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Presented Paper

Elena BAJ

Full assistant at the Chair of Topography, Politecnico of Milano
Assistant professor, Institute of Geodesy, Topography and Photogrammetry, University of Pisa, Italy

Title

Remarks about the monocular and stereoscopic observation of white strips on a zebra crossing.

Abstract

Observing white strip images on a zebra crossing with both monocular and stereoscopic method, it seems that their width is different, and precisely their width looks larger with stereoscopic observation than it looks with the monocular one. In order to establish if it is only a sensorial appearance we have tried to measure the width of the strips, always on the same photogram, with monocular as well as stereoscopic observation: the result was that the width obtained by stereoscopic observation is some micron larger. The measures have been performed with a Stereocomparator OMI-TA3/P, available at the Institute of Topography (Politecnico di Milano), which allows to get plate coordinates both with monocular and stereoscopic observation.

Text

Most of the instruments used in photogrammetry are based on binocular observation of stereoscopic photograms, but there are also other instruments, as the monocomparators, based on monocular observation.

The process of vision is much complicated and it is still being studied; in order to deepen it, the so-called evoked potential method is also used; this method consists in registering,by electrodes fixed on the skin of the head with a tape, the potentials which are evoked from the eye perceptions. These potentials are very weak, of about 5 microvolts or less, so it is very difficult to register them. However, it is known that the brain fuses the images of the same object received from the two eyes as it fuses the colours (anaglyphic method).

In the same way the brain fuses two completely different images which it receives from the two eyes; actually if you look f.i.

the tangent of the angle θ formed by the straight line and the X axis.
Analogously it is made for the other terns of points thus obtaining, given n straight lines, $n \times 3$ values of m, and thence of θ.

Among all the calculated values of θ, the max and min values are individuated and in this interval 10 values of θ are considered, differing in the constant increase.

Here is now the iteration: for each value of θ, the most probable position for each straight line based on the least squares principle is determined, that is the value for which the sum of the square residuals of the points collimated as regards the straight line is minimum.
A $\sum_{1}^{3} {}_i\, v_i^2$ is in fact calculated and memorized, and the elements are also kept defining the position of the straight line.
Analogously it is made for all the straight lines and at last if n are the straight lines $\sum_{1}^{n} {}_k \sum_{1}^{3} {}_i\, v_{ik}^2$ is calculated and memorized.
All these calculations are repeated for the 10 considered values of θ, still taking into account the above sum.
The chosen value of θ still based on the least squares criterion, is that corresponding to the double sum minimum value; for such a value the program has already calculated the optimum straight line position. The width between the white strips as the interval between the straight lines themselves and thence the mean and the m.s.e. may be obtained.

In order to simplify and improve calculations at each iteration the axes X and Y are rotated so as the considered direction be parallel to the axis X (Fig.1). Coordinates of collimated points are of course changed and for each value of θ considered, it will result for every considered tern

$$X' = Y \text{ sen } |\theta| + X \cos |\theta| \qquad Y' = Y \cos |\theta| - X \text{ sen } |\theta| \qquad \text{if } \theta \text{ is positive}$$

$$X' = -Y \text{ sen} |\theta| + X \cos |\theta| \qquad Y' = Y \cos |\theta| + X \text{ sen} |\theta| \qquad \text{if } \theta \text{ is negative}$$

When the coordinates are changed, the residuals v_i become Δy and therefore to obtain the condition $\sum_{1}^{3} {}_i\, v_i^2 = \min$, the straight lines must be moved parallelly with axis X.

Results

In the different rows of Table 1 are reported:

1) - the number of the zebra crossing taken into consideration;
2) - the number of the examined strips in the zebra crossing;
3) - the width of the white (and black) strip obtained with the stereoscopic observation;
4) - the width of the white (and black) strip obtained with the monocular observation;
5) - the difference between the width obtained with the stereoscopic observation and the monocular one;
6) 7) 8) - the m.s.e. respectively of the values in rows 3, 4, 5;

at the same time with one eye a cage and with the other eye a lion, of proper dimension , you'll see the lion in the cage.

It would be interesting to investigate if this fusing has some effect also on the measurements and if the monocular and the stereoscopic observations give the same results. In fact that is the aim of this study.

Subject of the experiments and methodology

As subject of study were taken the white strip images on a zebra crossing which are very common in urban aerial photograms and easily distinguishable.

