LOW COST AUTOMATIZED SYSTEM FOR CONTROL POINTS CAPTURE IN CLOSE RANGE PHOTOGRAMMETRY

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ABSTRACT:

This paper describes a system for the automatic control point measurement in close range photogrammetry. One of the most time consuming tasks in close range photogrammetry when surveyed control points are needed the correct point localisation, proper field sketch drawing and the coordinates object point measurement itself. Often, two persons are needed for that task, so survey price rises. A system has been developed in order to minimize and improve these operations. The system has been developed to integrate a robotized and reflectorless total station, a laptop computer and two digital cameras ("eyepiece camera" precise aims, and a second camera for panoramic views). Both camera images can be seen on laptop computer screen. Also, it is possible to handle the station from the laptop computer. The system allows get the sketch and the object coordinates of point in a short time. All of the processes are controlled by means of the software. The system presents some advantages with respects to the conventional control point capture method with manual elaboration of sketches, since this eliminates the hand made sketch control points. The marking of points in the image is instantaneously made along the report elaboration. As main advantage of this system, the whole system can be controlled by only one operator, which supposes the reduction of costs and organization; in consequence the time employed in the survey of the control points reduces. Finally, the paper explores future work and some system improvements.

1. INTRODUCTION

1.1 Introduction

The classical methods for capture of control points in close range photogrammetry often implicate two or more operators, this supposes a major cost of these works This paper present a project of low cost automatization system for capture and edition of control points in close range photogrammetry

The system is controlled by only one operator. The present document includes the general description of sensor system and his components, the methodology of operation and the software modules.

This method has been developed for object which lies in surface planes with different orientations. So, it can be employed in different applications fields such as archaeology and cultural heritage, industry, environment, etc.

2. SYSTEM AND METHODOLOGY

2.1 System (sensor)

The system has been developed to integrate a robotized and reflectorless Total Station TRCA 1203 (Leica), two small digital cameras and a laptop computer (Scherer, 2004).

The systems, (Total Station movements and cameras) is controlled by the laptop computer. The Figure 1 shows the cameras coupled to the total station.

Figure 1. Left: Prototype of sensor system. Right: cameras coupled to the total station.

The first digital camera is placed on top of the telescope so it can register a panoramic view of the area to be surveyed (Figure 2, Figure 3 up).

The second digital camera is place in the eyepiece. An adaptor (Figure 1 right) is made particularly for setup the camera to the eyepiece.

Figure 2. Panoramic camera detail.

This camera receives the image through the telescope (Figure 3 down), including the reticule image (crosshair) and therefore the possibility to do precise aims, and locate the control points.

Figure 3. Images made from panoramic (up) and eyepiece (down) cameras.

Both cameras are connecting to the laptop computer by de USB ports.

2.2 Methodology

In order to start working with the system we make the following operations. First, the panoramic view is captured and downloaded on the computer screen (in this case the images corresponding to a check zone).

A software (develop under Microsoft Visual Basic 6.0 © Microsoft Corporation) module allows visualize this image and two different levels of zoom (Figure 4).

In this image control points must be located and next the system will be "calibrated". Thus, we locate in the image at least four points in the surveyed area, although it is better five points for a further two dimensional projective transformation with redundancy. These points must been clearly visible in both images, the image taken through the station eyepiece and the

panoramic image, since these points must be measured from the reflectorless total station.
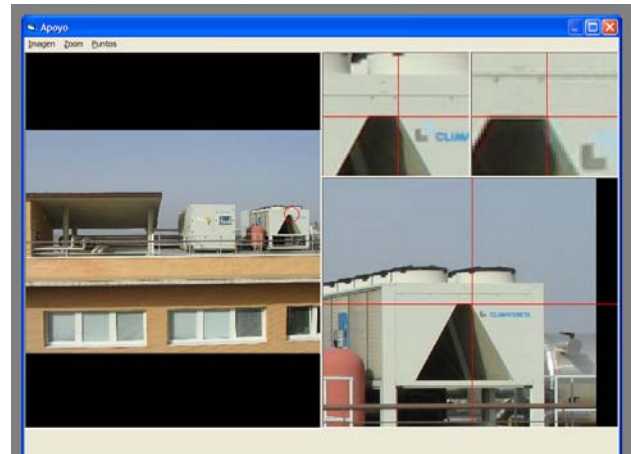

Figure 4. Image and zoom scenes of checks zones.

