

## ORTHOMAP: A SOFTCOPY SYSTEM FOR ORTHOIMAGES PRODUCTION AND MONOCOMPILATION

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### ABSTRACT:

The hardware and software architecture of the system is described. Tests on accuracy and productivity are presented

KEY WORDS: DTM, Orthophoto, Raster, Rectification, Image processing

### 1. INTRODUCTION

ORTHOMAP, a photogrammetric digital image-based mapping system, has been designed to fulfill two main needs:

- The production of ortho-rectified images using completely digital techniques.
- The performing of thematic cartography, maps updating and maps editing by means of a standard workstation, without need of a stereoplotter.

The operation of the System is totally software-driven using comprehensive menu commands; user's interaction with the system takes place with a standard keyboard and a mouse.

After a short software-hardware system architecture description, some tests executed in Galileo Siscam laboratories are presented, to describe the very fast and easy operative procedure to produce a digital hard-copy orthophoto; some results about accuracy and processing times are also presented.

### 2. HARDWARE ARCHITECTURE

Two main hardware architecture are available: a PC based system and a RISC workstation based system.

A typical PC based configuration (the same used by GALILEO SISCAM during the test) is the following:

-A Central Processing Unit consisting of a 80486 Personal Computer working with 32 bits and 33 Mhz with an integrated mathematic coprocessor

-4 Mbytes RAM

-A high resolution graphic board MATROX 1281 cv that provides a memory image of 1024x1280 pixels of 8 bits and a 24 bits look-up table to allow 256 colors from a palette of 16.7 millions.

-The hard disk with a sufficient capability (300 Mbytes) to store raster images, vector data, basic and application software.

-The peripheral devices to have a good user interface: 19" graphic color display, 2 buttons mouse and keyboard.

-One or more back-up devices (floppy disk, streaming tape, magneto-optical disk).

Is possible to use more or less powerful configurations changing the CPU (all the 80486 and 80386 machine can be configured), the total amount of RAM, the Hard Disk dimension to match individual production needs.

A typical RISC based configuration (the same used

by GALILEO SISCAM during the test) is the following:

-A Central Processing Unit consisting of a IBM RISC 6000 Mod 320 working with 32 bits and 20 Mhz with a computation powerful of 27 Mips and 9 Mflops.

-16 Mbytes RAM

-A high resolution graphic board that provides a memory image of 1024x1280 pixels of 8 bits and a 24 bits look-up table to allow 256 colors from a palette of 16.7 millions.

-The hard disk of 600 Mbytes

-The peripheral devices: 19" graphic color display, 3 buttons mouse and keyboard.

-The back-up devices (floppy disk, streaming tape)

The RISC version of Orthomap can run using also more powerful workstation.

The choice of GALILEO SISCAM to develop two different ORTHOMAP versions (PC and RISC version) is due to the will to offer the system at several prices and performance levels. Both the versions run on UNIX operative system, a standard in this kind of applications, the RISC version makes use of the X-Window-System graphic interface, all the software procedures all written in standard C-language; the design policy, dictating the use of absolutely standard components and modules throughout the whole System, ensures easy growth and updating of the System, as well as compatibility with other computers and peripherals, thus protecting customer's investments.

