

# PC-BASED INTEGRATED DIGITAL PUGGING AND MEASUREMENTS FOR BLOCK ADJUSTMENTS

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## PURPOSE:

Up to now, most of the research efforts in videogrammetry have been directed to digital plotting. Some experiments have also shown that videoplotters could be used with success to deal with aerotriangulation operations, the measurements being made on conventionally prepared aerial photographs.

But the new technology does also have the potential of replacing conventional pugging by digital pugging because it makes it possible to mark digitally the pixel or the portion of pixel chosen as pass point. This means that the physical materialization on the photographs is no longer necessary.

Pass points selection and marking are performed at the relative orientation step. As the relative orientation file can be saved and used to create the absolute orientation file, it also means that pass points have to be measured only once, from the pugging to the plotting operations. This results necessarily in an increase of geometrical stability, accuracy and efficiency.

**KEY WORDS:** Photogrammetry, Digital Systems, Aerotriangulation, Accuracy.

## 1. INTRODUCTION

The arrival on the market in 1990 of PC-based softcopy photogrammetric plotters has revolutionized the closed world of photogrammetry by opening this confined field of activities to a wide number of new users (land surveyors, public utilities, data conversion firms, resources management firms, architects, research & design, etc.). As a consequence of this democratization, some of the new users became interested by softcopy aerotriangulation, in order to become completely independent from conventional photogrammetric organizations.

The following year (Agnard and Gagnon, 1991), first successful attempts of aerotriangulation were performed, using the Laval University-Leica PC-based DVP with conventionally prepared aerial photographs.

Of course, photogrammetrists in general now share the same interest, as they become more and more aware that softcopy photogrammetry is the solution, if not of today for most of them, at least for tomorrow (Skalet, Lee and Ladner, 1992). In that paper, under the title: "FUTURE SOLUTION, Softcopy Aerotriangulation" we can read: "...traditional aerotriangulation uses of hardcopy image source makes the interface to a digital revision process cumbersome requiring the development of digital methods of control extension.", and farther: "Each pass point would be digitally located and measured at the same time."

In the conclusions of our paper of 1991, we had already mentioned that digital photogrammetry was particularly well adapted for a digital "pugging" or marking of pass points. Digital pugging means getting rid of mechanical devices for drilling of pass points, thus making the user fully independent from conventional procedures and/or organizations.

The results shown in this paper are the results of a research on this very sensitive problem of softcopy aerotriangulation, included in a doctorate thesis presented at the Tokyo University in May of this year (Agnard, 1992).

## 2. DIGITAL MARKING OF PASS POINTS

It is very easy, when the measuring marks (one on each image) are at the correct position of a prospective pass point, to store the exact position in pixel or fraction of pixel ( $\frac{1}{2}$  pixel in the case of the DVP Zoom function) of the one on the right image of the first model and to come back automatically with it at the exact same position on the same image, now on the left when measuring the second model.

Digital marking has several advantages. First, the choice of pass points is made at the very moment of the measurements for the filling of the relative orientation file, thus avoiding bad surprises when the pugging is made elsewhere by somebody else. Secondly, the quality of digital images being dependent on the contrast chosen when scanning, it