Image coordinates of the selected four-five points are measured in the image and object spatial coordinates are measured with the total station, bearing in mind that the station has been previously oriented if necessary. The aims will be guided from the computer keyboard cursors like a joystick. These points can also be used as control points.

From the spatial object coordinates of these points we made a least square adjustment and we can obtain a fit plane (Valle, 2004). Then points are projected onto this plane, so we can obtain plane object coordinates (2D).This step is necessary for later 2D projective transformation.

In order to relate both set of coordinates (plane object coordinates and image coordinates), we will do a 2D projective transformation.

The acquisition of eight transformation's parameters is made trough the five coordinates points. For this projective transformation we employed the last expression:

$$x = \frac{a_1 X'' + a_2 Y'' + a_3}{c_1 X'' + c_2 Y'' + 1}$$
$$y = \frac{b_1 X'' + b_2 Y'' + b_3}{c_1 X'' + c_2 Y'' + 1} \tag{1}$$

where $a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2$ = unknown parameters
x, y = image coordinates
X``, Y`` = "projected and rotate" plane object coordinates

In order to obtain the coordinates plane object we made the next stages: First, we obtain a fit plane trough the five points by means of a least square adjustment. The equation of the fit plane is shown below:

$$Ax + By + Cz + D = 0 \tag{2}$$

The object coordinates X, Y, Z, of these five points were obtained by means of the total station, so they were previously known.

Next the points are projected onto the plane as shown the Figure 5 and eq. 3.
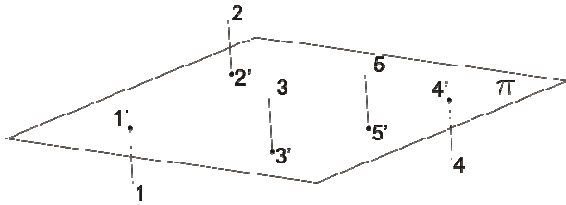

Figure 5. Fit plane (π), projected (1', 2', 3', 4', 5') and object points (1, 2, 3, 4, 5).

$$X_i' = X_i - d \cdot A$$
$$Y_i' = Y_i - d \cdot B \tag{3}$$
$$Z_i' = Z_i - d \cdot C$$

where X_i, Y_i Z_i= object coordinates
$X_i`$, $Y_i`$ $Z_i`$= "projected" plane object coordinates

$$d = \frac{AX_i + BY_i + CZ_i + D}{A^2 + B^2 + C^2}$$

Then, we rotate the plane, so we fix the Z_i' coordinate at a constant value, thus we have only 2d coordinates X`` and Y``. The expression below is employed to rotate the plane.

$$\begin{pmatrix} X_i'' \\ Y_i'' \\ Z_i'' = cte \end{pmatrix} = \begin{pmatrix} \cos\kappa & sen\kappa & 0 \\ -\cos\omega\, sen\kappa & \cos\omega\cos\kappa & sen\omega \\ sen\omega\, sen\kappa & -sen\omega\cos\kappa & \cos\omega \end{pmatrix} \begin{pmatrix} X_i' \\ Y_i' \\ Z_i' \end{pmatrix} \tag{4}$$

where

$$\kappa = arctg\left(-\frac{a}{b}\right)$$

$$\omega = \pm \arccos(c)$$

$$a = \frac{A}{\sqrt{A^2 + B^2 + C^2}}$$

$$b = \frac{B}{\sqrt{A^2 + B^2 + C^2}}$$

$$c = \frac{C}{\sqrt{A^2 + B^2 + C^2}}$$

With the (X``, Y``) and (x, y) image coordinates we can obtained the projective parameters a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2 by rewriting, the expression (1) as follow:

$$x = X''a_1 + Y''a_2 + a_3 - xX''c_1 - xY''c_2$$
$$y = X''b_1 + Y''b_2 + b_3 - yX''c_1 - yY''c_2 \tag{5}$$

