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Film-Glass Differences

Metrical differences of contact prints made using production techniques showed film deviations approx. 3 times those for glass, but it is not yet known whether these are significant in operation.

Abstract: *Five contact prints on film and on glass were made of one glass gridplate under normal production working conditions. The question arises whether these prints are different in metrical sense or not. On the prints 36 grid intersections were selected, regularly distributed over the print. After measuring the coordinates of these intersection points, they were transformed to a best mutual fit, applying linear conformal transformation. Furthermore the contact prints, film and glass, were compared with the original gridplate on glass.*

Introduction

With the introduction of the improvement of restitution instruments and the application of numerical photogrammetry, greater metrical stability of photographs is required. Especially in aerial photogrammetry where a large number of photographs are combined into a block by electronic computers, stability and reliability of the input, the photograph, is of the utmost importance. In recent years, several investigators studied the distortion of photographs using techniques adapted to their requirements, such as: grid method, moiré system, etc. (See references).

As a matter of fact many sources of distortion appear during exposure, developing, printing, storing, etc., of photographs, whether film or glass. Some of these sources are: lens distortion, refraction, flatness of sensitive material, deformation of photographic image by transport, processing of film, aging effect, temperature, relative humidity, etc.

A new problem arises when making contact prints from negatives. In a former investigation of Zijlstra and the author (1969) the following problem was studied: starting with two available film-negatives, the size of both being 23×23 cm, a grid-negative and a negative made in an aerial camera of a part of a photogrammetric test-field.

Several contact prints on glass were made under normal production working conditions. After measuring the coordinates of 25 and 20 points, respectively, regularly distributed over these plates, the coordinates were transformed to a best mutual fit, applying linear conformal transformation solved by least squares. Differences of only 1 to 3 micrometers were found.

In this paper another kind of distortion is studied. Starting with a gridplate on glass, several contact prints both on film and on glass were made, one directly after another. The question is, whether these prints are different in the metrical sense or not. Furthermore the contact prints, film and glass, are compared with original gridplate on glass. The reason for this investigation is that more and more film-positives are used in practice.

Materials and Measurement Investigated

Starting with a gridplate on glass, several contact prints were made in flow-production, 5 prints on Kodak Aerographic Duplicating film 4427, Estar base, thickness .007 inch, and 5 prints on Gevaert glass diapositive plates.

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TABLE 1. THE STANDARD DEVIATIONS OF THE OBSERVATIONS IN MICROMETERS, μm

Print	*Film*		*Glass*	
	σ_x^ρ	σ_y^ρ	σ_x^ρ	σ_y^ρ
$\rho=1$	1.4	1.0	1.4	1.5
2	1.8	1.9	2.3	0.9
3	1.6	1.7	1.4	2.1
4	1.5	1.2	1.7	1.5
5	1.3	1.3	1.5	0.9
Average	1.5	1.5	1.7	1.5

A private company made the contact prints under normal working conditions. The prints on film were made by a Milligan dodging printer and the machine-processing was done by a Versamat. The prints on glass were made by a Cintel dodging printer and then hand-processing.

The prints were measured in a Mann monocomparator set up in an air-conditioned room. On the prints 36 grid intersections were selected, regularly distributed over the print.

The coordinates of each on each print were measured two times, forward and backward, and recorded to the nearest micrometer, μm:

$$\begin{aligned} &\text{forward: } x_{p'}^\rho,\ y_{p'}^\rho \\ &\text{Backward: } x_{p''}^\rho,\ y_{p''}^\rho \\ &\text{Point } p \text{ on print } \rho\text{: } p = 1 \cdots n,\ \rho = 1 \cdots k. \end{aligned} \tag{1}$$

So, in this investigation for both film and glass, $n=36$ and $k=5$.

