TRANSPORTABLE TEST-BAR TARGETS AND MICRODENSITOMETER MEASUREMENTS - A METHOD TO CONTROL THE QUALITY OF AERIAL IMAGERY

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ISPRS Commission I, Working Group 1

KEY WORDS: Quality, Control, Targets, Imagery, Measurement

ABSTRACT

Transportable polyester plastic test bar targets were made and used to test their usefulness for determining the spatial resolution of aerial photography. The results show that it is possible to construct and measure by microdensitometer light transportable targets to test the spatial resolution of aerial photography.

1. INTRODUCTION

High quality is usually important for the user of aerial photographs regardless of whether they are used by the photographer or other users. When processing a photogrammetric task the quality of the camera, film and navigation devices are usually known and the task is carried out using controlled methods. Thus the quality of the photographs can be estimated in advance which is the basis for a good result. In practice, however, some unpredictable factors like atmospheric characteristics, defects in the camera, irregular movements of the platform, rapid changes in terrain radiances or problems in the film development process can significantly lower the quality of the images. To be able to monitor the quality of aerial photographs, objective testing methods are needed.

The main quality criteria of aerial photography are spatial resolution, geometric accuracy and the correctness of grey tones or the colours in the image. A lot of factors affect these criteria, (Hakkarainen et al., 1992). The spatial resolution of the image has been selected here as the only quality criterion, because the most important of these factors like poor transmittance of the atmosphere, camera, film or development process reduce the spatial resolution and thus the quality of the image.

The only objective method to test the spatial resolution of films or images is to use standardized test fields with known figures, contrasts and reflectances. These permanent fields are very few in number and usually used only for testing the quality of imaging systems. The fields cannot be used to control the quality of operational aerial photography which are carried out at different places and under different circumstances. To obtain an objective method to test the spatial resolution of aerial photography wherever wanted, transportable test targets are needed.

In summer 1995 the Finnish Geodetic Institute carried out an experiment to test the usefulness of transportable test targets. The idea of the targets is that they are so small and light that they can be placed in the terrain at the same time as the targeting of control points is made. The results of the experiment are presented in this paper.

2. METHOD

2.1 Targets

To be easy to transport the test target must be light in weight so that it can be transported to the area which will be photographed. The lightness of the targets were reached in two ways. The targets were made of strong polyester plastic which is light compared with wood or metal plates. The size of the target was made small by using continuously changing bar widths. This means that the width of the bars and the backgrounds decreases according to a selected constant. This reduces the length of the target by a factor of four or at least three. The bars were painted on the plastic using suitable paints (two grey tones). The reflectances and the contrasts of the painted bars and the background correspond approximately to green grass and bare soil. Thus the targets offer good possibilities to evaluate the spatial resolution of the images when rural areas are photographed. The size of the target depends on the scale of the photography and will be made as small as possible. In 1995 test targets for 1:3 000 and 1:60 000 scale aerial photography were made as Table 1 shows. Table 2 shows the characteristics of permanent targets of the test field for 1:3 000 (C) and 1:60 000 (D) scale photography. These permanent targets were used as a reference. Figure 1 shows a B-type test target in the field.

	A	B
size of target (m^2)	2.5x1.5	5.0x10.5
width of bars (cm)	3.0-12.0	53.0-212
length of bars (m)	2.5	5.0
range of spatial res. (l/mm)	25-100	28-113
weight (kg)	4	50
number of bars and back-grounds having the same width	1	1
ratio of the width between the adjacent bars	$\sqrt[6]{2}$	$\sqrt[4]{2}$

Table 1. The characteristics of the transportable test-bar targets for 1:3 000 (A) and 1:60 000 (B).