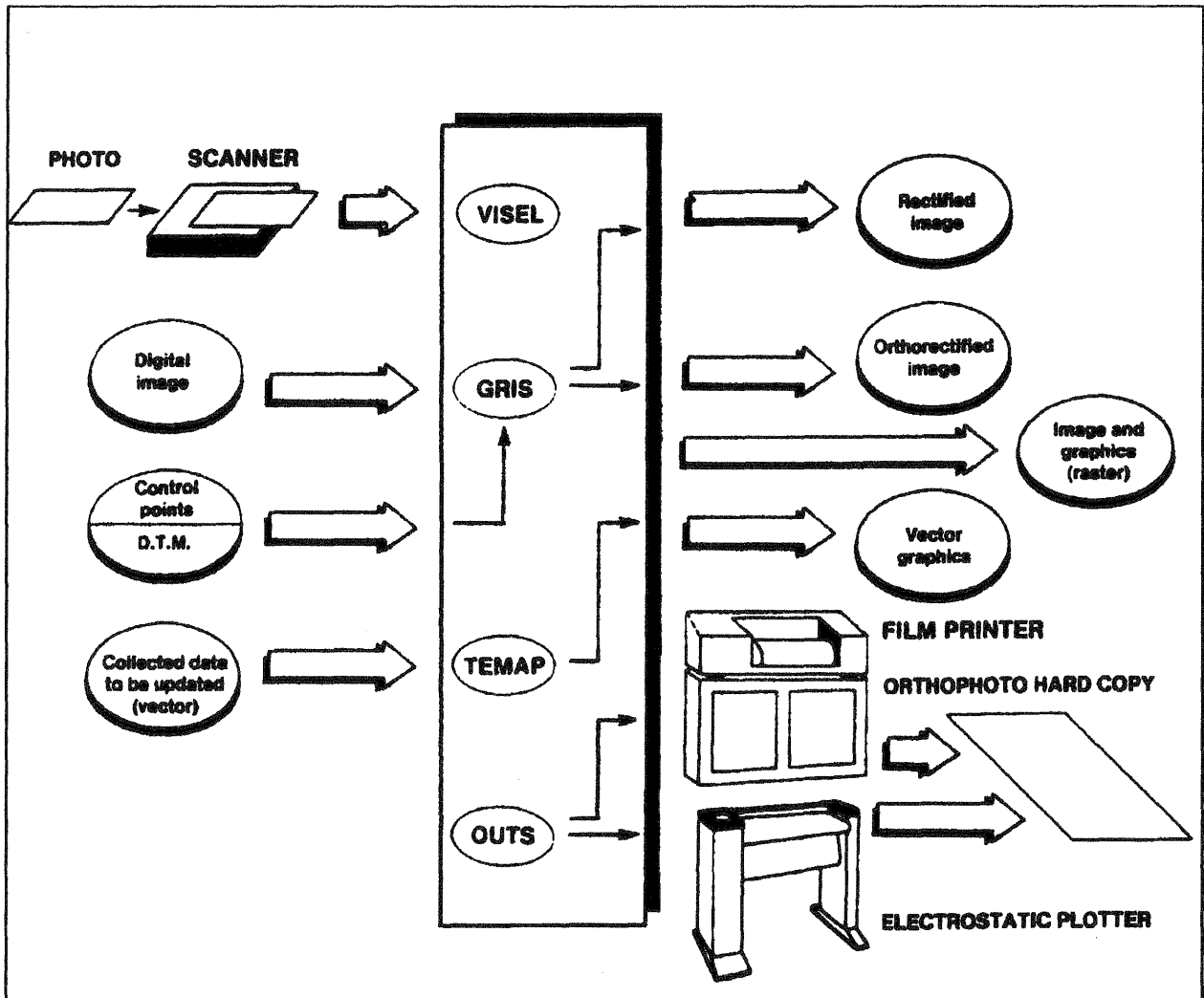


Figure 1 Orthomap system

### 3. SOFTWARE ARCHITECTURE

Orthomap software system is composed of four different subsystem, including four sets of functions respectively related to image acquisition and processing (VISEL), image rectification (GRIS), data collection (TEMAP), and image and vector output (OUTS). An UTILITY PACKAGE is also provided, including general purpose functions. A description of the above subsystems is given below (see figure 1).

#### 3.1 VISEL subsystem

Visel is the acquisition and processing subsystem, it is composed by 5 modules:

-Acquisition : to enter image files, vector data and DTM files into the system from the outside using floppy disc, magneto-optical disc, local area network. A package to digitize photo by a scanner is also available.

-Orientation : to perform four types of orientation (interior orientation, exterior orientation, parameter determination for projective transformation). The user can display the image at the magnification factor he wants and capture the fiducial marks and the control points and enter their coordinates before to perform one of the four orientations.

-Raster-Raster : this module allows the user to merge in a single raster image file, two different images, one representing a terrain portion and the other the corresponding map.

