

OIA AND BUILDING: TWO PROGRAMS FOR HOUGH APPLICATION TEACHING IN DIGITAL PHOTOGRAMMETRY

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ABSTRACT:

In the last decades, the photogrammetry has experienced important changes. The analytical photogrammetry, and afterwards the digital photogrammetry, has revolutionized the methods, processes and products of the photogrammetric works. These changes must be reflected in the educative university programs dedicated to the study of photogrammetry. In such a way that future technicians can receive an advisable and modern education. The main problems appear because most of the processes in digital photogrammetry are complex, and are solved generally by the digital photogrammetric systems (DPS) of internal way (black-box). In this context, the users (and the students, too) have a limited access to the applied procedures and the obtained partial results, making difficult the correct understanding and learning. A fundamental work of the professors dedicated to the education of the digital photogrammetry is to provide the adequate tools that allow to learn the basic processes through open software in which the student can have a total access to the individual operations (in most of the cases related directly to the treatment of the digital image) as well as to the partial results. With this aim, this paper is about two software applications: OIA program dedicated to the automatic interior orientation of images of metric and non metric cameras, and BUILDING program, dedicated to the automatic extraction of buildings, using the extraction of edges and prismatic models. The final objective of both programs is the knowledge of the Hough transformation application to the Digital Photogrammetry. OIA constitutes complete interior orientation software that uses the Hough Transform for the recognition and measurement of the basic elements that compose the fiduciales marks (circles and lines). This application also allows working with non metric images. In this case, the interior orientation is made by means of the location and measurement of the edges of the image. The program allows the interaction of the operator to know the partial results as well as the final transformation. BUILDING present a more complex application of the Hough transform, the automatic extraction of buildings by means of the extraction of edges in an oriented image using a digital model surface of the zone as additional information.

1. INTRODUCTION

The photogrammetric processes automation has experienced in the last years a large development thanks to the digital photogrammetry and to the advance of the technology in general and computing in particular.

This automation has produced that the basic photogrammetric processes (such as, interior, relative and absolute orientation, digital elevation models and orthoimages generation, etc.) have been converted into a black-box processes. In these processes, the operator has not access to the partial results, nor to the methodology used by the digital photogrammetric system. This lack of knowledge of the used methodology, can difficult the correct analysis of the obtained results for the operator in order to detect the presence of errors. Photogrammetry teaching must provide tools that allow solving this problem. It is basic the entire knowledge of the process and the results, both partial results and final products. Using these tools, the educators can show, in a detailed form, the different steps involved in the complex digital photogrammetric processes and the students can obtain an adequate understanding of the problem and processes. In this paper, we present two applications specially designed in order to allow to the students a total access to the entire process and partial results. The objectives of the automatic processes of the applications that we present in this paper are: a) the inner

orientation of metric and non-metric images; b) the location and prismatic modelling of buildings in urban zones (with isolated buildings).

2. METODOLOGY

One of the most used methodologies, for edge extraction (lines and circles) in digital imagery is the Hough transform (Hough, 1962). Elements extraction begins as an image processing operation. It can be carried out in various ways depending on assumptions about the imaging process and how the elements will be used in the algorithm. Using an edge operator, a point dataset can be extracted from the digital image. This dataset includes points that have certain differences with the surroundings pixels and, for this reason, they can be considered as "potential edges". The basic objective of the Hough transform is to establish which points of the previously extracted dataset belong to the same geometric element (line, curve,...). This geometric element will be expressed as a parametric function. All the points of the dataset are transferred from the image space into a parametric space. The parameters that we need to describe the geometric element are added to an accumulated table using a predetermined discretization. The cells of this table that contain the maximum values indicate the most frequent parameters and define possible geometric entities.

Using this procedure, for the determination of the edge pixels of a geometric feature is only necessary the search of the maximum values in the accumulated table.

In the location of straight lines ($y = m \cdot x + n$, $\rho = x \cdot \cos \theta + y \cdot \sin \theta$), the Hough transform is based in the transformation of the XY image plane into a mn image space (according the original formulation of the Hough transform) or into the $\rho\theta$ space (Duda and Hart, 1973) (figures 1 and 2). Using this procedure, all the lines that can be defined by one point A are transformed into two values (ρ, θ) –or m,n values if the original Hough expression is applied–. These couples of values will be stored in parametric form into the accumulated table increasing a unit the corresponding storage cell according the discretization parameters.

