
A PROGRAM FOR AUTOMATIC INNER ORIENTATION OF DIGITIZED NON METRIC IMAGES (35 AND 70 mm)

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ABSTRACT

A program for the automatic inner orientation of non-metric digitized images taken with 35 and 70 mm cameras has been implemented under I.D.L. 5.0 (Interactive Data Language, release 5.0 from Research System Inc.). The program is based in the detection of the four edges that define the frame format. The approach to detect the edges uses Prewitt filters that can detect horizontal (both lower and upper) and vertical (both right and left) lines. Once edges have been detected, they are measured by means of transverse profiles throughout the detected edges. A regression fit line is computed each edge. However it is necessary blunder detection and elimination of anomalous data or noise. Then lines are computed again without blunders and the frame corners are calculated by intersection of lines. The photo-coordinate system is referenced to the center of the format (the indicated principal point defined by intersection of diagonals) and the X-axis is forced to be parallel to the lower format edge. Moreover there is a possibility for coordinate transformations (4-parameters, 6-parameters, two-dimensional projective or 8-parameters bilinear) if fixed reference values exist for those corners, so some film or scanner errors can be corrected. The program runs with digitized images in grey scale or RGB TIFF files. Images have to be scanned without any cropping because the whole format is necessary for the inner orientation (edges must be clearly visible and contrasted). Non-Metric cameras and desktop scanners, equipped with transparency trays, combined with this method can be an effective option for low cost photogrammetric applications.

1 INTRODUCTION

Since last three decades, the development of analytical photogrammetry has allowed the extensive use of non-metric cameras for image acquisition. Several mathematical models permit the correction of different error sources affecting non-metric imagery and because the low cost of these equipment there has been a wide expansion of non-topographic photogrammetry (Karara, 1989). Also, at present these equipment (small format non-metric cameras) are being used from light aerial platforms (light and microlight aircraft's or helicopters) for fast and low cost mapping applications, environmental and natural resources purposes, urban planning etc. (Warner, et al., 1996). But important drawbacks persist in the use of such cameras. These drawbacks are mainly related to the unknown and instability of the inner parameters, film unflatness (affecting more to 70 mm than to 35 mm film) and the lack of fiducial marks.

Researchers have developed several approaches to avoid or minimize those problems. The unknown and instability of inner parameters can be solved by means of "in situ" calibration (this approach needs a dense network of surveyed spatial control points) or by a more effective (and complex) solution like the camera selfcalibration. Film unflatness can be minimized by means of additional parameters in the selfcalibration model or by installing (not always recommended) a réseau glass plate (see Karara, 1989 and Fryer, 1992, for a complete revision of these methods).

Moreover, different methods can overcome the lack of fiducials. The use of the Direct Linear Transformation (DLT, Abdel Aziz and Karara, 1971; in Karara, 1989) is an effective alternative when requirements on accuracy are not essential or when the availability of a dense and adequate control point network is not a problem. Also, Faig, et al. (1992) propose the use of "pseudo" fiducial marks, such as slits or holes made in the focal frame at the camera back. Finally, another solution for the film inner orientation without fiducials is the measurement of the frame corners. This method can be applied even with some commercial systems like those of ADAM technology (Elfick, 1986). This last approach has been selected in this paper for the automatic inner orientation of non-metric imagery.

2 AUTOMATIC INNER ORIENTATION OF NON METRIC 35 AND 70 mm IMAGES

2.1 Inner orientation of non-metric images

As mentioned, the inner orientation of non-metric images will be approached by means of measurements of the frame corners. These corners can define the coordinate system. But when a frame corner is magnified, both optically (film based image) or zoomed in (digital image), is difficult to determine the exact position of that corner because the image is not well defined and sometimes it's blurred. So, it is usual to make redundant measurements at the four format edges finding the best regression fit lines for those edges. Once the edge lines have been defined, corner frames are computed by intersection of lines. Then, the intersection of both diagonals locates the format center (indicated principal point, IPP). The photo-coordinate system is centered at the IPP and, usually X-axis is forced to be parallel to the lower edge (figure 1).