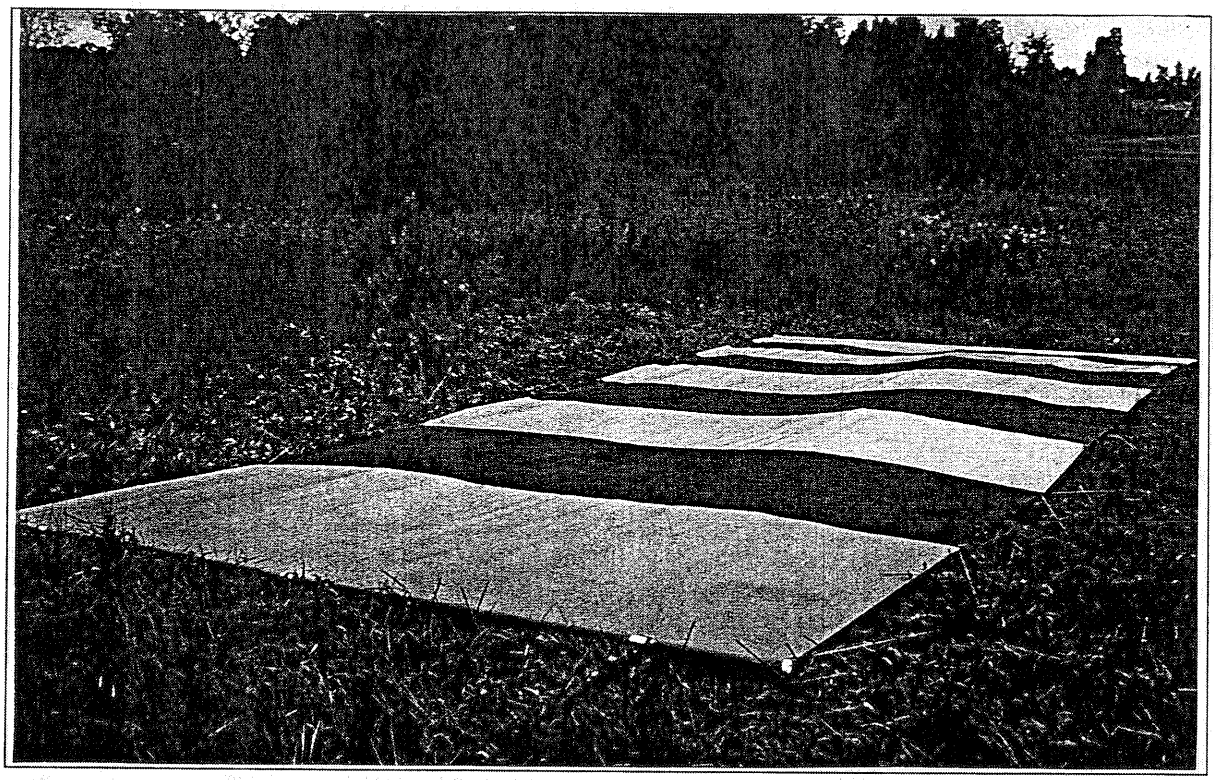

Figure 1. A transportable test target on the field in summer 1995.

	C	D
size of target (m^2)	1.0x8.0	3.0x3.75, 4.5x6.25, 6.0x7.5
width of bars (cm)	3.0-12.0	75.0-150.0
length of bars (m)	1.0	3.0-6.0
range of spatial res. (l/mm)	25-100	40-80
number of bars having the same width	4	3
ratio of the width of bars between adjacent bar groups	$\sqrt[6]{2}$	irregular

Table 2. The characteristics of permanent targets for 1:3 000 (C) and 1:60 000 (D).

2.2 Aerial photography

Test targets were photographed in summer 1995 using a Wild RC 20 camera. The experiment was carried out close to the permanent test field of the Finnish Geodetic Institute in Kirkkonummi, Finland. The characteristics of this test field is described in (Kuittinen et al., 1994).

If two targets are properly placed compared with the flight lines it is possible to get satisfactory results for computing the average spatial resolution of the photographs. One of the targets is placed so that the bars are parallel and the other so that the bars are perpendicular to the flight direction. Figure 2 shows the approximate location of these targets in the image. Depending on the photo overlap measurements of spatial resolution in several places of the photographs can be made. Figure 3 shows the location of all possible measurements as a function of the image radius when 80% forward overlap is used. As can be seen the measurements are distributed quite evenly over the whole image area. The targets can be seen in altogether five images.