Among the photograms which were at our disposal, we have chosen a photogram taken in Milan at a height of 1200 m; the photogram scale is 1: 8 000. It includes the images of about fifty zebra crossings.The stereoscopic observation needed of course the preceding and the successive photogram.

We have investigated whether the two different methods give the same value for the width of white strip images measured on the same photogram. The measures have been performed with an accuracy of about ± 2 μm, with a Stereocomparator OMI-TA3/P.

In order to obtain the width of each white strip image, the 4 coins delimiting it were firstly collimated; this method was however soon abandoned owing to its insufficiently accurated results. It must be noticed however how often the area surrounding the coin is quite badly defined.

Therefore it was thought it suitable to deduce the strip image width as the interval between the limiting straight lines: assumed such lines as parallel, theoretically the coordinates of 2 points of a straight line delimiting a strip and the coordinates of only 1 point for all the other straight lines are sufficient.

Aiming at gathering plentiful and thence more reliable results, 3 points were collimated for each separating line: 1 on the centre, 2 at the extremities of the strip, recording the coordinates.

A program was then studied for the computer to obtain for each zebra crossing, the width of each strip, which approaches 100μm.

In the repeated measurements however differencies nearing 6μm were obtained in the values of the width calculated for the same strip. On the other hand, taking into account the mean of the widths obtained, such differencies did not exceed 2μm. It was then deemed it useful to derive for each zebra crossing a mean more reliable than the single value, on which comparisons were made.

Measurements were carried out as above said by two different observing methods, namely:

a) - monocular viewing
b) - stereoscopic binocular viewing.

The program for the computer is iterative: given the coordinates of three points 1, 2, 3 of the separating line, the directions of the straight lines $y = mx + b$ defined by the couples of points 1-2 , 1-3 , 2-3 are calculated. In total 3 directions for the tern of points belonging to the first separating line; m is

TABLE 1

1	2		3	4	5	6	7	8	9	10	11	12
zebra crossing	number of strips	strips	strip width stereo vision μm	strip width monocular vision μm	Δl 3 – 4 4 – 3 μm	σ stereo vision μm	σ mono vision μm	σ Δl μm	image sharpness	X mm.	Y mm.	GDR
1	15	white	114	100	+ 14	1,12	1,30	1,72	×	87	97	$- 48^g$
		black	28	42	– 14							
2	3	w	111	101	+ 10	2,60	1,78	3,15	× × ×	89	100	$- 49^g$
		b	30	40	– 10							
3	13	w	111	102	+ 9	1,63	1,22	2,1	× × ×	77	87	$- 46^g$
		b	34	44	– 10							
4	14	w	102	93	+ 9	1,21	1,39	1,8	×	76	85	$+ 42^g$
		b	40	49	– 9							
5	9	w	113	106	+ 7	1,45	1,45	2,7	× × ×	73	75	$- 45^g$
		b	32	39	– 7							
6	9	w	105	97	+ 8	1,31	1,71	2,1	× ×	95	65	$+ 44^g$
		b	38	46	– 8							
7	6	w	95	90	+ 5	4,75	1,25	2,1	× × ×	93	- 59	$+ 89^g$
		b	47	50	– 3							
8	8	w	105	101	+ 4	1,55	1,51	2,2	× × ×	95	- 53	$- 45^g$
		b	36	40	– 4							

1	2		3	4	5	6	7	8	9	10	11	12
9	5	w	111	104	+ 7	1,86	1,51	2,4	×	90	- 49	- 45^{g}
		b	31	39	- 8							
10	10	w	108	103	+ 5	1,58	1,60	2,2	×	69	- 48	- 45^{g}
		b	34	39	- 5							
11	4	w	114	105	+ 9	1,07	2,11	2,4	× ×	54	- 67	- 46^{g}
		b	28	40	- 12							
11 bis	3	w	97	88	+ 9	2,12	2,07	2,9	× ×	54	- 67	- 46^{g}
		b	30	39	- 9							
12	16	w	104	98	+ 6	1,20	1,28	1,7	× × ×	56	- 60	+ 89^{g}
		b	39	45	- 6							
13	13	w	101	96	+ 5	1,44	1,66	2,2	× × ×	53	- 53	+ 43^{g}
		b	42	47	- 5							
14	13	w	107	103	+ 4	1,27	1,54	2,0	× × ×	40	- 53	- 44^{g}
		b	36	39	- 3							
15	11	w	99	99	0	1,39	1,17	1,8	×	38	- 60	- 89^{g}
		b	44	44	0							
16	5	w	97	91	+ 6	2,09	1,90	2,8	× ×	41	- 67	+ 43^{g}
		b	46	49	- 3							
17	10	w	104	101	+ 3	1,23	1,09	1,6	× ×	73	- 87	+ 44^{g}
		b	40	43	- 3							

