PRELIMINARY RESULTS OF THE OEEPE SCANNER TEST

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SUMMARY

The aims of this study are the analysis of the tone reproduction of photographic scanners and the development of simple test procedures. The most important arguments proposed are the image noise, image resolution, quality of colour reproduction, sensitivity of the scanner and the visual aspect of the images. A good scanner should show an image noise lower than ± 0.03 D for a pixel size of 10 µm and a resolution up to 10 µm. Furthermore, the dynamic density range and the fidelity of tone reproduction should be controlled.

1. SCOPE OF THE STUDY

Working methods of digital photogrammetry are more and more applied in practice. However the aerial camera using photographic films will remain for quite some time superior to all digital imaging techniques. Consequently scanners play a key role for the conversion of photographic images in a digital form. However the draw backs of digital cameras are also present during scanning and it is of great importance do control severely the quality of the scanning process. The main requirements for image quality could be summarized in the following way :

- Geometric quality
- Fidelity of tone and colour reproduction
- Image resolution

Additionally the user wants instruments, which are easy to use and they should operate rapidly.

Photogrammetric manufacturers, but also the printing industry have developed number of scanners of remarkable quality and for a user it is not always easy to evaluate the different products. However in practical use, one realizes very quickly that there are considerable differences in image quality between the different scanners. A photographic image generally has a rather wide contrast range and a high resolution. Very often difficulties must be faced when converting those high-quality images into a digital form. When comparing an image displayed on a digital work station and on an analytical plotter with a good optical system, one can see that the analytical plotter allows a better detail recognition, then on a digital work station even when the scanning was done with a rather small pixel size. High requirements with regard to image quality also stem from automatic image correlation, especially when treating low-contrast areas.

2. OEEPE WORKING GROUP ON SCANNER TEST

In order to develop criteria for a systematic analysis of a scanner and to gain experiences on different instruments OEEPE (European Organization for Experimental Photogrammetric Research) has created a working group. This working group has organized already a first workshop in November 1993 and conceived a comparative test for scanner. Furthermore a questionnaire was prepared, which should allow to collect technical data on the different systems.

For the experimental test a set of test material was compiled:

1. Grid plate, grid spacing 1 cm, dark lines on glass plate, line width 50 µm.
   Objective : Analysis of the general precision of the scanner.
2. Kodak Photographic Step Tablet no 2 (21 steps), density range ~ 0.05 - 3.05 D (CAT 152 3398).
   Objective : Analysis of the dynamic density range and of the noise of the scanner.
3. Kodak Ektachrome colour table (from Kodak Colour Reproduction Guides Q60A) (CAT 815 5822).
   Objective : Analysis of the quality of the colour reproduction and of the noise in the different spectral regions.
4. Fresnel pattern (black-and-white).
   Objective : Analysis of irregularities in geometry.
5. Black-and-white diapositive copy of aerial photograph no 101012 taken with camera Wild RC20 30/4 NATA-F no. 17027 on Agfa Pan 150 film (density range of the diapositive 0.1 - 1.1 D, copied on film Agfa Avitone P3p, aerial flight Penthaz of 15.4.1987).
   Objective : Analysis of the reproduction of a low-contrast image, computation of the MTF and of the image noise.
6. Original black-and-white negative of aerial photograph no 5266 taken with camera Wild RC20 15/4 UAGA-F no. 13129 on Kodak Panatomic-X film (density range 0.1- 2.0 D, aerial flight Dübendorf of 8.6.1994).
   Objective : Analysis of the reproduction of a high-contrast original negative, computation of the MTF and of the image noise.
7. Colour aerial photograph no 0439 taken with Wild RC20 30/4 NATA-F no. 17027 on Kodak MS2448 colour film.
   (density range 0.2 - 2.5 D, aerial flight Nyon of 15.8.1994).
   Objective : Optimal reproduction of a colour aerial photograph. It would be desirable that the signalized points can be properly recognized and easily measured on a digital working station. Furthermore, it would be important that details in the shadows remain recognizable.