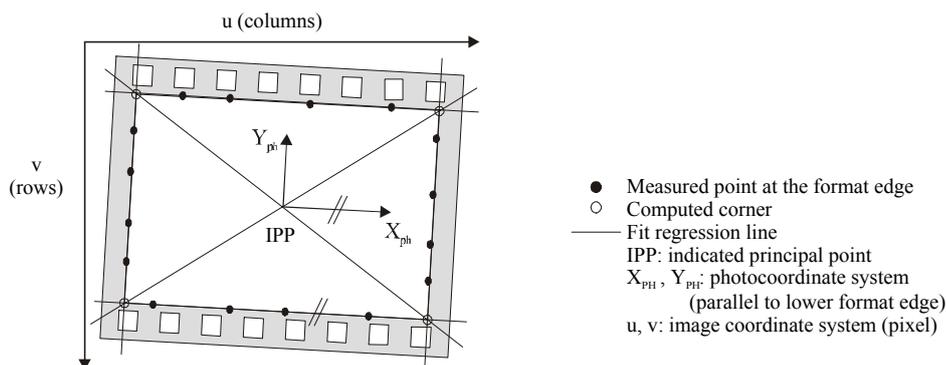


Figure 1. Coordinate systems in digitized images and explanation of inner orientation process in non-metric images.

Although this methodology has shown to be efficient and it is routinely used, it is very cumbersome and affected of some uncertainties. Some of the drawbacks can be resumed in a larger number of points to be measured (efficiency is diminished), final results can be influenced by the number of points per edge, edge irregularities, etc. Moreover, most commercial software does not allow plotters do the inner orientation by measuring the edges. In order to avoid most of these problems, an approach using digital image analysis is proposed. Thus, the automatic detection of the frame edges with high redundant data is possible and lines defining edges and corners are computed in a much more objective way. Manual and subjective measurements are overcome. Even it is possible drawing marks on the computed position (with any image analysis software), allowing for inner orientation with a conventional digital plotter.

Photographs have to be previously digitized, well from the film well from paper prints. But, frame edges have to be clearly visible, so no cropping is allowed. Till recent years this was a real problem, because scanners for slide or negative films cropped the edges and the total surface frame were not scanned. In any case, Warner, et al. (1992) employ successfully such scanned images (with cropped edges) and compare results with paper prints. At present, there are low price desktop scanners equipped with transparency trays, which allow scanning the whole format without any cropping at high resolutions (up to 1200 dpi). Some of them can even be employed for medium precision photogrammetric works (Baltsavias and Waegli, 1996).

2.2 Algorithm for automatic frame edge detection

An algorithm for automatic frame edge detection and further inner orientation of photographs has been implemented under I.D.L.[®] 5.0 (Interactive Data Language, Research System Inc.). IDL has been chosen because a high capacity for working with digital images, a powerful and fast computation and a comfortable widget environment. The algorithm is based in the fact that, usually, an edge is a well defined line if contrast is satisfactory. A directional filter is used for detecting the edge. We have tried to use the simpler approach, so other complex approaches, such as Hough filters, have not been considered. Another operators, such as Sobel or Roberts, were also tested but they extract edges in all directions. Prewitt (directional) filters can extract preferentially horizontal (upper and lower) and vertical (left and right) lines, so these operators were considered more convenient (figure 2).

When the program starts, this one opens the main window where the image can be loaded (figure 3). In a first step, the user can extract the rectangular areas where the edges are found, although the program can search for default areas (spending more time). On these extracted areas would be necessary the application of the four templates (figure 2) which means designing four algorithms for all edges. With some simple operations only one algorithm needs to be implemented.