1	2		3	4	5	6	7	8	9	10	11	12
19	11	w	102	99	+ 3	1,18	1,18	1,7	× × ×	110	- 20	- 39^{g}
		b	39	43	- 4							
20	5	w	99	96	+ 3	1,72	2,06	2,7	× × ×	110	2	+ 41^{g}
		b	45	49	- 4							
21	6	w	103	100	+ 3	1,51	1,77	2,3	× × ×	112	2	- 89^{g}
		b	39	42	- 3							
22	8	w	92	87	+ 5	1,45	1,24	1,9	× ×	109	8	+ 89^{g}
		b	49	56	- 7							
23	6	w	88	82	+ 6	1,10	1,60	1,9	×	109	11	+ 89^{g}
		b	52	58	- 6							
24	8	w	110	103	+ 7	1,45	2,09	2,5	×	103	104	- 44^{g}
		b	32	38	- 6							
25	10	w	99	102	- 3	1,23	1,20	1,7	× ×	105	103	+ 42^{g}
		b	42	38	+ 4							
26	8	w	101	100	+ 1	1,39	1,50	2,0	× ×	81	76	+ 44^{g}
		b	43	42	+ 1							
27	13	w	107	96	+11	1,70	1,39	2,2	× × ×	20	60	- 45^{g}
		b	36	47	-11							
28	13	w	109	98	+11	1,30	1,36	1,9	× ×	18	58	- 45^{g}
		b	33	45	-12							

1	2		3	4	5	6	7	8	9	10	11	12
29	9	w b	97 45	91 52	+ 6 – 7	1,45	1,36	2,0	× ×	20	– 55	$+ 43^{g}$
31	13	w b	106 36	101 42	+ 5 – 6	1,68	1,46	2,2	×	14	– 30	$- 57^{g}$
32	7	w b	96 44	91 47	+ 5 – 3	2,15	1,88	2,9	×	15	– 34	$+ 51^{g}$
33	8	w b	100 41	99 41	+ 1 0	1,79	2,13	2,8	× × ×	15	– 37	$- 59^{g}$
34	7	w b	107 38	101 43	+ 6 – 5	1,65	1,91	2,5	× × ×	31	– 17	$- 46^{g}$
36	4	w b	95 45	92 50	+ 3 – 5	1,51	1,16	1,9	× ×	31	19	$+ 42^{g}$
37	7	w b	95 45	97 43	– 2 + 2	2,55	2,11	3,3	× ×	38	17	$+ 42^{g}$
38	8	w b	104 42	96 47	+ 8 – 5	1,48	1,45	2,07	× ×	– 6	– 1	$- 58^{g}$
39	9	w b	105 48	94 49	+11 – 9	1,71	1,50	2,3	×	– 4	– 5	$- 58^{g}$
40	13	w b	107 36	100 43	+ 7 – 7	2,11	2,27	3,1	×	3	– 43	$- 46^{g}$

1	2		3	4	5	6	7	8	9	10	11	12
41	6	w	98	102	– 4	2,44	2,31	3,4	× ×	65	– 46	-46^{g}
		b	41	39	+ 2							
42	7	w	97	95	+ 2	1,56	2,19	2,7	×	3	– 45	$+43^{g}$
		b	45	47	– 2							
43	7	w	92	88	+ 4	1,51	1,43	2,1	×	– 19	100	$+22^{g}$
		b	46	52	– 6							
44	11	w	95	93	+ 2	1,09	1,64	2,0	× × ×	– 43	88	-67^{g}
		b	48	49	– 1							
45	6	w	102	99	+ 3	1,85	1,87	2,6	× × ×	– 44	91	-66^{g}
		b	41	43	– 2							
46	16	w	103	102	+ 1	1,28	1,55	2,0	× ×	– 43	60	-56^{g}
		b	40	41	– 1							
47	10	w	98	96	+ 2	1,98	2,07	2,9	× × ×	– 77	60	-34^{g}
		b	45	46	– 1							
48	7	w	102	97	+ 5	2,29	2,39	3,3	× ×	– 87	– 77	$+88^{g}$
		b	38	45	– 7							
49	9	w	93	87	+ 6	1,48	0,99	1,8	× ×	– 83	– 77	-2^{g}
		b	51	58	– 7							
50	13	w	105	105	0	1,23	0,77	1,4	× × ×	– 54	–101	$+46^{g}$
		b	38	39	– 1							