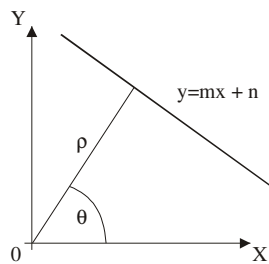


Figure 1. Parametric representation of a line (mn and ρ, θ space)

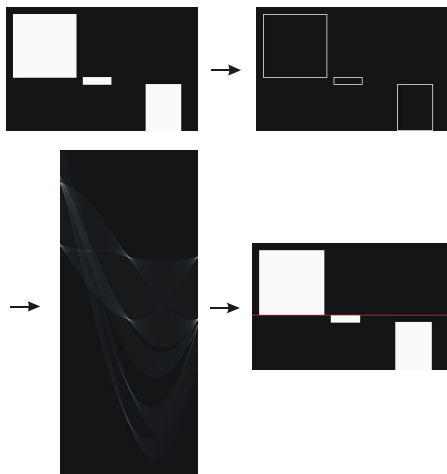


Figure 2. Hough transformation for line extraction. a) synthetic images showing a set of blocks, b) edge detection, c) Hough transformation partial results (ρ, θ accumulative matrix), d) selection of the edges that belong to the same line

In the case of the circles, the nonparametric equation of the curve to locate can be written like FORMULA, where (x_c, y_c) and r are the center and the radius of the circle, respectively. In this case, the parameters space is now a 3-dimensional space (x, y, r) . Consequently, there will be necessary to define a storage cell of 3 dimensions $-N \times M \times NR-$ (figure 3).

2.1 Edge operator

For the edge point extraction, a Canny filter has been used. Previous to the filter application, a noise reduction process is carried out. Usually, in order to solve this problem, which can

affect to the edge detection quality, a gaussian filter with a σ value between 1 and 3 is applied. The σ value is dependent on the noise level of the image.

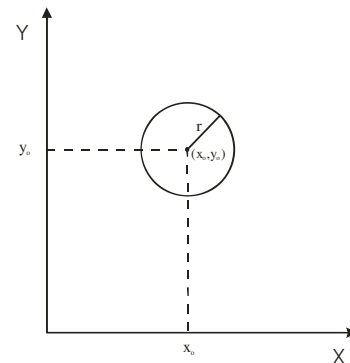


Figure 3.

Once the image noise is reduced, the edge operator itself begins with the gradient calculation in all the image pixels. For this calculation, filtering based on first and second derivate are usually applied. In this paper, the Sobel operator has been used in order to obtain the gradient direction G_x and G_y . The gradient module and direction for each pixel of the image can be obtained using the following expressions:

$$|G| = \sqrt{G_x^2 + G_y^2}$$

$$\theta = \arctan(G_y / G_x)$$

In most cases the characteristics of the photogrammetric images produce a large number of extracted edges so several pixels can be related to the same edge. In order to avoid this problem and simplify the problem, it is necessary to reduce the total number of pixel that are considered as edge pixel. Using this procedure we obtain edges that are defined by a edge pixel chain. The procedure applied to this selection is the local maximum (suppression of non-maximum). The resulting edges will have a thickness of a single pixel. Finally, a binarization process is carried out in order to debug the extracted edges and minify the noise influence in the edge extraction.

3. APPLICATION

3.1 Interior Orientation Process Automation (OIA Program)

3.1.1 Metric cameras images

There are several methodologies for the inner orientation process automation (see Schenk, 2000 for a comparison and analysis of the different methods applied to metric images). In

metric cameras, the well-known shape and size of fiducial marks, simplify the problem. These marks are composed by several symmetrical elements (the centre of symmetry coincides with the centre of the mark) and they are easily differentiated from the image background. These characteristics allow the use of several measurement techniques: binarization and centroid localization, area-based matching or feature-based matching.