PROCESSING THE MEASURING DATA

The differences v and w between the individual set, and the mean value for the x- and y-coordinates, respectively, provided the possibility of calculating the measuring accuracy as follows. The mean value is, (see equation 1):

$$\begin{aligned} x_p^\rho &= \tfrac{1}{2}(x_{p'}^\rho + x_{p''}^\rho) \\ y_p^\rho &= \tfrac{1}{2}(y_{p'}^\rho + y_{p''}^\rho). \end{aligned} \tag{2}$$

The over-all measuring accuracy for n points on print ρ is:

$$\begin{aligned} \sigma_x^\rho &= \left\{\frac{[v_{p'}^\rho v_{p'}^\rho + v_{p''}^\rho v_{p''}^\rho]_1^n}{n}\right\}^{\frac{1}{2}} \\ \sigma_y^\rho &= \left\{\frac{[w_{p'}^\rho w_{p'}^\rho + w_{p''}^\rho w_{p''}^\rho]_1^n}{n}\right\}^{\frac{1}{2}} \end{aligned} \tag{3}$$

in which:

$$\begin{aligned} v_{p'}^\rho &= x_p^\rho - x_{p'}^\rho \qquad & v_{p''}^\rho &= x_p^\rho - x_{p''}^\rho \\ w_{p'}^\rho &= y_p^\rho - y_{p'}^\rho \qquad & w_{p''}^\rho &= y_p^\rho - y_{p''}^\rho. \end{aligned}$$

The σ_x^ρ and σ_y^ρ are tabulated in Table 1.

The average standard deviations σ_x and σ_y are given in the last row of Table 1. (Remark: one of the prints on film, No. 2, gave a large standard deviation of the observations. The defect could not be established. This print was remeasured.)

The observations introduced in the further considerations are (see Equation 2):

$$x_p^\rho \quad \text{and} \quad y_p^\rho \tag{3}$$

and the standard deviations of these observations. The mean of the two are in accordance with Equation 2 and the last row of Table 1 taken as follows:

$$\text{Film: } (1/\sqrt{2})\sigma_x = 1.5/\sqrt{2},\ (1/\sqrt{2})\sigma_y = \lfloor\overline{1.5/\sqrt{2}}\rfloor \tag{4}$$

$$\text{Glass: } (1/\sqrt{2})\sigma_x = 1.5/\sqrt{2},\ (1/\sqrt{2})\sigma_y = \lfloor\overline{1.5/\sqrt{2}}\rfloor.$$

In order to refer the measurement of different prints to a common datum, the coordinates of all prints were transformed into one system, the system of Print No. 1, applying linear conformal transformation solved by least squares:

$$\begin{aligned} (x_p^1 + v_p^1) &= (x_p^\rho + v_p^\rho)(1 + \Delta p^\rho) \\ &\quad - (y_p^\rho + w_p^\rho)\Delta q^\rho + \Delta c_x^\rho \\ (y_p^1 + w_p^1) &= (y_p^\rho + w_p^\rho)(1 + \Delta p^\rho) \\ &\quad + (x_p^\rho + v_p^\rho)\Delta q^\rho + \Delta c_y^\rho \\ \rho &= 2 \cdots k. \end{aligned} \tag{5}$$

The transformation parameters, Δp, Δq, Δc_x^ρ and Δc_y^ρ are small.

The following quantities were computed according to the formulas of Standard Problem II: the corrections.

$$v_p^\rho,\ w_p^\rho \qquad \rho = 1 \cdots k,\ p = 1 \cdots n. \tag{6}$$

And we write,

$$\begin{aligned} X_p^\rho &= x_p^\rho + v_p^\rho \\ Y_p^\rho &= y_p^\rho + w_p^\rho. \end{aligned} \tag{7}$$

From the corrections a mean-square value was calculated (see Table 2):