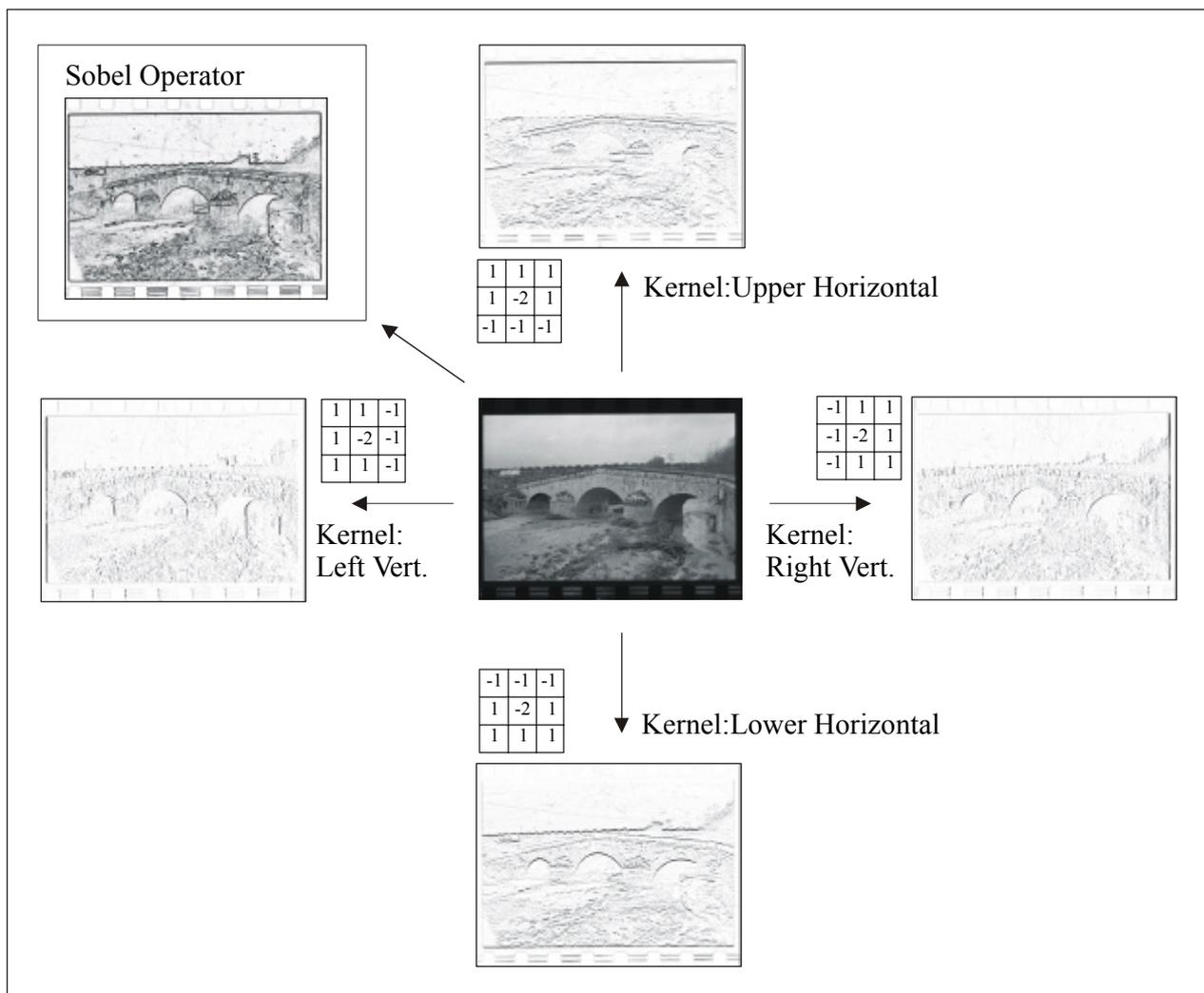


Figure 2. Linear line detecting templates (Prewitt filters) and comparison with Sobel operator for edge extraction.