3. PARTICIPANTS IN THE OEEPE TEST

In order to attain the scope of the working group it appeared most appropriate to invite in a first phase the manufacturer to scan the test material and to proceed on an analysis of the scanned images. The members of the working group intended to run different test on the material and should be rather free to develop their proper strategy. The synthesis of these analysis should then allow to develop standard procedures for testing of scanners. However the scanning of the material took much longer time than planned. As only one test set was available composed of originals, the delay within one only organization extended seriously the scanning phase. Therefore the analysis of the test material remained very limited and only results of the pilot centre (Technical University of Lausanne) can be presented up to now.

The following firms have participated up to now in the scanner test, which is highly appreciated :

Agfa, Mortsel, Belgium with the Agfa Horizon Plus

Intergraph, Huntsville USA with the PS1

Wehrli & Assoc, Valhalla USA, with the RM1

Helava, San Diego USA with the DSW200

Complementary scanning have been made by the following organizations :

ICC Barcelona with the PS1

Cetop, Lausanne with the PS1

Institute of Photogrammetry of the ETH-Zürich with the Agfa Horizon

Institute of Photogrammetry of the EPF-Lausanne with the DSW200

4. ANALYSIS OF THE TEST MATERIAL

Although the invitation for the test scanning was sent out in spring 1995, we disposed only beginning of February 1996 of some representative test material. The time for the analysis was therefore very short and is by far not finished. Earlier publications concentrated on the analysis of black and white photographs and showed how to determine the image noise, image resolution and the dynamic range (cf. [1],[2]). The current tests included resolution patterns, photographed with aerial cameras on high resolution film (test 6), colour test patterns (test 3) and the gray wedge (test 2). It appeared of great interest to accelerate the analysis of the image resolution and of the colour reproduction, as these criterias have not been treated earlier too intensively.

4.1 Image resolution

A lot was already discussed on image resolution and very often the pixel resolution is considered as limiting factor. However when analysing the reproduction of small objects in photographs, like signalized points one realizes that the cut off frequency is not at all decisive, much more important is the loss of contrast for larger frequencies. This loss of contrast is given by the modulation transfer function (MTF). In order to determine the MTF, one should know the object function and of course the image function, but which is anyhow given by the digitized image. By computing the Fourier transforms one can then determine the spread function or its Fourier transformed, the modulation transfer function. By some simplifications the modulation transfer function can also be deduced from the contrast reduction of a rectangular pattern, a way which was chosen here.

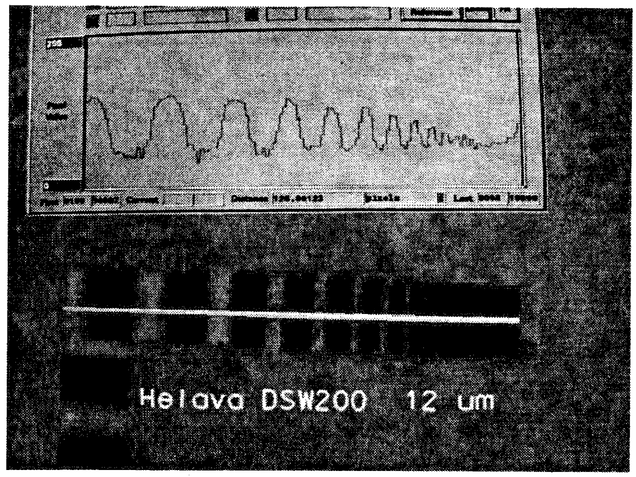

Fig. 1

Resolution pattern (test 6) and density profile scanned on the DSW200.

Figure 1 shows a reproduction of the resolution target (lower part) as negative. A density profile was determined with the software tools of ISI of the ImageStation of Intergraph. One recognizes that the contrast diminishes with the increasing frequencies and the signal vanish for frequencies of about 50 lines/mm.