And the matrix form is:

$$\begin{pmatrix} X'' & Y'' & 1 & 0 & 0 & 0 & -xX'' & -xY'' \\ 0 & 0 & 0 & X'' & Y'' & 1 & -yX'' & -yY'' \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ b_1 \\ b_2 \\ b_3 \\ c_1 \\ c_2 \end{pmatrix} = \begin{pmatrix} x \\ y \end{pmatrix} \tag{6}$$

Once we have known the parameters, applying the inverse projective transformation (eq. 7):

$$\begin{pmatrix} x & y & 1 & 0 & 0 & 0 & -xX'' & -xY'' \\ 0 & 0 & 0 & x & y & 1 & -yX'' & -yY'' \end{pmatrix} \begin{pmatrix} a_1' \\ a_2' \\ a_3' \\ b_1' \\ b_2' \\ b_3' \\ c_1' \\ c_2' \end{pmatrix} = \begin{pmatrix} X'' \\ Y'' \end{pmatrix} \tag{7}$$

We can achieve the (X``, Y``) plane object from the (x, y) images. Next, undo the projection and with the fixed Z coordinate we can obtain the object coordinates. Therefore, if we mark a point in the image by means of a device pointer (i.e. mouse cursor), automatically their object coordinates are known.

This information is sent to the total station and translated to the telescope horizontal and vertical movements; thus the collimation axis of total station is directly pointed to the control point.

In any case, if the aim is not correct because presence of residual errors, the measurement can be improved, since the software allows guiding the total station crosshair to the exact point by means of the computer keyboard cursors.

The next step will be the measurement and the recording of the object coordinates of the point. The measured data with the station will be registered and will get associated to the point marked on the image.

2.3 Software description

All of the processes are controlled by means of software with the following modules:

Visualization of digital cameras module. This module permit eliminates the direct observation from the total station.

Control of the reflectorless total station movements module (control is made from laptop computer) (Leica-Geosysytems, 2004).

Capture and storage of point observations and coordinates module (all points, control points and other points employed for 2D projective transformation, are stored).

Least square adjustment and coordinate transformation module.

Visualization module of the digital image for the control point location; this module include two images enlargement windows. Module for marking points in the image, image coordinates measurement and immediate point sketch drawing.

Point edition and visualization module (including image points and object points) Figure 6.

Export module. Exported reports include images that are used as sketch. These images include the marked control points. The report also includes the control point coordinates.

	X	Y	Z	x	y	Observaciones
1	1278.332	1456.654	302.382	597.33	487.65	
2	1279.879	1457.309	304.087			
3	1281.056	1456.665	302.532			
4	1279.476	1455.556	301.982			
5	1279.889	1455.992	302.916			
6						

Figure 6. Object and image coordinates points (from the edition point module).

3. CONCLUSIONS

All of processes reduce largely the time employed for control survey. Thus, this eliminates the hand drawing sketches and the hand marking of points in the images. The look up "in situ" of control point is not necessary over the object, since this operation is made from the sensor and laptop computer by the cameras images.

The simultaneous confection of the sketch and reporter including the coordinates of control points reduce furthermore the time of works. Futures work will be developed, in order to improve the subject as the automatic focusing. And other hand, we have in study methods for different situations as not plane surfaces, like cylinders and other kind of surfaces.

REFERENCES

Leica-Geosystems, 2004, TPS1200 Series GeoCOM Reference Manual V1.0. pp. 141

Scherer M., 2004. How to optimise the recording of geometrical data and image data for the purpose of architectural surveying. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Istanbul, Turkey, Vol. XXV, Part B5, p.p. 228 - 232

Valle, J. M., Rodriguez, A., Lopetegui, A. 2004. Enfoque cartográfico de los Modelos Virtuales de elementos patrimoniales. *VIII Congreso Nacional de Topografía y Cartografía TOPCART 2004*, Madrid, Spain, 12 p.

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