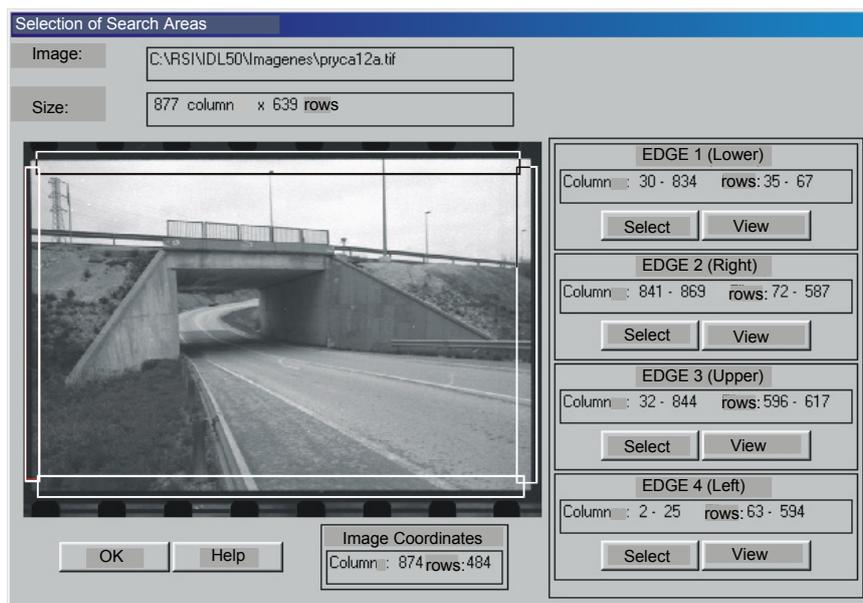


Figure 3. Selections of search areas for format edges. Main window of the non-metric images inner orientation program under I.D.L. 5.0.

Once the areas have been extracted, by means of two rotations (left and right edges) and a vertical flip (lower edge), the left, right and lower edges can be converted into an upper horizontal edge, so only a template (upper horizontal line, in figure 2) will be used (figure 4). Once the edges have been extracted and measured they will be returned back to the original positions.

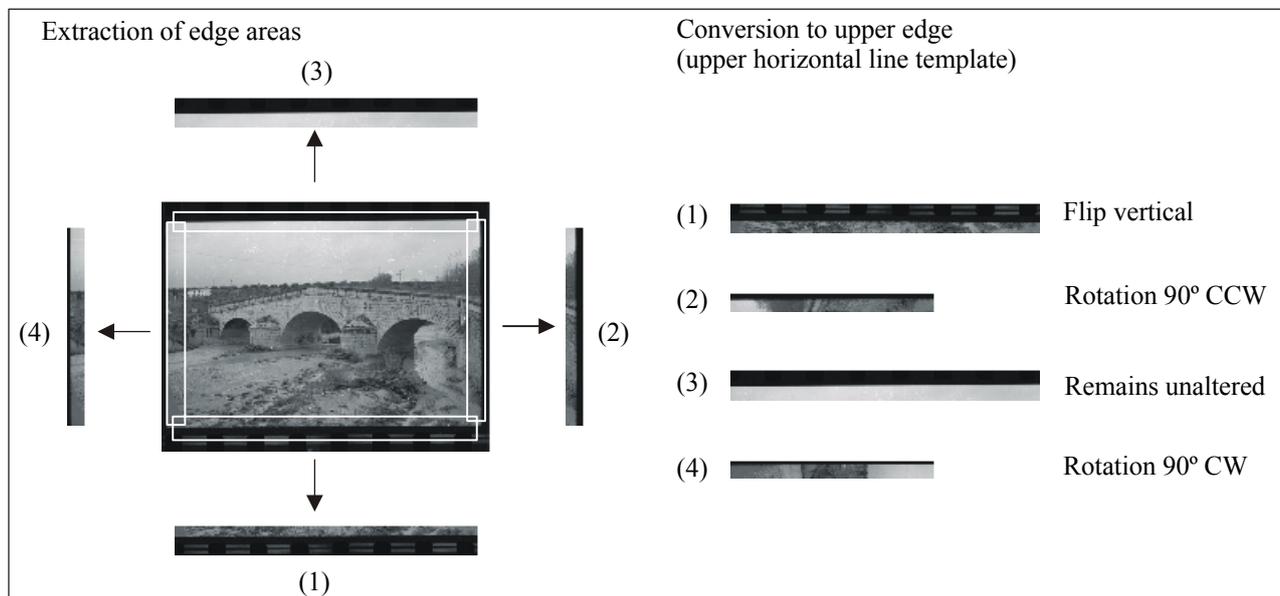


Figure 4. Conversion of lower, right and left edges into upper ones in order to use only one filter (upper horizontal template). After detection and measurement of edges, windows are returned back to original positions.