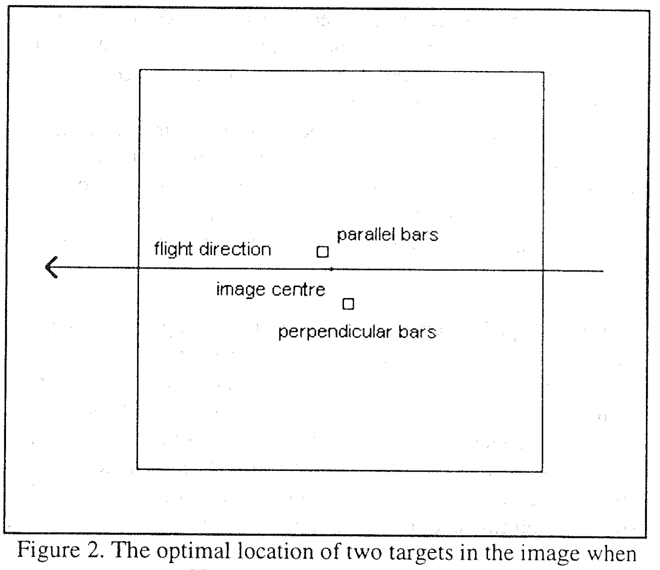

Figure 2. The optimal location of two targets in the image when 80% forward overlap is used.

The altogether ten measurements allow the determination of AWAR-values for the photographs using the following equation.

$$AWAR = \Sigma \frac{A_i}{A} \sqrt{R_i T_i} \quad (1)$$

where A_i is the area of the circular zone between radius r_i and r_{i+1} and,
R_i is the radial spatial resolution in the area A_i,
T_i is the tangential spatial resolution in the area A_i,
A is the area of the whole image.

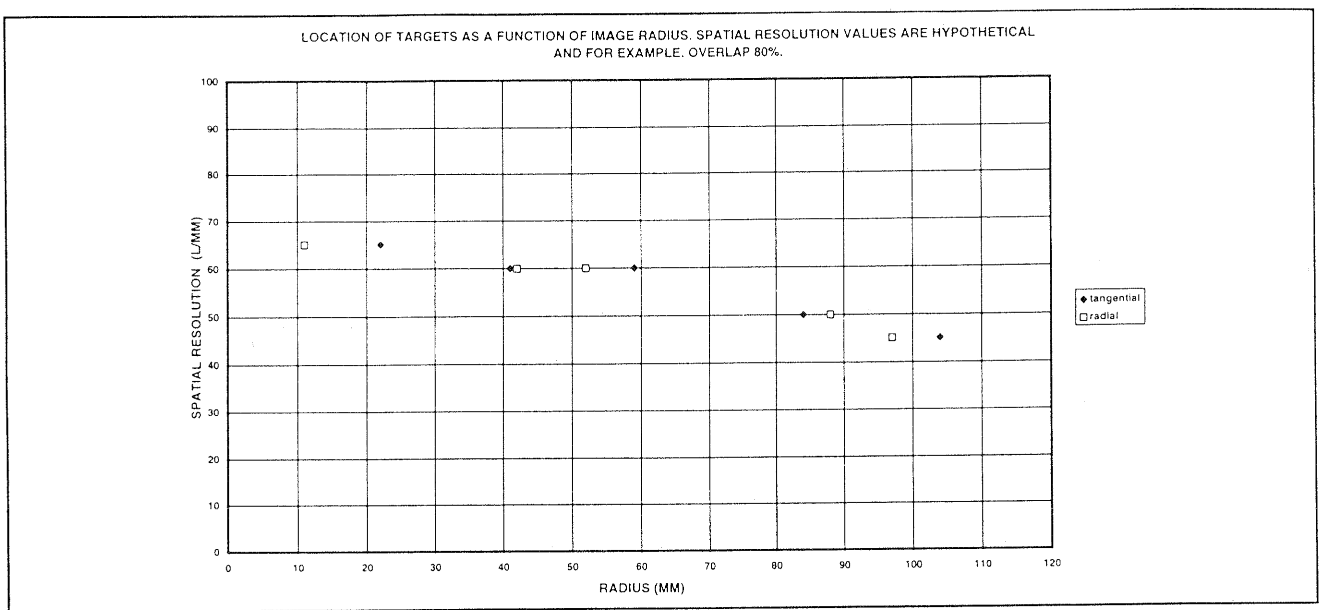

Figure 3. The location of targets as a function of the image radius when two targets and 80% forward overlap is used.