-Processing : this module provides three sets of functions to achieve the image quality standard required for orthophoto production: cutting of images along arbitrary poly-lines, interactive grey-level modification and histogram equalization, image filtering.

-Mosaicking : to generate an image from two or more adjacent or overlapping images.

### 3.2 GRIS subsystem

GRIS is the geometric correction subsystem to obtain rectified and ortho-rectified images starting from previously processed and oriented images with the VISEL subsystem modules. Four software modules are into GRIS subsystem:

-Photoplane : to perform the rectification of a digital image; just an image of which the projective transformation computation has been performed is required.

-Orthophoto : to perform the differential rectification of a digital image; an image of which the space-resection computation has been performed and the corresponding DTM are required.

-K angle correction : to perform the rotation of a geo-coded image to generate a North-referenced image.

-Merging : to merge two photoplane or orthophoto images.

### 3.3 TEMAP subsystem

TEMAP subsystem provides the integration between geo-coded digital raster images and corresponding vector graphics. The vector graphics can come from external vector files (several format conversions are provided) or generated by TEMAP itself. TEMAP provides over 200 compiling and graphic editing function.

### 3.4 OUTS subsystem

OUTS is the image output subsystem, the user can interactively generate an image file ready to be printed with a raster plotter or a quality film printer. Several selections can be made : image area to be plotted, plotting scale, grey level palette, vector graphic plotting, type of plotter, parameters. All the symbols and texts necessary to have a hard-copy orthophoto can also be generated using a friendly graphic interface.

## 4. SOME OPERATIVE TESTS WITH COMMERCIAL INSTRUMENTS : DISSERTATIONS UPON ACCURACY AND PROCESSING TIMES

Let's see now a test, executed in the GALILEO SISCAM laboratories, suitable to compare some measurements carried out either with an analytical stereoplotter (DIGICART 40) or with ORTHOMAP system.

### 4.1 Materials and instruments used during the test

1) Two stereopairs, coming from an aerial shot executed with a WILD RC 10 camera having a focal length of 153.26 mm. and a mean relative fly altitude of 5000 meters (so that the photo mean scale is 1:32600).

2) A 8165 points DTM, distributed along a regular grid on the plate. The terrain zone covered by that DTM is approximately a rectangle with 7000 meters by 6000 meters edges; so the surface measures 46 squared kilometers. The mean distance between one DTM point and its neighbors is about 80 meters and their mean difference in altitude is 13 meters, a perspective view of the DTM is shown in figure 2.

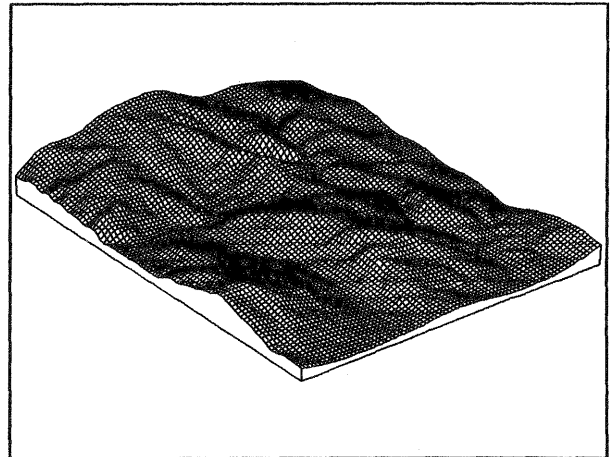


Figure 2 DTM perspective view

3) The ORTHOMAP system described above using either the PC version or the RISC version.

4) A digital orthophoto at 1:10000, scale obtained with ORTHOMAP using the data described at point 1 and 2.

5) The high performance analytical stereoplotter DIGICART 40 (manufactured by GALILEO SISCAM), to obtain the "real" measures to be compared with the measures coming from ORTHOMAP.

#### DIGICART 40 TECHNICAL SPECIFICATIONS

Measure systems resolution	: .001 mm.
Optical system magnification	: 8x
Observed field diameter	: 33 mm.
Output pupil extraction	: 4 mm.

6) The high precision flat bed plotter TG 200, manufactured by GALILEO SISCAM, provided with a collimation microscope and used like a digitizer to take the measurements on the orthophoto.