The fiducial marks in most present aerial cameras are composed by lines and circles (concentric rings) that define the centre of the mark. For this reason, it is possible use the capabilities of the Hough transformation in order to define which pixels belong to the same circle. The method provides the parametric characteristics of the extracted circles (centre coordinates and radius), basic information for the results debugging. The obtained maxima in the accumulated table define the characteristics of the circles, and therefore the position of the fiducial marks. The measurements of the marks will be used in order to obtain the transformation between the image space (pixel) and the calibrated photocoordinates (obtained from the calibration certificate). This methodology has been implemented in a software program developed under C++ Builder language programming (Figure 5).

The program input informations are: calibrated coordinates of the fiducial marks obtained from the camera calibration certificate (this information can be introducing using the keyboard or imported from a camera file); digital image where we want to apply the interior orientation process (using this image it is necessary obtain a gaussian image pyramid); direction of the +x coordinate axis (that can be provided indicating the marginal information position) (Figure 4).

With this information (and information that the system obtain directly from the header of the digital image file such as resolution) it is possible to obtain an initial approximation to the fiducial marks position in the digital images.

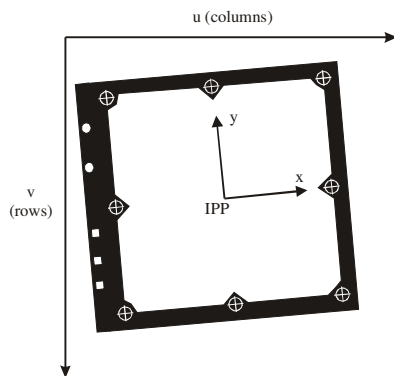


Figure 4. Image space coordinates (u,v in pixels) and calibrated photocoordinates (x,y in milimeters)

For each fiducial mark, the system will go to the previously selected zone and will search the corresponding circle. The process begin using the initial available approximations in the higher level of the image pyramid (with low resolution, low accuracy and a small number of pixels) and this results will be used as approximations for the next levels –lower levels– (with higher resolution, higher accuracy and larger number of pixels). Once, all the measurements are finished, an affine transformation (6 parameters transformation) is carried out.

The obtained results (measurements) have been compared with

the obtained ones using a commercial digital photogrammetric workstation (SOCET SET –in manual and automatic modes–). The obtained results are compared in Table 1.

Mark	OIA		SOCET SET manual		SOCET SET automatic	
	X	y	x	y	x	y
1	15247	7684	15248	7684	15248	7684
2	188	7682	188	7683	187	7683
3	7716	153	7716	153	7716	153
4	7717	15213	7717	15213	7717	15213
5	15245	153	15246	154	15246	153
6	188	15213	188	15212	188	15213
7	186	152	187	153	186	152
8	15246	15215	15247	15214	15247	15214

Table 1. Comparison of the mark measurement working with OIA and SOCET SET (values in pixels)

If there is any problem in the automatic measurement it is possible use the manual measurement option for solve any measurement error.

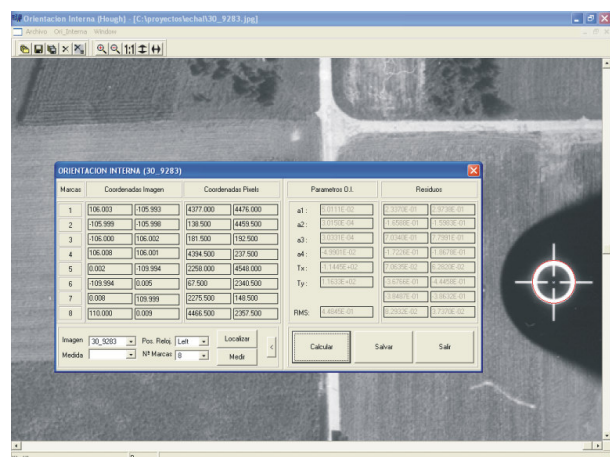


Figure 5. OIA program. Main display and results windows

3.2 Non-metric camera images.

In the non-metric cameras digital imagery, one of the most frequent methodologies is based in the location of the frame image corners by the frame borders line intersection. These lines can be extracted using the Hough transformation for straight lines. This type of automatic inner orientation consists in the calculation of the format centre (indicated principal point, IPP) (Figure 6).