The final process to extract the edges is summarized in figure 5. It is usual that in 35 and 70 mm films appear a lot of marginal data (photo and ISO marks, film type and trademark), holes for film advancement, etc. All these elements can be confused with linear elements (in fact, they do). This problem has been solved by an image binarization on the extracted and filtered areas. By default a threshold of 80 digital number (DN) has been selected. This threshold has shown to be efficient for properly contrasted edges. Once the image is binarized, the line with more white pixels (255 DN) is searched. Because the edges can be slightly tilted, this line is looked for with a tolerance between 0.5-1°. Then a narrower window (30 pixel width) is extracted again around this line, window (d) in figure 5. This way allows working with a narrow band around the edge in the filtered image, but the most part of details that can produce anomalous data have been suppressed.

Once edge has been detected, transversal profiles regularly spaced are made and the gradient through those profiles is measured. Where gradient shows higher values the edge is expected to be there. But the edges can be a few pixels width because of poor image definition and the scanning resolution. So, a routine will measure the three higher gradient values in each profile. This implies that for a horizontal line three row values, y-coordinates, correspond to one column value, x-coordinate. With all these data (one x-coordinate and three y-coordinates per profile) a fit line is computed. User can select the number of profiles. The resolution and the image size limit the number of profiles, but fine results can be achieved with 50-200 profiles each edge (for 600-1200 ppi image resolutions). As mentioned, the measurements involve the three higher gradient values each profile. That means between 150-600 measurements per profile made automatically in a few seconds (with a conventional PC Pentium™ II at 350 MHz and 64 Mb RAM).

The calculation of the fit regression line is made with high redundant data. Because noise can produce high gradient values, there will be a need for blunder detection. Although rigorous treatments, such as robust statistics (Huber, 1981), can make efficient blunder detection, a simpler approach has shown to be efficient enough. User can state a maximum limit for rejection of observations. For the most cases, a limit of residuals based on 3 times the standard deviation can filter the noise. Once blunders have been rejected, the lines are fitted again. For color photographs, the three RGB channels are separated and an adjustment is made for each channel, getting the values for the best adjustment.