1	2		3	4	5	6	7	8	9	10	11	12
51	8	w	129	108	+ 11	1,82	1,53	2,4	× × ×	− 52	− 101	− 47^g
		b	33	38	− 5							
52	7	w	107	103	+ 4	1,66	1,17	2,0	× × ×	− 52	− 99	+ 43^g
		b	38	42	− 4							
53	8	w	112	110	+ 2	1,26	1,40	1,9	× × ×	− 54	− 98	− 48^g
		b	31	34	− 3							

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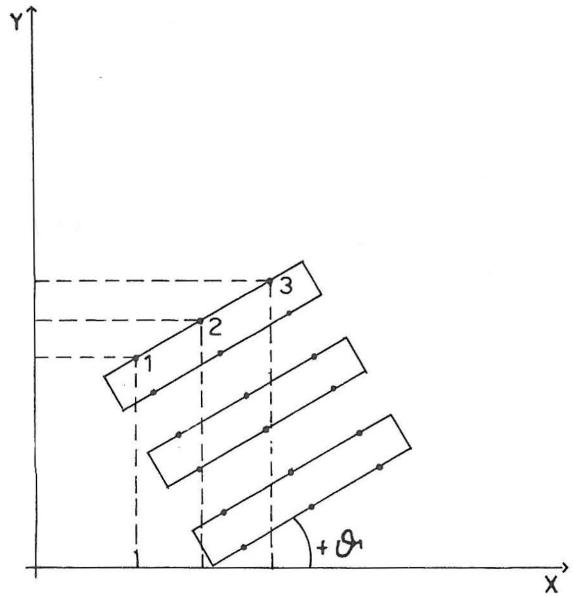

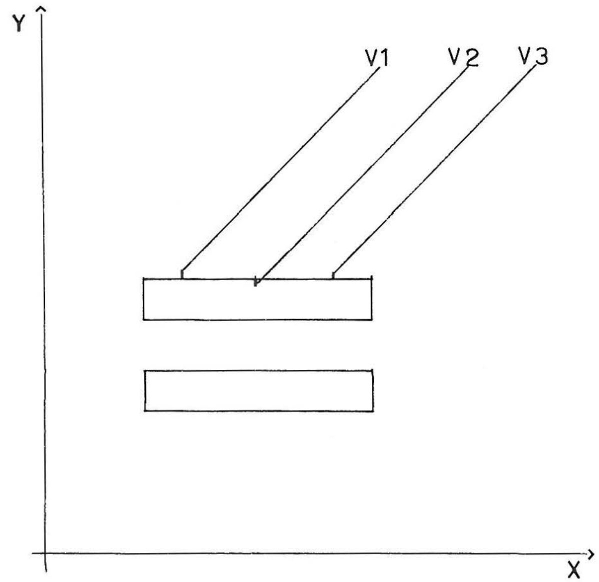

FIG.1

9) - the image sharpness: three asterisks correspond to the highest degree of sharpness;

10) - the x coordinate of the centre of the zebra crossing as regards the axes of the photogram; the X direction is the flight one;

11) - the y coordinate;

12) - the angle θ between the X axis and the direction of the strips of the zebra crossing.

Table 1 shows that the width of white strips obtained with stereoscopic observation is greater than the one obtained with monocular observation. The greatest difference is 14 μm, but the weighted mean of the obtained values is 4.9 $\pm$ 0.5 μm and this is the most meaningful result obtained.

Moreover, it does not seem to exist a remarkable correlation between the values of the resulting differences and the examined variables X, Y, θ.
At this point we have got to present some hypotheses on the point of the major strip width obtained with the stereoscopic observation in comparison to the monocular one. The major width can be attributed:

a) - to the instruments;
b) - to the operator because of his faulty sight;
c) - to the operator as an ordinary consequence of the stereoscopic observation.

Of course the various hypotheses might coexist.
In order to ascertain the validity of the hypothesis a), the same operator needs to repeat the measurements with many instruments of high precision; as for the hypotheses b) and c) we can't help repeating the same measures on the same instruments with different operators.

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