TABLE 2. THE MEAN SQUARE VALUES OF THE CORRECTIONS IN μm

Print	*Film*		*Glass*	
	m_x^ρ	m_y^ρ	m_x^ρ	m_y^ρ
$\rho=1$	1.8	1.7	0.7	0.8
2	2.0	2.9	1.6	1.3
3	1.4	2.4	0.8	0.8
4	1.3	1.6	0.9	0.8
5	1.7	1.9	0.8	1.0
Average	1.6	2.1	1.0	0.9

$$m_x^\rho = \left\{\frac{[v_p^\rho v_p^\rho]_1^n}{n}\right\}^{\frac{1}{2}}$$
$$m_y^\rho = \left\{\frac{[w_p^\rho w_p^\rho]_1^n}{n}\right\}^{\frac{1}{2}}. \tag{8}$$

Furthermore, from these corrections diagrams are constructed, two examples are added, one of film and one of glass (see Figures 1 and 2). The other diagrams show more or less the same pattern. The remaining corrections, v and w, contain the influence of measuring according to Equation 4 and the irregular metrical differences, d; subtracting the former influence leaves the latter, d:

$$d_x^\rho = [(m_x^\rho)^2 - \tfrac{1}{2}\sigma_x^2]^{\frac{1}{2}}$$
$$d_y^\rho = [(m_y^\rho)^2 - \tfrac{1}{2}\sigma_y^2]^{\frac{1}{2}}. \tag{9}$$

In Table 3 d_x^ρ and d_y^ρ are tabulated.

Besides the corrections v_p^ρ and w_p^ρ, the parameters Δp^ρ and Δq^ρ are computed according to the formulas of Standard Problem II.

The scale factor can be defined as follows:

$$\lambda_1^\rho = [\sqrt{(1 + \Delta p^\rho)^2 + (\Delta q^\rho)^2}]^{\frac{1}{2}}. \tag{10}$$

The index 1 indicates that the scale factors refer to the system of Print No. 1.

Comparing the prints on film respectively on glass with the original gridplate is done as follows. According to Equations 5 and 7 we can write,

$$X_p^1 = X_p^\rho(1 + \Delta p^\rho) - Y_p^\rho \Delta q^\rho + \Delta c_x^\rho$$
$$Y_p^1 = Y_p^\rho(1 + \Delta p^\rho) + Y_p^\rho \Delta q^\rho + \Delta c_y^\rho. \tag{11}$$

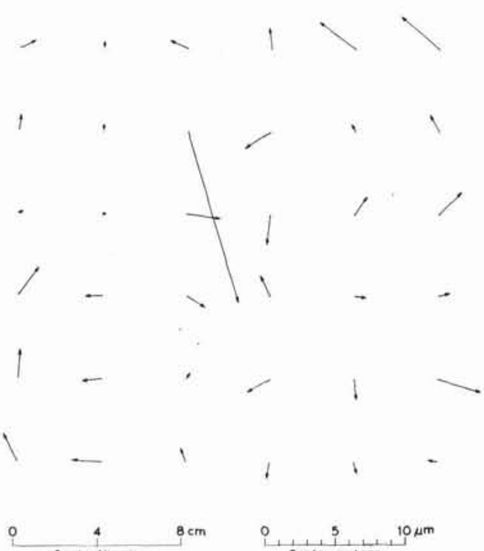

FIG. 1. The corrections of one of the prints on film (print 3).

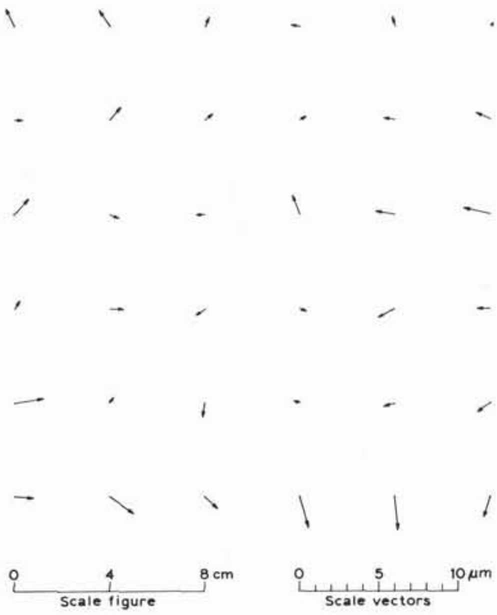

FIG. 2. The corrections of one of the prints on glass (print 3).