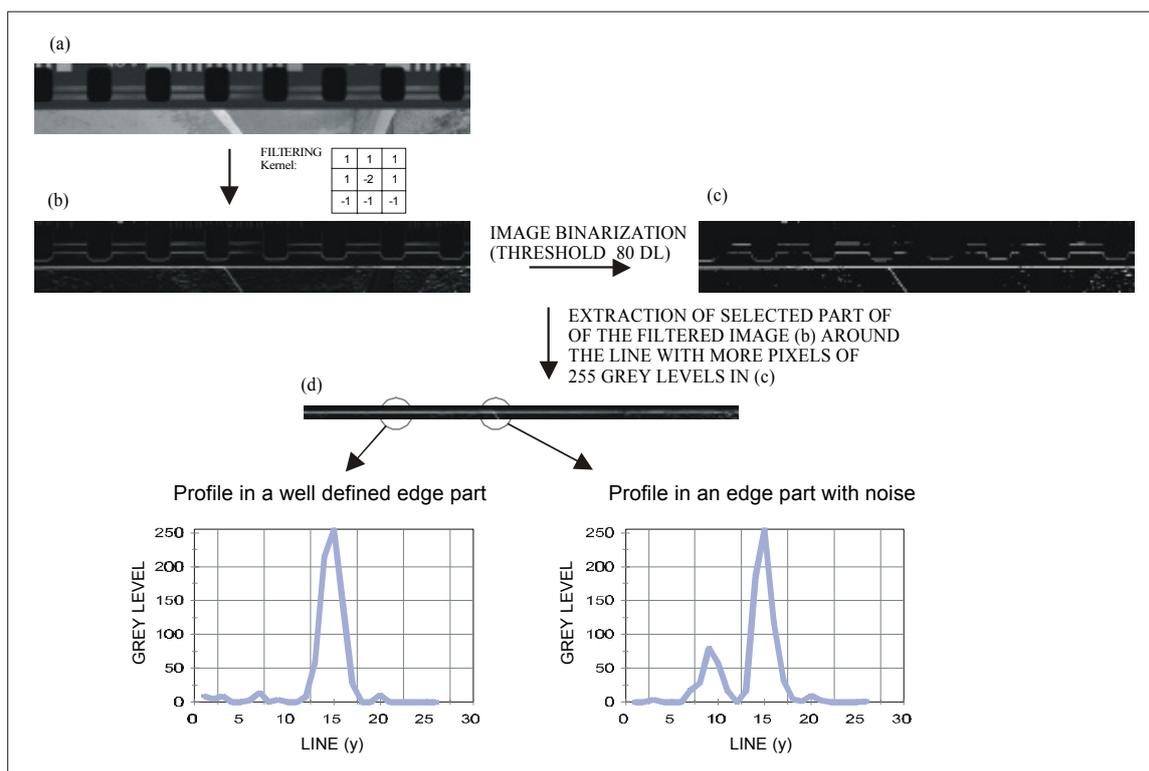


Figure 5. Process for the inner orientation based in edge detection.

2.3 Automatic inner orientation and coordinate transformations

Once corners have been computed, inner orientation is made following the process stated in figure 1. The coordinate system is centered at the IPP (computed by intersection of diagonals) and the image x-axis is forced to be parallel to the lower edge. This implies a translation and a rotation. Pixel coordinates can be transformed in mm by scaling the image according to the pixel size. Thus any point measured in the image can be adequately referred to the IPP. But also, because the program marks a pixel in the computed corner positions, an inner orientation by means of a conventional digital plotter is possible measuring the marked position.

The method applied this way does not consider any film or scanner deformation. Scanner errors are supposed to be high because the use of a desktop scanner instead of a photogrammetric one, according to the low cost philosophy employed in this work. But if exact corner positions for the camera are known those errors can be partially corrected. There are several ways to know accurate corner coordinates. These coordinates could be considered as “calibrated” corner coordinates. In some cameras, especially those where the magazine can be removed, the backside at the focal frame is accessible and it can be measured by any precision instrument (a caliper or jig). Also some glass plates can be exposed (as made by Donnelly, 1988) and then the format edges can be accurately measured with a comparator. Finally, if there is not possibility to obtain glass plates for a small format camera, several film frames can be measured with a comparator and then the mean values of the frame corners are considered as “calibrated” corners. In this last case, the errors are averaged between all the measured frames. With any of these methods at least there are some reference fixed values (“calibrated”) that can be compared with the measured/computed ones.

Coordinate transformations permit removing some film and scanner errors. With film-based images and inner orientation by means of computed corners, Fryer (1992) proposes the use of conformal (4-parameters) transformation instead of an affine (6-parameters) one. Affine transformation can transfer and distribute errors across the entire frame because corners are computed, not measured. But in the case of scanned images additional errors are introduced and may be a transformation with two scale factors (affine) is closer to reality, although measurement with an indirect method is necessary to get “calibrated” corners. The uncertainties of the correct position of corners for a particular frame can be overcome by the high redundancy in the measurement of the edges. But anyway different errors have their largest impact at the frame edges, such as film unflatness, deformation, distortion and others, so some cautions have to be taken in the use of any transformation. User should decide the best transformation to employ. More information can be found in Fryer (1992) and Robson (1992). The program presented in this work permits the inner orientation with different transformation types. If no “calibrated” corners are present, inner orientation is reduced to center the reference coordinate system at the IPP and to scale the image according to the scanning resolution. If the “calibrated” corners have

been measured, several transformations can be made and the user can decide the best solution. The conformal and affine transformations between the corner coordinates computed for a frame and the “calibrated” ones for the camera will give residuals. But two additional transformations have been considered. A two-dimensional projective transformation allows correction for lack of parallelism between two planes. This can be useful when a paper print (without the edges cropped) is scanned. This can correct for errors introduced in the optical enlargement of the paper print. Also a bilinear transformation (see Ghosh, 1987) can partially correct for some non-linear errors. But special care has to be taken because both transformations have 8 parameters. With 4 corners only 8 equations can be written and there will not be residuals.