The areas A_i are determined on the basis of the available spatial resolution measurements. The image is divided into six zones, which have radius r values between 0-23, 23-46, 46-69, 69-92, 92-115 and >115 mm. If the measurements presented in Figure 3 are used, spatial resolution are calculated for r = 16, 36, 59, 81, 104 and 127 mm, which are centres of gravity in each of the 23 mm wide circular zones.

2.3 Method of analysis

2.3.1 Mathematical method

The photographs were measured using a J-L Automation Ltd Microdensitometer 3CS. Let the dimensions of the measurement slit be Δx (width) and Δy (length) when the slit is moved in the direction x. ΔX is the width of one test bar. The narrowest bar of the target ΔX_{min} defines the width of the measuring slit so that $\Delta x < 0.5 \cdot \Delta X_{min}$.

The 1:3 000 scale photographs were digitized with a slit size of $\Delta x = 5\mu m$ and $\Delta y = 100\mu m$. Altogether seven profiles were scanned over each test target. The 1:60 000 scale photographs were digitized with a slit size of $\Delta x = 5\mu m$ and $\Delta y = 20\mu m$. The number p of scanned profiles over the test targets varied.

To determine the spatial resolution the following calculations were made

mean of bar maxima $\quad f_{vmax}(x,y) = 1/m\Sigma f_{ivmax}(x,y)$, (2)

mean of background bar minima $\quad f_{tmin}(x,y) = 1/m\Sigma f_{itmin}(x,y)$, (3)

standard deviation of bar maxima

$$s_{vmax} = \frac{1}{m-1}\sqrt{\Sigma\,(f_{iv\,max}(x,y) - f_{v\,max}(x,y))^2}\,, \quad (4)$$

standard deviation of background bar minima

$$s_{tmin} = \frac{1}{m-1}\sqrt{\Sigma\,(f_{it\,min}(x,y) - f_{t\,min}(x,y))^2}\,, \quad (5)$$

where m=number of bars or background bars in the group.

Each measured profile and bar group is analysed separately. The bar group is accepted as resolved if the condition

$$f_{\upsilon vmax}(x,y) - f_{\upsilon tmin}(x,y) \geq a \cdot s_{vt} \quad (6)$$

holds when a=2. The constant a was determined by comparing the calculated results with visual observations.

The common standard deviation of the bars and the background bars is determined by

$$s_{vt} = \sqrt{((m_1 - 1)\cdot s_{vmax}^2 + (m_2 - 1)\cdot s_{t\,min}^2)\,/\,(m_1 + m_2 - 2)} \quad (7)$$

where m_1=number of bars in the group,
m_2=number of background bars in the group.

The majority of the determined p spatial resolutions gives the final resolution of the image.

2.3.2 Visual method

The spatial resolution in all images was also analysed by visual inspection. No extrapolation was made and thus the results correspond with the spatial resolution of the smallest detectable bar width.

3. RESULTS

3.1 Spatial resolution as a function of image radius

Figures 4-7 show the spatial resolution as a function of the image radius when permanent and transportable targets and two types of exposures are used.