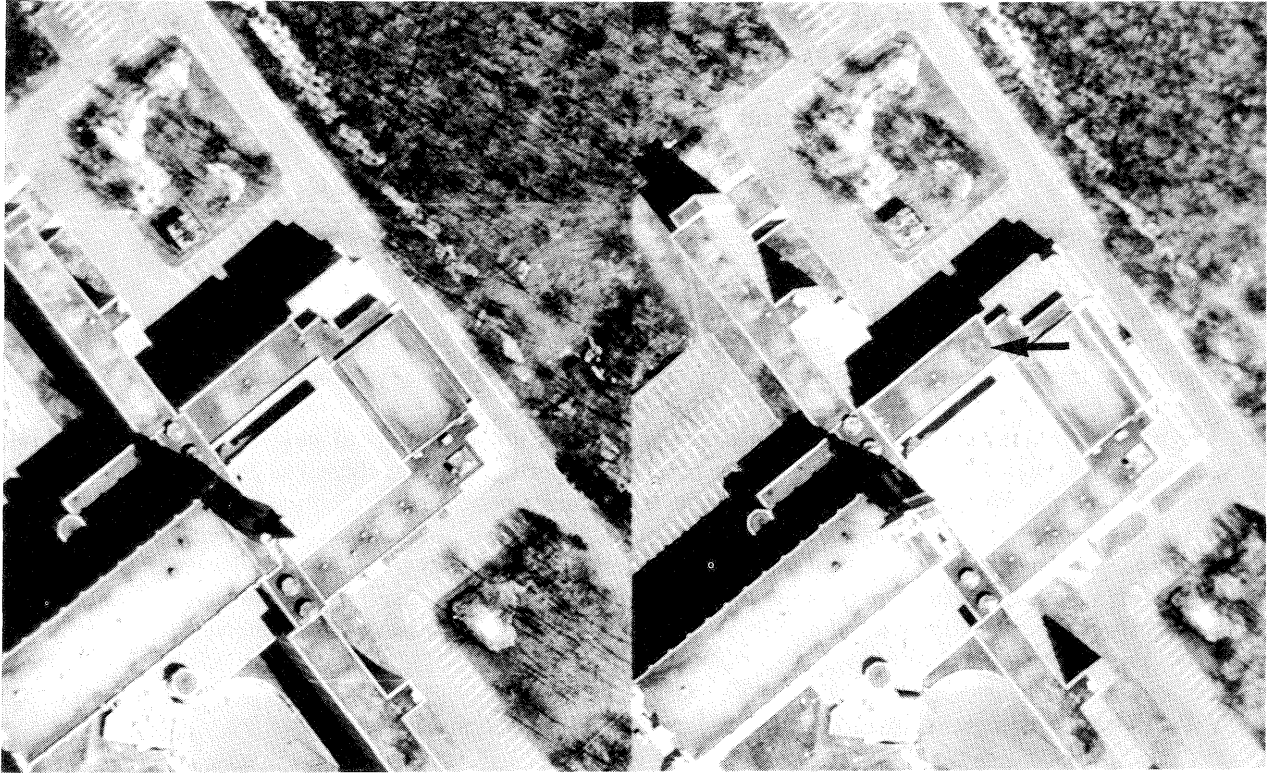


Figure 1 : Materialization of Digital Pass Point

is not always evident that this chosen contrast will allow to show, without any doubts, the mechanical pugs, specially if placed in white areas even though, on the original photograph, they are clearly seen. Finally, with the digital marking, the coordinates of the pass point are exactly the same on the common photo of two consecutive models, which is not the case when centering twice the floating mark into the same hole.

To be able to recognize the area of the chosen pass point, the program draws a colour circle around the pixel of which a quarter has been selected (Figure 1). These positions are stored in a file NAMEOFMODEL.PUG, and they generate colour circles as soon as a part of the image concerned is shown on the PC screen.

### 3. DIGITAL DOVE PRISMS

The digital image being stored under the form of a matrix, rotations of  $\pm 90^\circ$  for parts of the images is almost instantaneous. This characteristic gave us the idea to transpose into softcopy photogrammetry the mechanical Dove prisms (Figure 2) mounted on first-order plotters or on stereocomparators, very useful to get rid of any residual y-parallax.

These digital Dove prisms are installed inside of the Zoom function (Figure 3) of the DVP. The top view shows a part of the image being zoomed (2X inside of the first larger square). The central view shows the same part being rotated by  $-90^\circ$  inside of the smaller square and the bottom one being rotated by  $+90^\circ$  or by  $+180^\circ$  from the previous position.