We compared one of the print ρ with the original gridplate. According to Equation 11 it makes no difference which print. We take Print No. 1 of film respectively of glass, whose coordinates X_p^1 and Y_p^1 were transformed to the system of the original gridplate, x_p^r and y_p^r:

$$x_p^r = (X_p^1 + V_p)(1 + \Delta p^1) - Y_p^1 \Delta q^1 + \Delta c_x^1$$
$$y_p^r = (Y_p^1 + W_p)(1 + \Delta p^1) - X_p^1 \Delta q^1 + \Delta c_y^1. \tag{12}$$

The deviations V_p and W_p contain the influence of the measuring accuracy and the irregular difference between X_p, Y_p and x_p^r, y_p^r (see Figures 3 and 4).

The mean-square value of V_p and W_p is 2 (see Table 4):

TABLE 3. THE MEAN-SQUARE VALUES OF THE METRICAL DIFFERENCES IN μm

	Film		*Glass*	
Print	d_x^ρ	d_y^ρ	d_x^ρ	d_y^ρ
$\rho = 1$	1.5	1.3	0	0
2	1.7	2.7	1.2	0.7
3	0.9	2.2	0	0
4	0.7	1.2	0	0
5	1.3	1.6	0	0
Average	1.2	1.8	—	—

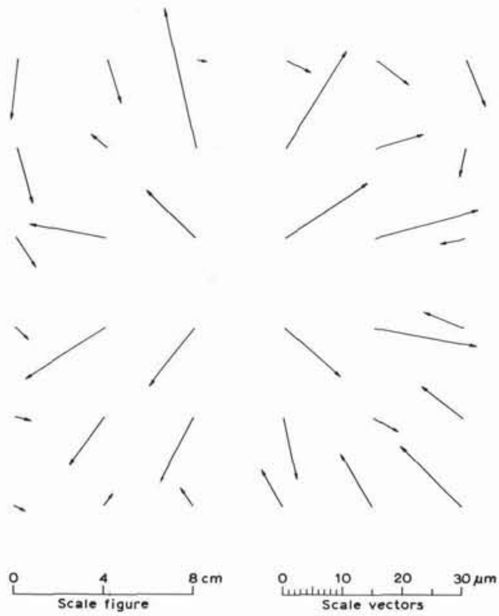

FIG. 3. The deviations V_p and W_p of the prints on film.

$$M_x = \left\{\frac{[V_pV_p]_1^n}{n}\right\}^{\frac{1}{2}}$$
$$M_y = \left\{\frac{[W_pW_p]_1^n}{n}\right\}^{\frac{1}{2}}. \qquad (13)$$

Just as in Equation 10, the scale factor derived from Equation 12 is:

$$\lambda_1 = (1 + \Delta p^1)^2 + (\Delta q^1)^2]^{\frac{1}{2}} \qquad (14)$$

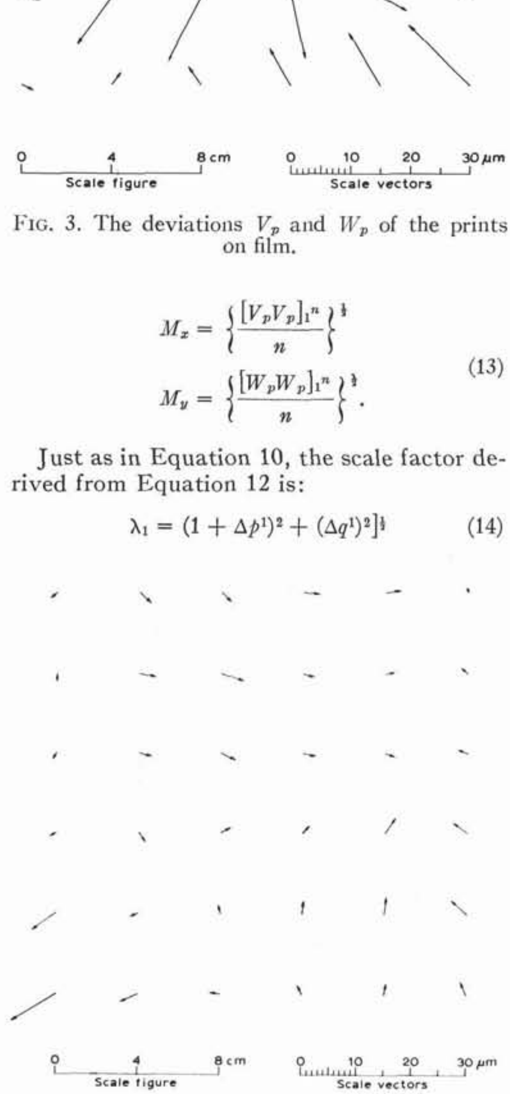

FIG. 4. The deviations V_p and W_p of the prints on glass.

TABLE 4. THE MEAN-SQUARE VALUES OF THE DEVIATIONS V_p AND W_p IN µm

	Film	*Glass*
M_x	7.4	2.4
M_y	7.9	1.8

Taking account of Equations 10 and 14 the scale factors of the prints are (Table 5):

$$\lambda^p = \lambda_1{}^p \cdot \lambda_1.$$

CONCLUSIONS AND REMARKS

- The measuring accuracy is the same for points on film and glass; see Table 1.
- In one of the points of the prints on film a relatively large correction, as defined in Equation 6, was found. The remeasuring gave about the same result and therefore we accept this as a valid measurement; see Figure 1.
- From Table 3 we note that the metrical differences between the contact prints on film are small, but they are significant as compared with the measuring errors given in Equation 4.
- Between the contact prints on glass no metrical differences could be established; see Table 3.
- Comparing the measurements plus corrections (as defined by Equation 7, and also 11) with the original gridplate on glass, relatively large deviations V_p and W_p were found (see Table 4 and Figures 3 and 4). These deviations contain also the influence of the measuring accuracy.
- Further investigations will be necessary to analyze the deviations with the original gridplate, especially for the deviations of the prints on film which are more or less regular (see also the scale factors in Table 5).
- The influence of the metrical differences in practical application of photogrammetry is not studied here.

TABLE 5. THE SCALE FACTORS OF THE PRINTS AS COMPARED WITH THE ORIGINAL GRIDPLATE

	Film	*Glass*
Print	λ^p	λ^p
$p=1$	0,999782	1.000048
2	0,999751	1.000056
3	0,999722	1.000047
4	0,999726	1.000039
5	0,999712	1.000088

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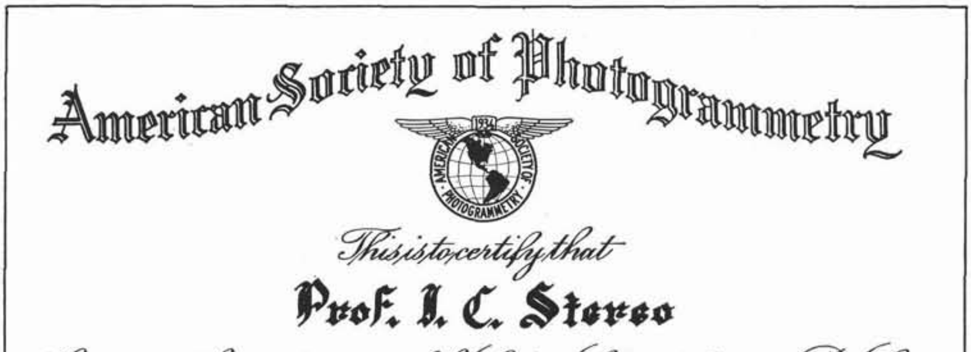

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