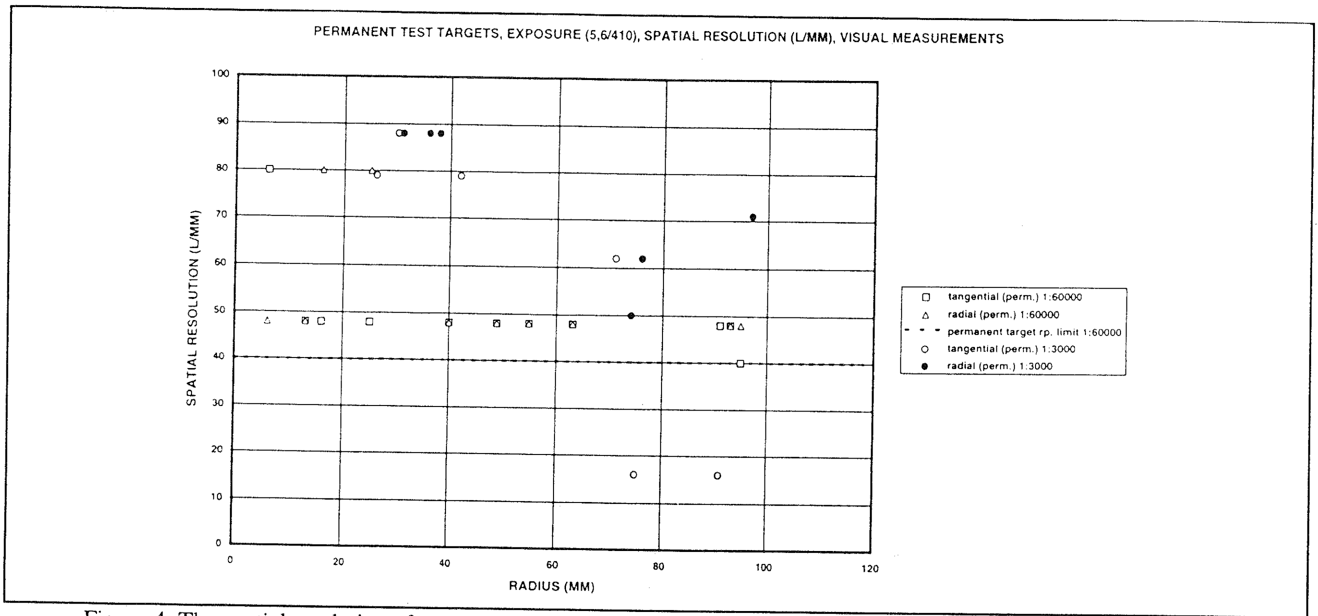

Figure 4. The spatial resolution of permanent targets using the visual method (exposure: aperture=5.6, time=1/410s).