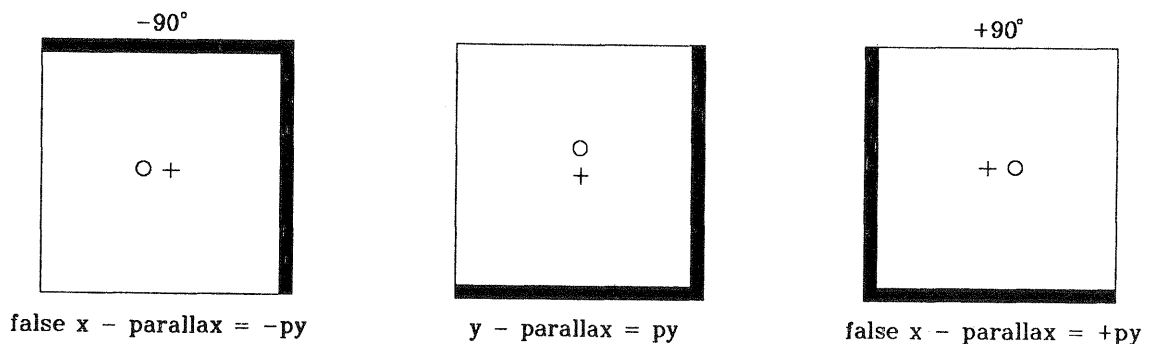


Figure 2 : The Principle of DOVE Prisms



Figure 3 : Digital DOVE Prisms

#### 4. SCANNER CALIBRATION

Scanner deformations that could have been neglected at a resolution of 300 DPI for plotting purposes, have to be considered at a resolution of 600 DPI, specially for aerotriangulation measurements.

Table 1 shows results of block adjustments with and without scanner corrections, the photographs being scanned at 600 DPI with the Sharp JX-600 scanner. Maximum deformations found after calibration of the scanner were  $\pm 20 \mu\text{m}$  in the x direction and  $\pm 40 \mu\text{m}$  in the y direction.

#### 5. RESULTS

A block of two strips, each having eight models, was chosen on a test site established by the Canadian National Research Council. This site is provided with hundreds of materialized points (178 for the block considered). Each point is made of a four-arm white cross, the center of which is a 30 by 30 centimetres square. The photographs are at a scale of 1/6 200. AT 600 DPI, the pixel has a size of  $42 \mu\text{m}$ . The DVP measuring, inside of the Zoom function, the half pixel, we were starting with models measured with a precision corresponding to

	Control Points		Check Points	
	X(m)	Y(m)	X(m)	Y(m)
Without Scanner Corrections	1.11	1.53	0.99	1.18
With Scanner Corrections	0.23	0.29	0.26	0.28

Table 1 : Results of Block Adjustments with and without Scanner Corrections

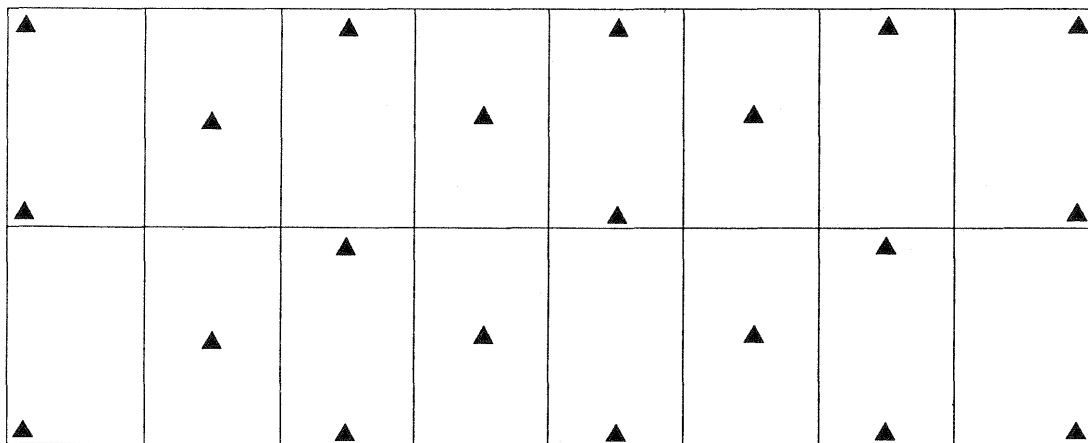


Figure 4 : Disposition of Control Points for the Second Pass

	n	X(cm)	Y(cm)	XY(cm)	Z(cm)
Control Points	5	10	12	16	17
Check Points	173	19	21	29	29