#### TG 200 TECHNICAL SPECIFICATIONS

Accuracy	: 0.05 mm.
Repeatability	: 0.03 mm.
Resolution	: 0.025 mm.

7) A low cost flat scanner XEROX 7650 to digitize the photos.

#### XEROX 7650 TECHNICAL SPECIFICATION

Resolution	: 400 d.p.i.
Format	: A3
Grey levels	: 256

8) A low cost Thermal Plotter OCE GRAPHICS Mod. 9845 to plot the orthophoto produced by ORTHOMAP

OCE' GRAPHICS 9845 TECHNICAL  
SPECIFICATIONS

Resolution : 406 d.p.i.  
Format : A0  
Accuracy : 0.1 % (Max error along the X axis)

4.2 Test description

A) As first step of the test, the set up of the stereoscopic model has been carried out using the DIGICART 40. Eight points have been used to perform the relative orientation obtaining residuals lower then 3 microns and 5 points to perform the absolute orientation with residuals lower then 0.9 meters; the details about the orientations are described in table 1 (A, B).

RELATIVE ORIENTATION  
RESIDUALS IN MICRONS

1)	-2
2)	3
3)	-1
4)	1
5)	-2
6)	1
7)	-2
8)	2

TABLE 1 A

ABSOLUTE ORIENTATION  
RESIDUALS IN METERS

	X	Y	Z
1)	-0.55	-0.23	-0.58
2)	0.38	-0.11	-0.17
3)	0.08	-0.25	0.60
4)	0.90	-0.33	0.45
5)	-0.81	0.92	-0.30

TABLE 1 B

B)As second step, the three terrain coordinates (X,Y,Z) of 30 points, omogeneously distributed on the stereoscopic model, have been measured and recorded using the DIGICART 40 and the orientation parameters. Figure 3 and Table 2 show the details about the coordinates and the distribution of the 30 points on the model.

X	Y	Z
33204.16	82702.40	265.86
35412.64	83198.72	254.70
36344.48	83091.52	170.42
33218.40	81815.68	278.79
34569.92	81954.88	321.05
36138.56	82064.96	274.09
36768.64	81745.92	208.41
33764.16	80855.04	242.31
34820.48	81418.24	312.88
36458.88	81488.64	256.97
34371.68	79945.60	142.21
34736.16	79947.52	103.75
35660.16	80429.44	136.62
36735.52	80384.96	114.57
35519.52	81182.72	334.87
34491.84	82693.12	216.39
33694.24	79750.08	137.24
34145.44	79297.60	148.30
36519.48	78901.32	299.01
35664.48	79871.68	154.49
36706.56	79628.80	164.66
37048.64	79290.56	176.27
34094.24	78778.88	202.81
34303.36	78715.52	177.51
35004.64	78887.68	228.24
36044.64	78523.52	346.80
35888.80	79404.48	224.46
35462.88	82308.48	227.10
35422.08	82508.18	200.12
35162.88	79651.77	166.13

TABLE 2 ( ground coordinates from stereoplotter)