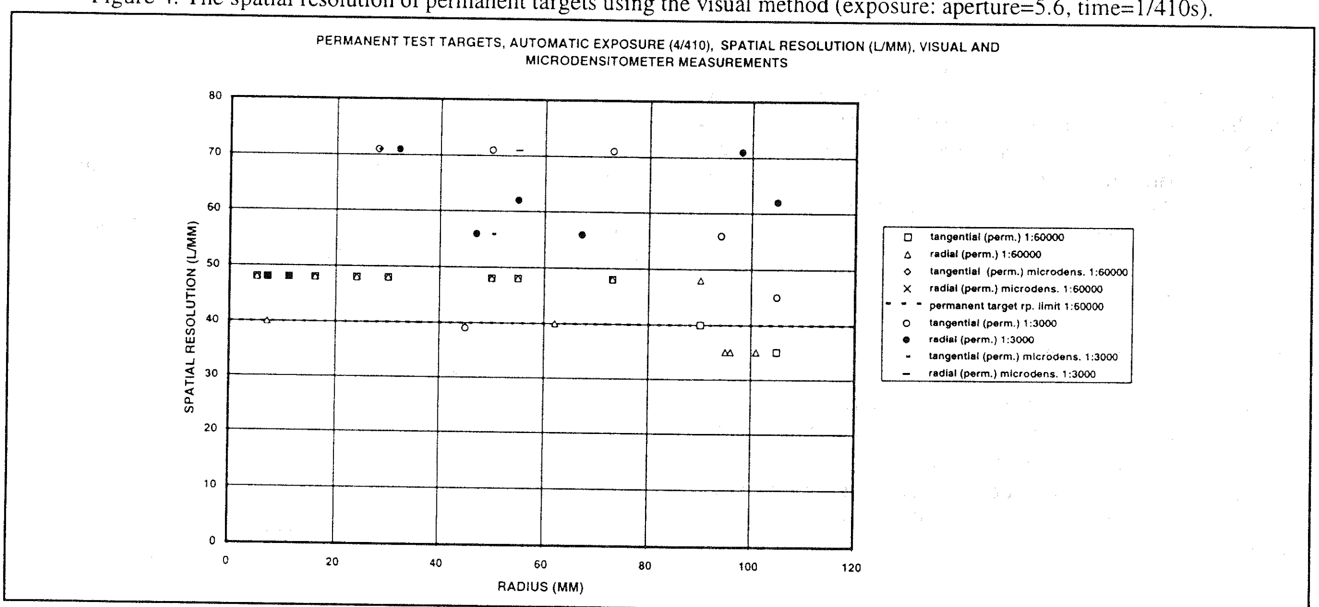

Figure 5. The spatial resolution of permanent targets using the visual and mathematical method (exposure: aperture=4, time=1/410s).

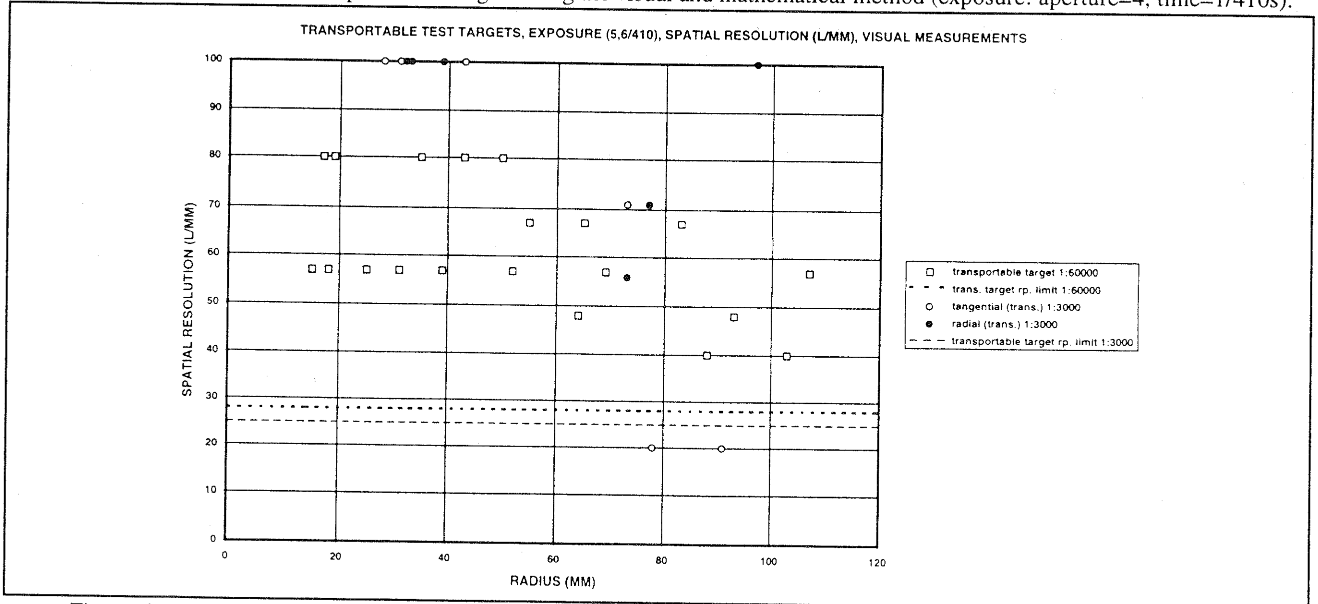

Figure 6. The spatial resolution of transportable targets using the visual method (exposure: aperture=5.6, time=1/410s).

