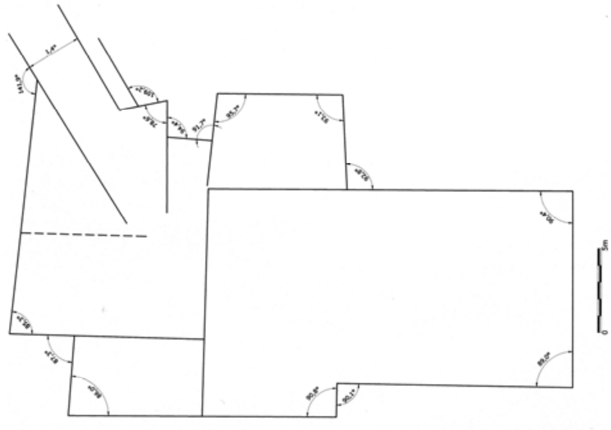

Fig. 5

5 Evaluation with 3D laser scanning and conclusions

After the previous step was completed, a 3D laser scanning survey of the church was carried out with a Z+F scanner Imager 5006, by the company 3D Total. From the 3d model obtained it was produced a horizontal section and a façade ortho-image with RGB values assigned.

These two elements served as basis for accuracy verification, by comparison, of the proposed photogrammetric surveying method. It was assumed that laser scanning provides reliable results.

Two evaluations were done.

First, façade survey was overlapped to the ortho-image both being in the same scale. This procedure was accomplished identifying two corresponding horizontal lines. In the overlapped drawing and image this line is identified as L_1 and its extremities are identified as P_1 and P_2 as shown in fig. 6.

Fig. 6

Then distances between corresponding points were taken. It was observed that in the lower part of the façade, distances vary within a range of 4cm and that in the upper part of the upper part of the façade distances vary within a range of 8cm.

These differences can be explained with the assumptions that were made when surveying, with the control measurements and with the fact that camera distortions were not taken into account.

In an analogous way, the plan survey was overlapped with the section obtained from the 3d model and discrepancies were measured, as shown in fig. 7.

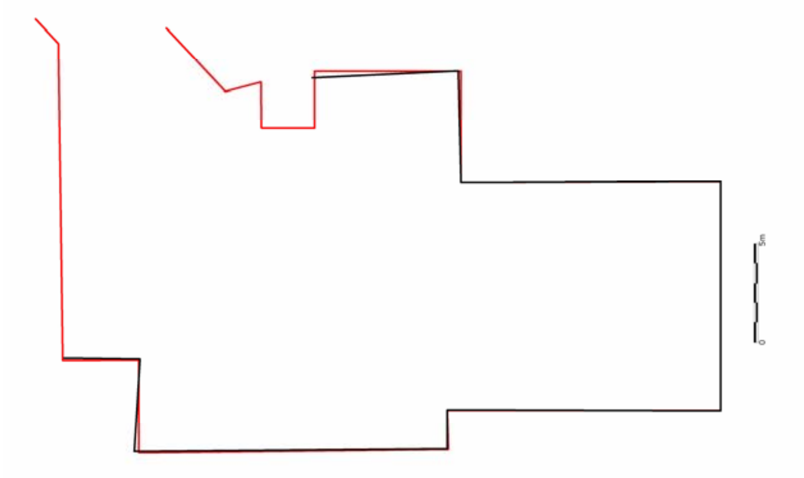

Fig. 7

In red we have the 3d model section and in black we have the survey carried out with the present method. The alignment between both surveys was accomplished identifying both lines corresponding to the principal façade.

Here two verifications were made.

On one hand, it were measured distances between corresponding points. In this case, and for the selected area, distances vary from 0 to 25cm.

On the other hand, corresponding angles were compared. In this, case and for the selected area, angles vary from 0 to 2.5º.

These differences can be explained with the assumptions that were made when surveying (façades being plan), with the control measurements, with the fact that camera distortions were not taken into account, with the fact that camera axis is not exactly horizontal, and with the fact that the registration between angles is manual and errors are summed.

With respect to façade surveying, this evaluation shows that the results can be found reliable for some architectural applications that don’t involve structural changes such as area calculation, pathology mapping, and stylistic analysis, among others.

With respect to plan surveying the results are more difficult to accept. It is required that further work is done in order to minimize discrepancies verified. This can consist on the consideration of camera distortion parameters, a better control while taking the pictures, and a more accurate mean of to proceed to angle registration.

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