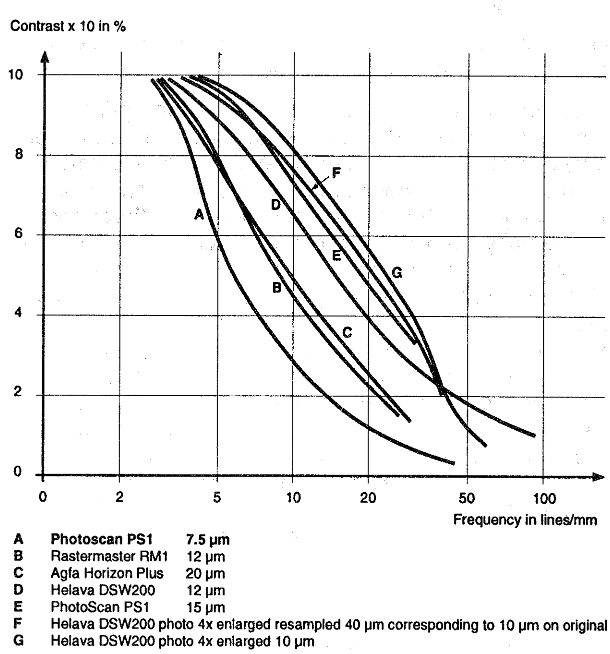

Fig. 2

Modulation transfer function for different scanners.

Figure 2 gives an overview of the determined transfer functions for the different scanners tested and different image configurations. The best curve was obtained for a simulated pixel size of 2.5 µm for the Helava DSW200. In this case the original photograph was enlarged 4 times on the Durst enlarger with a Rodenstock optic and then scanned with an effective pixel size of 10 µm. This image was then resampled to a pixel size of 40 µm, corresponding now to 10µm with respect to the original. The effective transfer function for 12 µm is about 10% lower. It is however astonishing that a very similar transfer function was obtained with the PS1 with a pixel size of 15 µm as with the enlarged photographs. An other scan on the PS1 with a pixel size of 7.5 µm at a private firm gave a much more unfavourable result. The result of the Rastermaster RM1 of Wehrli (12µm pixel size) and the Agfa Horizon Plus (20 µm pixel size) are very similar.

The results do not show the importance of the pixel size as one would expect; but it must also be stated that these results are very preliminary and have still to be verified. It will also be interesting to compare these results from the MTF determined earlier form the noise. Furthermore it most be kept in mind that the MTF determined here is the sum of the taking camera, the performance of the film and the performance of the scanner. The MTF of the scanner could be deduced when knowing or making asumptions for the MTF of the other components. The force of this test lies however in the comparative analysis. By using an enlargement of the test film (curve F and G in fig. 2) one also realisis that the quality of the scanner limits the resolution of the scanned images.

4.2 Image Noise and the Dynamic Density Range

The determination of the image noise is rather simple. It is sufficient to scan the Kodak Photographic Step Tablet (Test film 2) and to compute the RMS of the pixel values within homogenious areas. The variance of the gray values is in general constant if one uses a logarithmic look-up table over a certain range of density values. If one analysis the variance of the initally obtained gray values, which are in general proportional to the tansparency of the film on observe a dimiuation with increasing density. In order to obtain a comparable result which also gives information on the dynamic range it is strongly recommanded to transfer the variance of gray values into the optical density. The image noise in density values is given for the different scanners in table 1 and 2.

One remarks that the image noise is rather uniform up to the density 1.0 and remains beneath ±0.02 D. May be the RM1 of Wehrli shows somewhat higher values whereas the Agfa Horizon seems more favorable. A noise level of ±0.03 D is reached for 1.5 D and increases then rapidly. That would mean that the tested scanners have a dynamic range of about 1.5 D nearly independently whether a logarithmic or a linear look-up table is used for the transformation of the gray values. Also the pixel size influences hardly the image noise, only for the Helava DSW 200 one has the impression that the image noise is more favorable for a pixel size of 25 µm then for 12 µm.

It is understood that this test was run on material with very fine grain. It must be suspected that effects like the illumination used in the scanner will also influence the graininess, an effect which should be proportional to the pixel size. However this effect could not be demonstrated here.