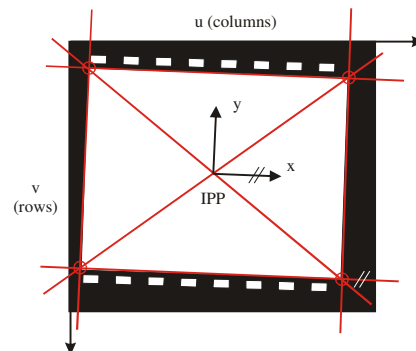


Figure 6. Non-metric camera inner orientation

First, the straight lines that represent the borders of the image format are obtained. Some authors (Cruz et al., 2000) use a linear regression of the edge points that define the image frame. In OIA program, the Hough transform applied to the straight lines extraction is used in order to determine which edge pixels belong to a specified frame edge.

In order to simplify the edge location and reduce calculation times, an iterative procedure is carried out using the different images (with different resolution) that constitutes the image pyramid. The process begins with the small resolution image with the edges extraction and the results are improved according to the resolution. Once the frame edges are extracted the corners of the image frame will be defined as the edge intersections. Finally, the IPP is obtained as the intersection of the diagonal lines (defined between opposite computed corners). The image x-axis is defined parallel to the upper extracted frame edge.

Figure 7. OIA main display window (non-metric cameras)

3.3 BUILDING.

BUILDING is an application software for semiautomatic building prismatic modelling using Hough transformation (Figure 8). Indeed, this is a more complex photogrammetric process.

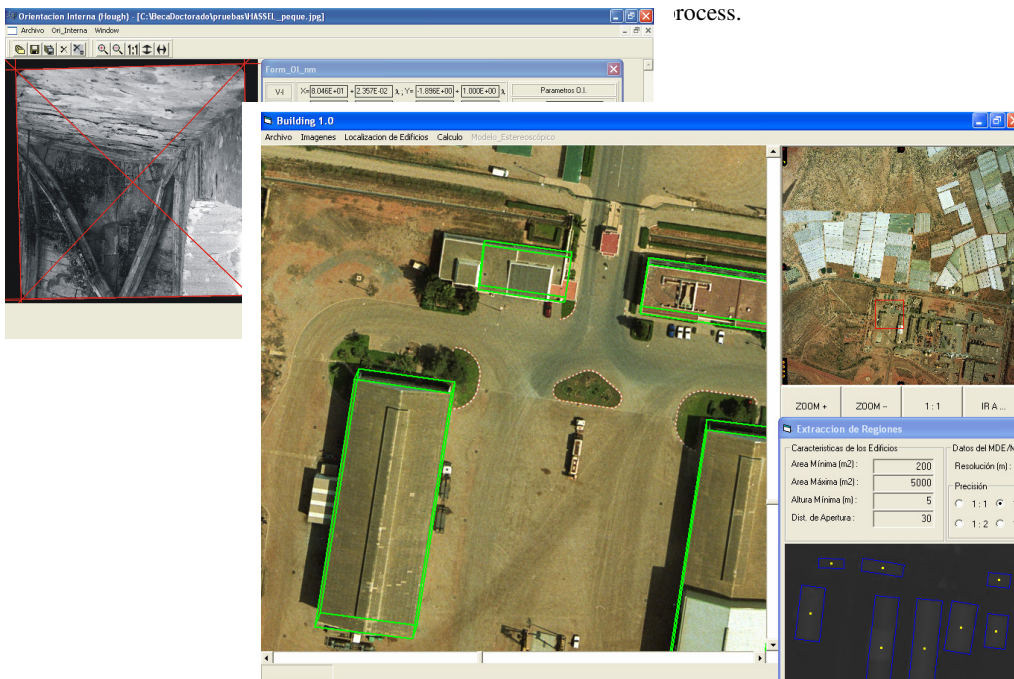


Figure 8. BUILDING program main display window

BUILDING is organized in several steps: a) preparation, b) location, and c) extraction.