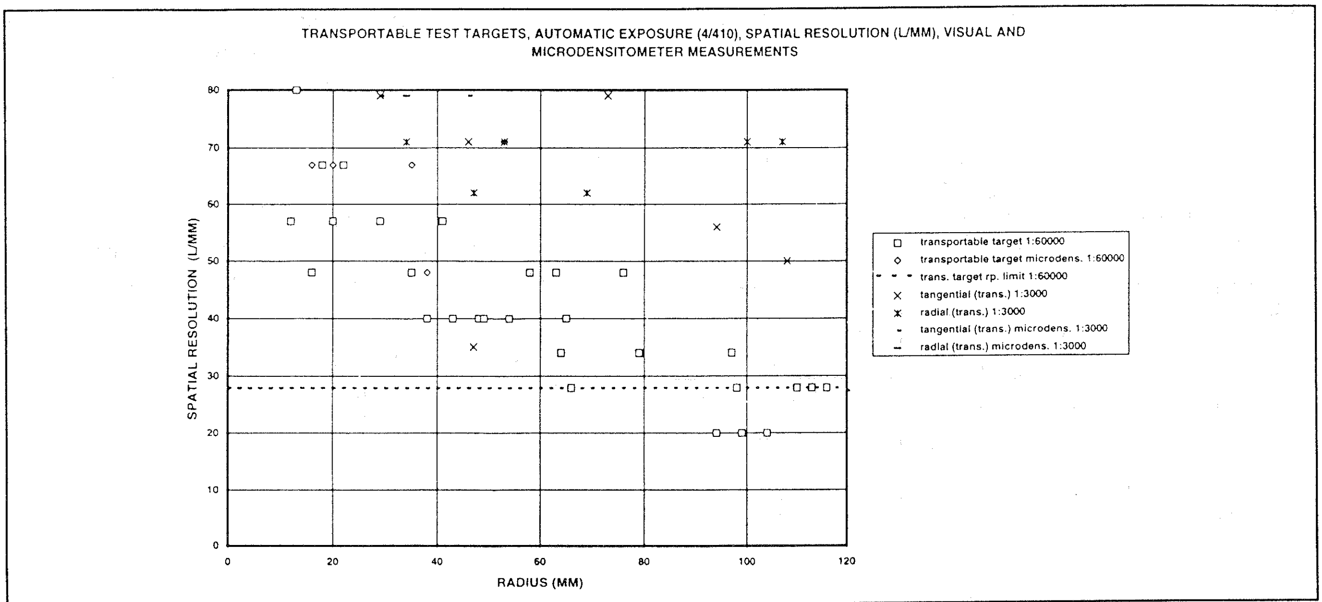

Figure 7. The spatial resolution of transportable targets using the visual and mathematical method (exposure: aperture=4, time= 1/410s).

3.2 Comparisons between permanent and transportable targets

Tables 3, 4 and 5 show the differences between the spatial resolution of permanent and transportable targets. Visual interpretation was used. Images 72 and 78 have moved in the flight direction during exposure resulting in poor tangential resolution. In the AWAR-calculations a tangential resolution of 16 l/mm for permanent targets and 20 l/mm for transportable targets is used when the table indicates resolution values <25 l/mm. In case of high altitude photographs, scale 1:60 000, resolution 35 l/mm is used for permanent targets when table indicates resolution values <40 l/mm. For transportable targets resolution 20 l/mm is used when the table indicates resolution values which are <28 l/mm.

Target type		aperture=4, time=1/410s						aperture=5.6, time=1/410s					
	image number	50	51	52	62	63	64	70	71	72	76	77	78
Permanent	tangential	56	71	71	45	39	71	79	88	<25	62	79	<25
	radial	71	71	56	62	56	62	88	88	71	50	88	62
Transportable	tangential	56	79	79	50	35	71	100	100	<25	71	100	<25
	radial	71	71	62	71	62	71	100	100	100	56	100	71

Table 3. Spatial resolution (l/mm) of permanent and transportable targets. Image scale 1:3 000.