The limited dynamic range of the scanner explain the difficulties encountered when scanning negatives with a contrast greater then 1 - 1.5 D.

4.3 Analysis of the Colour Reproduction

When working with colour photographs one is in general not too strict as for colour fidelity like in printing industry. Furthermore one is aware that haze degrades considerable the colour reproduction; even worth very often one prefers false colour photographs instead of true colours as they give more information. All this might explain why the colour reproduction was not really analysed up to now.

The Kodak Ektachrome colour table Q60 gives an efficient tool for the testing of the colour reproduction. The table includes batches which are only transparent in the 3 bands (red, green, blue) and transparency in the other bands is below 1%. When controlling the pixel values after scanning one has the impression that the Agfa Horizon scanner gives a very adequate response whereas

Density	RM1 Wehrli 12 µm	DSW200 Helava 12 µm		PS1 Intergraph 15 µm	Horizon Agfa 23 µm
	linear	linear	log.	log.	linear
0.04	0.014	0.014	0.010	0.012	0.006
0.21	0.011	0.015	0.017	0.020	0.005
0.37	0.018	0.021	0.016	0.020	0.008
0.52	0.024	0.018	0.020	0.021	0.007
0.68	0.016	0.014	0.020	0.024	0.012
0.84	0.027	0.031	0.022	0.030	0.010
0.99	0.036	0.029	0.026	0.042	0.010
1.15	0.037	0.022	0.056	0.031	0.011
1.30	0.051	0.032	0.022	0.034	0.020
1.45	0.031	0.036	0.027	0.041	0.025
1.60	0.078	0.049	0.032	0.031	0.027
1.75	undef.	0.044	0.049	0.093	0.050
1.91	undef.	0.068	0.086	0.088	undef.

Table 1

Determination of the image noise for different scanners in function of the optical density. The image noise is also given in density values; small pixel sizes specified in the header.

Density	RM1 Wehrli 24 µm	DSW200 Helava 25 µm		PS1 Intergraph 30 µm	Horizon Agfa 23 µm
	linear	linear	log.	log.	linear
0.04	0.013	0.008	0.008	0.013	0.006
0.21	0.011	0.007	0.015	0.011	0.005
0.37	0.012	0.009	0.012	0.012	0.008
0.52	0.012	0.015	0.012	0.012	0.007
0.68	0.014	0.019	0.017	0.014	0.012
0.84	0.018	0.014	0.020	0.018	0.010
0.99	0.019	0.018	0.021	0.019	0.010
1.15	0.029	0.021	0.018	0.029	0.011
1.30	0.029	0.022	0.018	0.029	0.020
1.45	0.050	0.024	0.018	0.048	0.025
1.60	0.055	0.032	0.028	0.055	0.027
1.75	0.070	0.055	0.019	0.072	0.050
1.91	undef.	0.071	0.028	undef.	undef.

Table 2

Image noise for larger pixel size; other elements as in table 1.

the Helava DSW200 and also the PS1 are not too sensitive in the blue band and one misses about 30% of light density. This seems to be compensated by a smearing effect of the green band. That means that the transparency of the blue filter is too wide and is affected by light from the green band.

This is often not noticed as our eyes are not very sensitive to the blue light and in aerial photographs only few objects are blue. The situation is different when one wants to derive an image with more or less natural colours from a infrared false colour film. Then it is disturbing when the measured blue band, which corresponds to the green band in nature, corresponds largely to the neighbouring band. It must be admitted that these measurements are also very new and will need confirmation, however that they can contribute for a discussion.

5. CONCLUSIONS

Although a lot of studies have already been made with scanners it seems that many aspects still have to be studied. We are aware that the discussion here is still limited to the scanning process and should finally also include the presentation of the image on a screen and the printing technique. It is hoped that the study of the OEEPE will initiate a wider discussion and that finally recommendations can be given for an overall scanner test.

Due to difficulties to obtain the test material in time it was not possible to do all the planned tests in time. It is the intention to continue this study and to complement the publication gradually.

References

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