The preparation step (figure 9) consists in the acquisition of the basic information required for the process. The basic required information are: a) digital image in which the building extraction process will be carried out (using this original image a gaussian image pyramid will be made); b) calibrated coordinated of the fiducial marks (from the camera calibration certificate); c) exterior orientation parameters; and, d) digital surface model in grid format (XYZ) stored in an ASCII text file.

The XYZ data will be transformed into an image format in order to improve the required storage space. Finally, the automatic inner orientation of the image will be made using the OIA program.

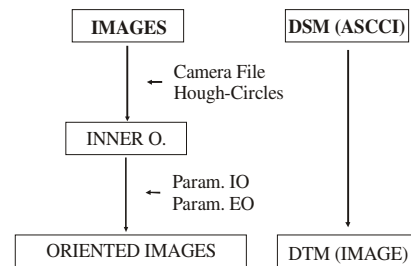


Figure 9. Preparation

The next step is the building location (figure 10). This step begins with the study area selection using the DSM. This zone will be studied using mathematical morphology procedures considering an approximation of the building characteristics

that we want to extract (maximum and minimum area, minimum height, etc.). From the original digital surface model it is possible to obtain a digital terrain model through an opening process (Baltsavias et al., 1995) that eliminate the constructions or another obstacles that can be present on the terrain. The difference between both models, DSM and DTM, will allow obtaining a new model that contains only the objects located on the terrain (buildings, trees, etc.). Using this new model, a binarization process is applied. The binary model will contain the regions in which the buildings can be located. These regions will be examined using shape descriptors as the invariant geometric moments (Gerke et al., 2001) obtaining for each one of the extracted regions the mass centroid, the surrounding and minimum bounding box as well as the height of the region (Figure 11).

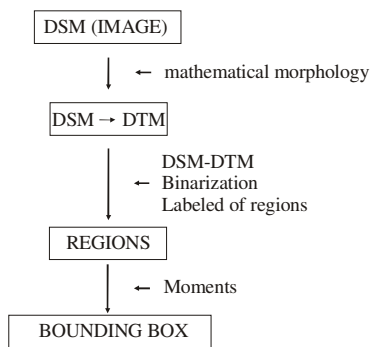


Figure 10. Location step

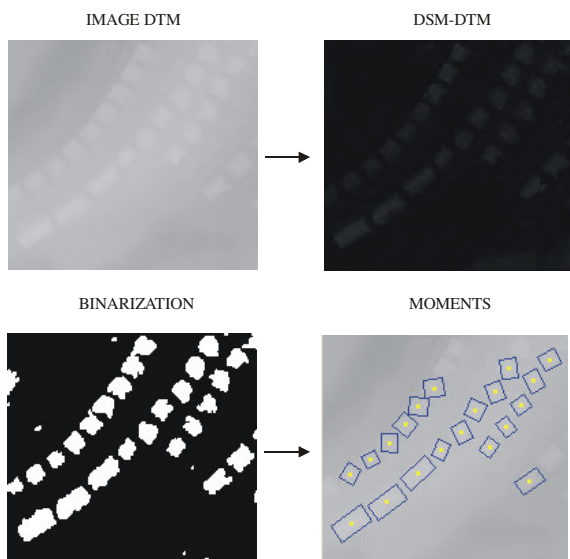


Figure 11. Partial results obtained from the location (building detection)

These zones that are selected from the terrain are the input data for the following steps that provide the characteristics of the extracted buildings (Figure 12).

It is possible to project the bounding box (that probably includes a building) from ground –terrain- space into image space by means of orientation parameters. Then, we can apply different algorithms in this region to obtain the most representative rectangle of the building.

The analysis applied to these images has different steps. First, if the original image has a low contrast, a linear histogram stretch is applied obtaining an optimum contrast balance in the image. Then, in order to eliminate minor significant edges and noise that could be presented in the image, an image smoothing by means of a gaussian filter is carried out.

Next step, it is a Canny filtering in order to obtain the image edge. Since the filter is applied in a local level (that contains the extracted built area) we obtain two main gradient directions that correspond with the main building orientations. Then, we use the Hough transform for the straight lines extraction considering these orientations and an additional condition about the number of pixels involved (Figure 13).