3 SOME EXAMPLES OF AUTOMATIC INNER ORIENTATION

The method presented in this paper has been tested with some examples. Several photographs taken with non-metric cameras have been oriented. The cameras are RICOH KR10M (35 mm format) and a HASSELBLAD 500 CM (70 mm format). Several frames had been measured in an analytical plotter (Wild AP1 used like monocomparator), so values for “calibrated” corners were available for both cameras. The frames (slide and negative films) were scanned with two desktop scanners AGFA ARCUS II (at 600 dpi maximum optical resolution) and AGFA ULTRA-HORIZON (at 1200 dpi). Several examples are shown in figures 4, 6 and 7 with the results of different transformations (4 and 6 parameters) in Table 1. In general errors are higher in 70 mm film format than in 35 mm format. Figure 6 shows an example of inner orientation in a 70 mm frame. Typical marks of the Hasselblad frame (slits at the left edge and special frame corners) do not disturb the application of the method. In this case the error is slightly higher than the pixel size (21 μm) using the 4-parameters transformation (table 1).



Figure 6. Inner orientation in photograph taken with Hasselblad 500 CM and scanned at 1200 dpi.

	Affine Tr. (6-par.)		Confomal Tr. (4-par.)	
	σ_X (mm)	σ_Y (mm)	σ_X (mm)	σ_Y (mm)
Ex. 1 (Fig. 4)*	+0.008	+0.014	+0.015	+0.010
Ex. 2 (Fig. 6)**	+0.014	+0.018	+0.026	+0.028
Ex. 3 (Fig. 7A)**	+0.012	+0.004	+0.023	+0.015
Ex. 4 (Fig. 7B)*	+0.001	+0.068	+0.101	+0.121

Table 1. Coordinate transformation errors (in terms of σ_X and σ_Y) for the examples of figures 4, 6 and 7. (*): 600 dpi; (**): 1200 dpi

Two additional cases are shown in figure 7. These examples show cases where weak conditions for the application of this method can be found. The first case (A), although it was successfully solved, corresponds to a photograph of a soil (taken from Carvajal, 1999). The camera is mounted on an aluminum frame that allows near vertical stereoscopic pairs from 2 meters height. Because there are targeted control points at the base of the aluminum frame, it is possible to obtain the digital elevation model of the soil surface. The comparison between different DEMs can permit calculation of soil losses as well as detailed studies of the micro-relief. These kind of photographs can have problems for the automatic inner orientation as the frame structure can be confused with the edge because that is contrasted enough and it appears near parallel to the edges. Also contrast is very weak at the lower corners because poor illumination conditions. At the center, the lower edge is clearly detected because is marked by the edge frame and the aluminum rod, but near the corners the aluminum frame (largely affected by distortion) is more contrasted than the edge frame. Gradients are higher at the aluminum frame than at the format edge. Because the measurements in the aluminum frame at the corners have high residuals they are eliminated and they don't contribute to the line fitting. Line is only fitted with the measurement at the center of the format where the edge frame is clearly visible. However this situation not always is properly solved if the aluminum frame had been pictured clearly separated (but very close) to the lower edge. In the upper edge, because the aluminum frame is more separated from edge, it is possible to avoid this situation when the search areas are defined.

The second case at the figure 7 (B) shows a frame taken with the Hasselblad camera. The lower right corner has not been properly computed (it appears displaced upward the true position, B2) and high residuals are obtained (table 1). Some white lines (from the road in the lower part) appear very close the lower edge format throughout the edge (such as the white line at the right corner, B1). These lines have a strong influence in the regression fit line and it has been impossible to adjust automatically the correct position of the lower corners. Finally, the inner orientation of the frame was made manually and the residuals were lower than the pixel size ($42 \mu\text{m}$).