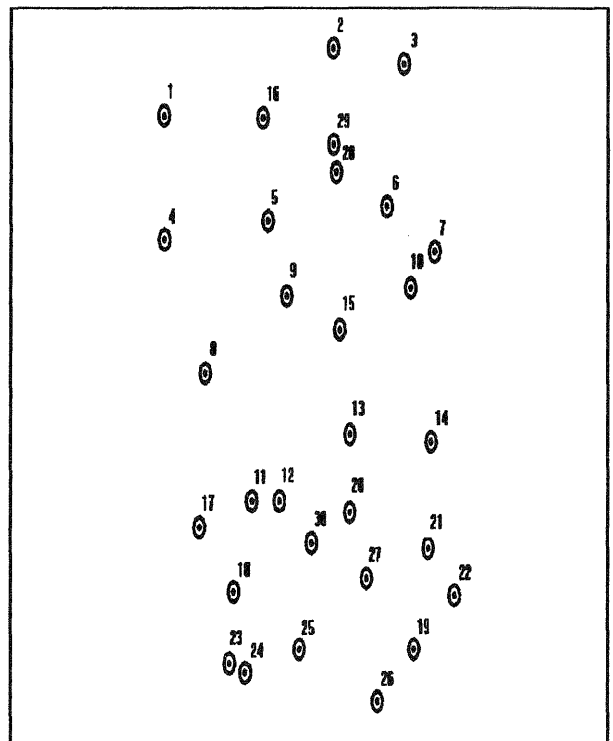


Figure 3 Points distribution on the stereomodel

C)As third step of the test, a digital orthophoto has been produced using ORTHOMAP. The complete operative procedure, consisting in 6 different run, will be described below, also the processing times will be given step by step specifying for the PC and RISC machine when they are different.

1)SCANNING. The scanning has been done using software procedures that allows, with a friendly graphic interface, to select the following features:

a)OUTPUT FILE FORMAT: the TIFF format has been selected because of its large spreading in this kind of applications.

b)RESOLUTION:a scan resolution of 400 d.p.i has been selected, this corresponds to have a pixel every 80 microns; so, because of the scale of the photo (1:32600), each pixel depicts, in first approximation, a squared zone having an edge 2.5 meters long.

c)GREY LEVELS: 256 grey levels have been selected, this is the maximum value available for the scanner we used. Because ORTHOMAP manages up to 64 grey levels, a compression has been performed using stretching algorithms.

d)CROPPING: this step allows to define a rectangular or squared block area within the entire scanner format.

The entire scanning operation described above, has been done in 8 minutes, the product of this step is a file 14.3 Mbytes large.

2)IMAGE PROCESSING. Using a specific software package of VISEL, an interactive processing of the transfer function of the 'Look Up Table' has been carried out. This step, completed in 7 minutes, allowed to obtain a beautiful image and to make the control point capture easier.

3)ORIENTATION. In this processing step, using an interactive software procedure of VISEL, the parameters of the interior and exterior orientation are computed. The operative procedure is the following:

- Fiducial marks capture with mouse.
- Interior orientation computation.
- Control points capture using mouse and some specific software functions (pan, zoom, blow-up).
- Control points terrain coordinates input by keyboard.
- Exterior orientation (Space Resection) computation with residuals and parameters printing.
- Exterior orientation acceptance or terrain and image coordinates correction using editing function.

At the end of this step, the residuals shown in table 3 has been achieved; the time spent by the operator to finish the orientation procedure was 25 minutes.

SPACE-RESECTION  
RESIDUALS IN METERS

	X	Y	Z
1)	-1.12	-0.85	0.37
2)	-0.15	-0.74	0.88
3)	-0.91	1.24	1.03
4)	2.03	-1.88	-1.55
5)	0.15	2.23	-0.73

TABLE 3

4)TIN GENERATION. Starting from the DTM points described above, this procedure generates a corresponding Triangular Irregular Network file, which represents an approximation of the terrain shape. The purpose of the TIN file is to provide, by triangles interpolation, the elevation of every pixel of the rectified image. The time spent for this step was 241 seconds with the PC based machine, and 86 seconds with the RISC based machine.

5)DIFFERENTIAL RECTIFICATION. Using the specific software module of GRIS subsystem, the triangle file generated in the previous section, the orientation parameters and the image file, a digital orthophoto has been generated in 31 minutes with a PC based system and in 13 minutes with a RISC based system. These times are exclusively machine times, because the rectification procedure is a batch (not interactive) procedure. The module performs a pixel by pixel geometric correction of the image, the result is a geo-coded, metric image. To avoid aliasing problems due to uninterpolated image resampling, a bi-linear resampling has been performed too.