Once the principal straight lines of the considered image region are extracted, the possible intersections among them are calculated. All the possible rectangles considering the intersection points are generated. Different weights will be assigned to these rectangles. These weights will depend on the number of edge pixels in the rectangle and its similarity with the bounding box of the corresponding region. A final rectangle is defined, this rectangle is combined with the information derived from the DSM in order to obtain the height of the building and to create its prismatic model (Figure 14).

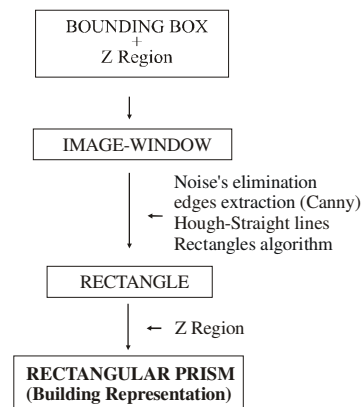


Figure 12. Building Extraction

Using the BUILDING program, the students will be able to know one of the most complex procedures related with the photogrammetric processes automation. The program provides an entire set of all the partial results and finally, its results are obtained in a 3D AutoCAD compatible format.

Using this final file, the results can be evaluated and edited using a conventional stereo digital photogrammetric system. This task will allow to the students analyze the own limitations of the methodology, and learn to necessity of the edition processes in the automatic information extraction from photogrammetric imagery.

4. CONCLUSIONS

The Hough Transform is a very powerful and simple tool for the automation of different photogrammetric process. Using OIA and BUILDING programs, the students can obtain (and analysis) all the partial results of the different steps in both processes (automatic inner orientation and prismatic building models extraction).

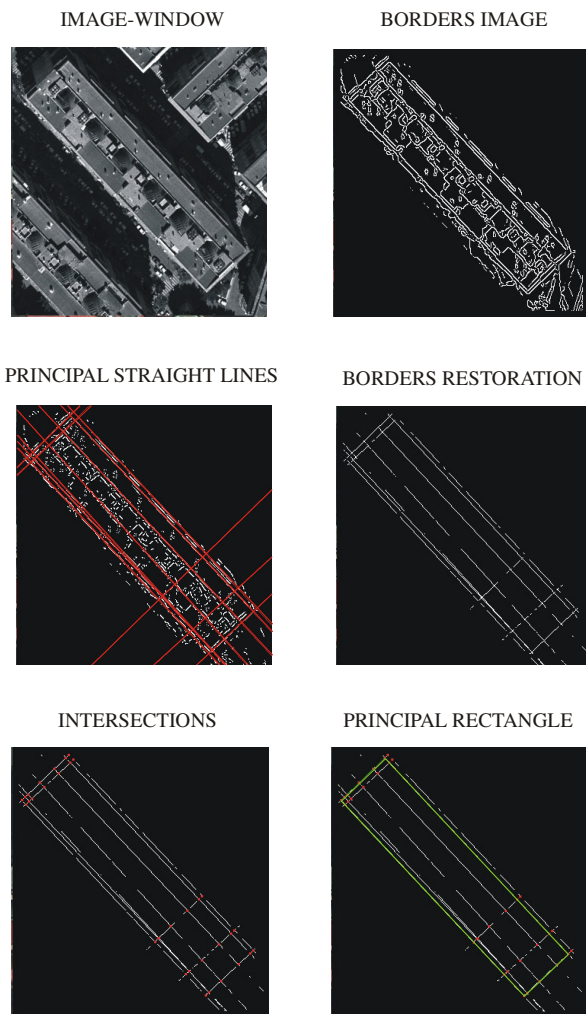


Figure 13. Rectangle detection

RECTANGULAR PRISM



Figure 14. Building prismatic models projected over the original digital imagery

The students can learn some of the automatic methodologies used in Digital Photogrammetry, in a practical way using these open systems. Thus, the automatic processes implemented in the digital photogrammetric workstations become open processes that allow the analyses the input data, the detailed methods, the partial and final results. Through these systems it is possible to obtain a complete knowledge of the processes that allow to a student perform an adequate analysis of the results and errors in its future professional labour.

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