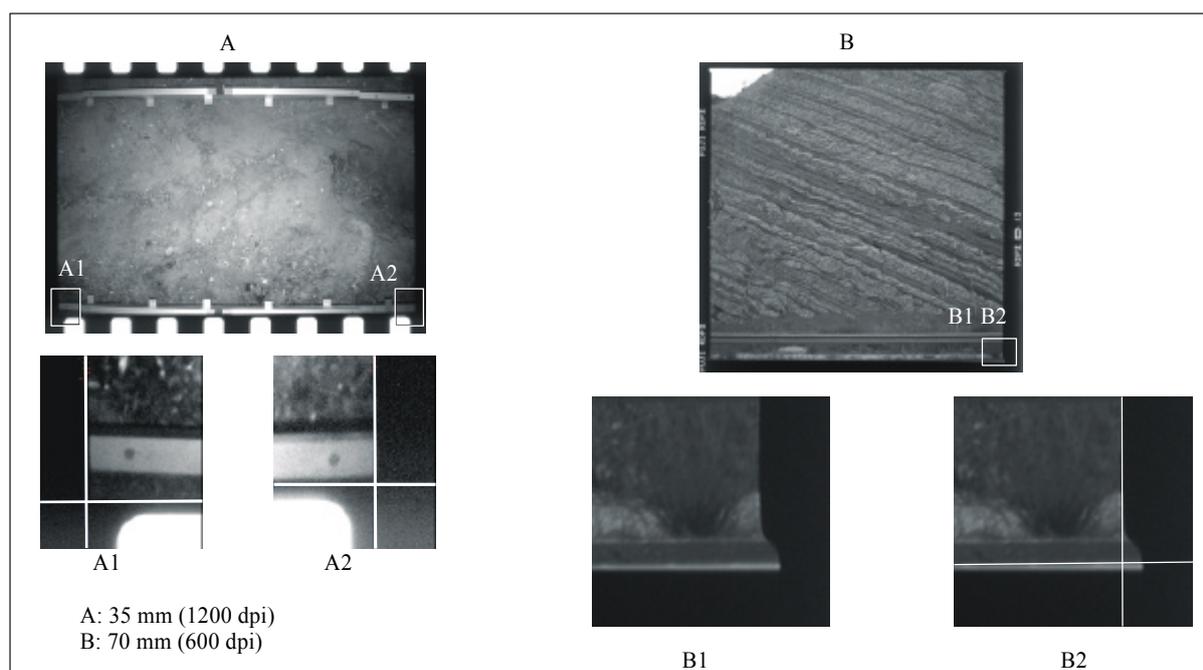


Figure 7. Weak conditions for application of the automatic inner orientation.

Example A: Successfully solved, but similar situations can cause problems.

Example B: Unsuccessfully solved, white lines of the limit of the road, just at the lower format edge (B1), displace the computed corner upward the true position (B2).

4 CONCLUSIONS

A program for automatic inner orientation of digitized images taken with non-metric cameras (35 and 70 mm) has been presented. This program, under IDL 5.0, detects the format edges and computes the regression fit lines that define the frame. Frame corners are computed from intersection of lines as well as the indicated principal point (intersection of diagonals). Routines for coordinate transformations (4 and 6 parameters, two-dimensional projective and bilinear) has

also been implemented, so a full inner orientation process is possible. Because an image file is saved with four marks in the computed corner positions, inner orientation with conventional digital plotters is allowed since these equipments need fiducial marks for the inner orientation.

Some cautions have to be taken in order to obtain appropriate photographs for inner orientation. Good and uniform illumination conditions are necessary since frame edges have to be clearly visible and contrasted enough. Also it is better to avoid some situations such as making pictures with large linear features very close and near parallel to the edges, otherwise the computation of regression lines can be more influenced by the linear features than by the edges.

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