Target type		aperture=4, time=1/410s														
	image number	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Permanent	tangential	48	48	48	48	48	40	<40	1)	48	48	48	48	1)	1)	1)
	radial	48	48	48	48	48	48	2)	<40	48	48	40	48	40	<40	<40
Transportable	field	34	67	57	57	48	28	28	<28	40	67	48	57	28	<28	<28
	forest	3)	48	40	48	80	40	48	34	40	57	40	40	34	28	28

Table 4. Spatial resolution (l/mm) of permanent and transportable targets. Image scale 1:60 000. Exposure values: aperture=4, time=1/410s. 1) tangential 40 l/mm target does not exist. 2) radial 40 l/mm target does not exist. 3) target outside the image.

Target type		aperture=5.6, time=1/410s										
	image number	21	22	23	24	25	26	27	28	29	30	31
Permanent	tangential	40	48	48	48	48	48	48	80	48	48	48
	radial	48	48	80	80	48	1)	48	48	48	48	48
Transportable	field	40	48	57	57	67	67	80	57	80	80	48
	forest	57	80	57	57	57	2)	67	57	80	57	40

Table 5. Spatial resolution (l/mm) of permanent and transportable targets. Image scale 1:60 000. Exposure values: aperture=5.6, time=1/410s. 1) radial 40 l/mm target does not exist. 2) target outside the image.

The results show that transportable targets give slightly higher spatial resolutions than permanent targets. This is possibly caused by the materials of the targets, gravel does not give as sharp edges as the painted bars in the transportable targets.

3.3 Comparisons between the visual and the mathematical method

The coefficient *a* in equation 6 was determined on the basis of the visual method. Table 6 shows the differences of spatial resolution of both methods for 1:3 000 and 1:60 000 photographs. Transportable targets for scale 1:60 000 were on the field (fi) and near the forest (fo) and their direction cannot be expressed in terms of tangential or radial.

Type		1:3 000				1:60 000			
		visual		mathem		visual		mathem	
	image	51	64	51	64	9	16	9	16
Perm	tan	71	71	71	56	48	48	48	48
	radial	71	62	71	71	48	40	48	48
Tran	tan/fi	79	71	79	79	57	48	67	67
	rad/fo	71	71	79	71	48	40	67	48

Table 6. Spatial resolution (l/mm) determined visually and mathematically from images number 9, 16, 51 and 64.

No difference between the methods was detectable.

3.4 AWAR-values

The AWAR-values were determined from the visual method measurements. The image was divided into circular zones. The mean values for tangential and radial spatial resolution were calculated in each zone. Spatial resolution values were determined graphically from 4 or 9 radius values depending on the method. Extrapolation was used when needed. Detailed description of the calculation method is given by (Hakkarainen et al., 1992). AWAR-values were calculated using equation (1) and they are presented in table 7. The two methods gave almost the same results. There is a little difference between permanent and transportable targets. This is possibly due to the range of spatial resolution and also to the ratio of widths of bars of the permanent targets.

Target type	Ap. 4, time 1/410s		Ap. 5.6, time 1/410s	
	4 r's	9 r's	4 r's	9 r's
Permanent	40	36	48	47
Transportable	34	32	52	52

Table 7. AWAR-values for 1:60 000 scale photographs.

4. DISCUSSION

Preliminary measurements and calculations show that the usage of transportable test-bar targets and the mathematical method can be developed to a routine. It needs the standardization of the measurement procedure and the determination of the constant *a* values. The constant *a* has to be determined for targets having groups of equal width bars and for targets, which have continuously changing bar width. It seems that for large scale photography traditional or standard targets can be used because the size of the target still remains moderate whereas for small scale aerial imagery targets having continuously changing bars are needed.

The spatial resolution measured from five overlapping images, if 80% forward overlap is used, is strictly speaking the spatial resolution of those images. A photogrammetric block may consist of hundreds of aerial images and the area can be very large. The properties of the atmosphere can be different in various parts of the block. In practise the results of the transportable test-bar target method to control the quality of aerial imagery have to be generalized over the whole photogrammetric block. If more observations are needed the targets can be photographed again at the end of the task.

References

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