6) PLOTTING. The orthophoto plotting at 1:10000 scale has been carried out using the OUTS subsystem and the thermal plotter OCE' GRAPHICS Mod 9845. The procedure has been executed in two subsequent steps: first of all the bit-map file has been generated, subsequently this file has been plotted. To generate the bit-map from the digital orthophoto, after the 'scale' and the 'zone of interest' selection, an advanced dithering technique is used which optimizes the performance of each brand of plotter: the grey level of a pixel is obtained using 16 plotter dots (a matrix of 4x4 dots called "pattern") each of them can be black or white; because of very small dots, they create the illusion of multiple grey shades depending on the number and arrangement of black and white dots into the pattern. Using this technique is possible to display 31 grey levels with a "real resolution" of 100 dpi. Finally the bit-map has been sent to the plotter to be printed; the time spent for these operations is 14 minutes with the PC based

machine and 6 minutes with the RISC based machine.

At the end of the plotting procedure, a digital image orthophoto and a digital orthophoto on paper have been produced.

D) As fourth step, the three ground coordinates (X,Y,Z) of the same 30 points described in figure 3 have been measured on the digital orthophoto image using specific software function of the TEMAP subsystem. The coordinates obtained from TEMAP, shown in table 4, are expressed in the terrain coordinate system, so that they are directly comparable with the coordinates, shown in table 2, obtained from the Digicart 40 without other computations. The differences between the two measurements in the X ,Y and Z axis are shown in table 5, while figure 4 shows the planimetric (X and Y) displacements as regards the position of the points within the photogrammetric model. The RMS along the X,Y and Z axes are respectively 1.90, 1.97 and 1.56 meters.

X	Y	Z
33201.52	82702.56	264.12
35412.07	83199.18	257.15
36342.00	83091.50	172.14
33217.90	81818.65	275.99
34570.45	81956.75	322.12
36135.13	82064.29	274.55
36766.44	81746.96	208.99
33763.24	80852.82	245.02
34822.89	81419.74	312.22
36458.02	81486.33	256.12
34371.87	79946.74	143.86
34735.08	79948.60	103.22
35657.06	80428.20	136.54
36736.63	80385.98	115.77
35518.57	81183.99	333.43
34493.37	82689.80	217.23
33691.95	79751.08	137.54
34145.73	79298.53	148.35
36517.95	78903.96	297.63
35661.36	79873.89	153.02
36707.98	79630.80	164.88
37049.68	79293.81	176.27
34090.66	78782.59	203.08
34301.96	78718.27	178.34
35005.30	78890.17	228.81
36042.42	78527.01	348.80
35888.24	79403.99	225.03
35464.99	82308.92	230.14
35425.22	82510.12	197.23
35162.11	79651.77	169.12

TABLE 4 (ground coordinates from TEMAP)

X	Y	Z
-2.64	0.16	-1.74
-0.57	0.46	2.45
-2.48	-0.02	1.72
-0.50	2.97	-2.80
0.53	1.87	1.07
-3.43	-0.67	0.46
-2.20	1.04	0.58
-0.92	-2.22	2.71
2.41	1.50	-0.66
-0.86	-2.31	-0.85
0.19	1.14	1.65
-1.08	1.08	-0.53
-3.10	-1.24	-0.08
1.11	1.02	1.20
-0.95	1.27	-1.44
1.53	-3.32	0.84
-2.29	1.00	0.30
0.29	0.93	0.05
-1.53	2.64	-1.38
-3.12	2.21	-1.47
1.42	2.00	0.22
1.04	3.25	0.00
-3.58	3.71	0.27
-1.40	2.75	0.83
0.66	2.49	0.57
-2.22	3.49	2.00
-0.56	-0.49	0.57
2.11	0.44	3.04
3.14	1.94	-2.89
-0.77	0.00	2.99

TABLE 5 (differences between DIGICART 40 and TEMAP coordinates)