Table 2 : Residuals with 21 Control Points

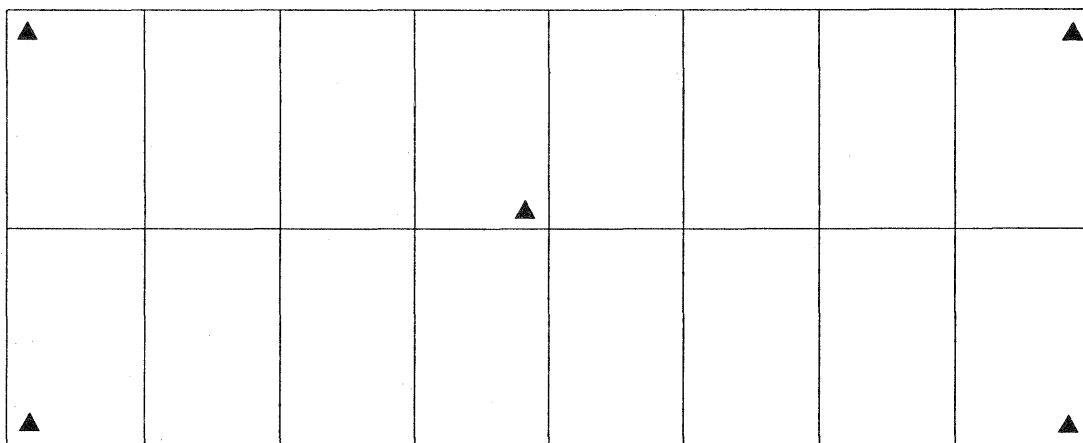


Figure 5 : Disposition of Control Points for the Third Pass

	n	X(cm)	Y(cm)	XY(cm)	Z(cm)
Control Points	21	08	12	15	14
Check Points	157	14	21	25	24

Table 3 : Residuals with 5 Control Points

13 centimetres on the ground along both X and Y axis. This gives 19 centimetres in planimetry and 22 centimetres in height measurements [13 cm : 90 mm (base) x 152 mm (focal length)].

The adjustment software used was the least-squares block adjustment of independent stereoscopic models SPACE-M written by J. A. R. Blais for the federal Department of Energy, Mines and Resources of Ottawa, Canada.

A first adjustment pass has been made with weight of 0.1 on the control points, when the pass points are at 1.0, to check the strength of the geometry of the block. For the 82 pass points, the results are respectively 10 centimetres in planimetry and 15 centimetres in altimetry, that is to say a quarter of pixel in planimetry and one third of a pixel in altimetry.

A second pass with 21 control points (Figure 4) weighted as recommended, which is three for planimetry and two for altimetry when the weights on pass points are 0.1 for both planimetry and altimetry, gives the results shown on Table 2.

A third pass with only five of them was made (Figure 5) and gave the results shown on Table 3.

If we consider that an aerial triangulation, for a governmental organism, is accepted or rejected, most of the time, only on the criterium of residuals on the control points (no check points are required), we can see that, these maximal residuals for 1/6 200 photo scale being 21 centimetres in planimetry and 16 centimetres in altimetry, we satisfied these requirements (being also just inside of the precision of the measuring device).

Another remarkable result, in using digital "pugging", is that not a single pass point had to be removed as it often happens during the conventional process of aerial triangulation. With the adjustment of the same block, measured with DVP and conventionally drilled photographs, 7 pass points had to be removed out of 107 measured which represents 6.5%.

## 6. CONCLUSIONS

The proof is now established that softcopy photogrammetry, even on PC platforms, can be successfully used, not only for digital mapping, but also for aerotriangulation purposes, and with many advantages.

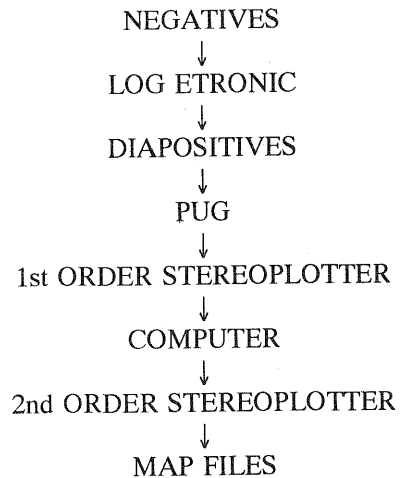
Among these advantages, let us mention:

- only one measuring operation is made for: pugging, relative orientation, triangulation measurements, and absolute orientation, saving time
- more geometrical strength for the block, increasing stability (none or less pass point rejection)
- no more dependance towards part of conventionnal photogrammetric procedures.

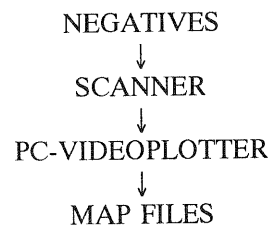
To achieve these results we must:

- use at least 600 DPI scanner resolution
- calibrate the scanner
- use digital Dove prisms.

Positive transparencies being no longer needed, as negatives can be scanned directly and reversed by the software of the scanner itself, the scanner taking the place of Log-Etronic-type printing device in photographic labs, the usual processing steps, involving the chain:



will be replaced by:



## 7. REFERENCES

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