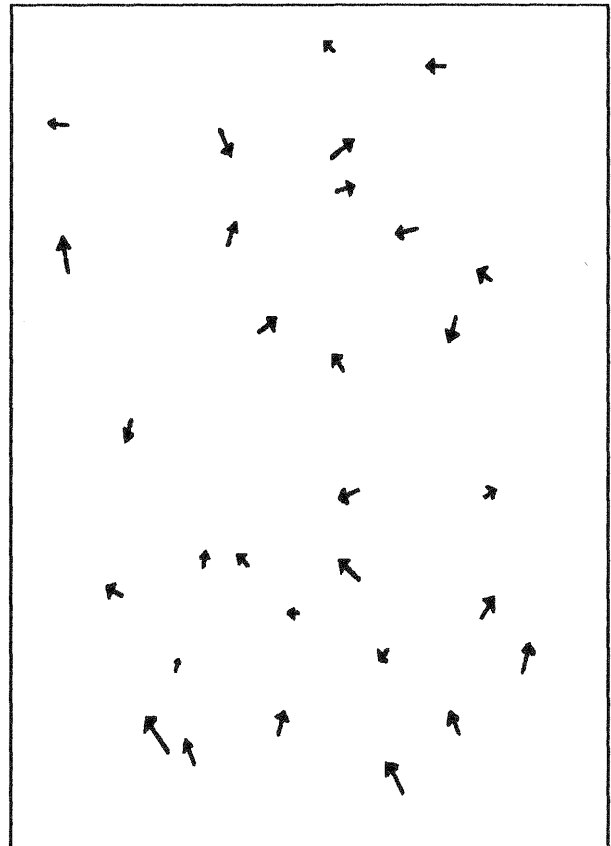


Figure 4 Digicart-Temap displacements magnification factor : 50

E) As fifth step, the measurements of X and Y, on the plotted orthophoto has been carried out using the TG 200 plotter, with a collimation microscope mounted on the pen holder, as a digitizer. The results of the measurements are shown in table 6, they are expressed in the PLOTTER reference system, so to compare these measurements with the ones shown in table 2, is necessary to compute a coordinate transformation using a least-squares adjustment. Supposing that between the plotter coordinates shown in table 6 and terrain coordinates shown in table 2 there is a relationship such that:

$$X = A + Bx + Cy$$

$$Y = D + Ex + Fy$$

where (X,Y) are the ground coordinates and (x,y) are the plotter coordinates of the same point, and applying the least-squares adjustment using the 30 test's points, the residuals shown in table 7 has been carried out. The RMS along the X and Y axes are respectively 2.77 and 2.86 meters.

X	Y
180.20	344.95
400.12	385.38
492.95	371.63
184.99	256.15
319.85	264.95
476.66	269.93
541.20	235.55
243.42	157.47
347.25	210.16
511.47	210.51
307.45	63.82
344.55	63.21
435.24	107.43
543.06	98.59
418.10	183.68
309.06	338.63
240.65	46.78
287.94	-0.04
526.66	-48.77
437.46	51.32
543.15	23.26
578.62	-11.95
284.12	-52.06
305.32	-58.39
375.06	-44.33
480.87	-84.75
462.04	3.93
408.48	296.98
403.75	316.71
388.60	31.74

TABLE 6 (X Y plotter coordinates)

X	Y
1.94	-3.28
-3.96	4.66
4.84	-0.42
2.07	-3.77
1.79	-4.04
0.63	-3.70
-1.55	-3.51
1.17	0.21
-0.75	-3.24
-4.55	0.97
4.18	2.94
-2.07	-3.23
-1.74	1.81
-1.12	4.55
-0.09	-0.96
3.52	1.39
1.13	3.35
-2.65	1.04
2.95	0.84
1.78	4.35
-2.22	1.69
-1.38	2.04
4.17	3.99
3.75	-4.19
2.29	0.75
-0.29	0.40
-1.68	1.68
-3.71	-4.70
-4.67	-0.51
-3.78	-1.11

TABLE 7 (DIGICART - PLOTTER residuals)

## 5. CONCLUSIONS

The analysis of tables 5 and figure 4 show that the differences between the measurements computed with the stereoplotter and the measurements computed with TEMAP, are less than the pixel dimension (about 2.5 meters); considering also the amount of residuals obtained during the model orientation (see table 1) the result is very good. Table 7 shows a decrease of accuracy during the plotting operation due to the kind of plotter and to the kind of medium. More accurated plotting can be done using more expensive instruments like laser-technology film printer and shape-retaining support. The table 8 shows the results about the time spent step by step during the orthophoto generation, these times are just indicative, in fact they depend on the scanning resolution, the DTM dimension and the plotting resolution.

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