Practical Scanner Tests Based on OECF and SFR Measurements

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The technical specification of scanners has always been used as a marketing instrument since the introduction of commercially available scanners. The scan resolution specified is, in some cases, an interpolated sampling rate, and the color depth is 'improved' by using 'bit or bit depth enhancement technologies.' However, these numbers do not tell the customer anything about the quality of images that can be achieved by a particular scanner and are, more often than not, misleading.

We were asked by German photographic and computer magazines to develop a method to evaluate the overall quality of scanners. We based our tests on developing ISO standards and procedures for digital still cameras and modified these to fit the specific characteristics of scanners. In this paper, we outline our methodology and discuss our results.

Characteristic Data of a Scanner

Following is a short description ot the four main scanner parameters that influence image quality.

1. Resolution. The ability to capture fine detail found in the original film or print is one of the most important characteristics of a scanner. This ability to resolve detail is determined by a number of factors, namely the performance of the scanner lens, the number of addressable photoelements in the image sensor(s), and the electrical circuits in the scanner. Different measurement methods will provide different metrics to quantify the ability of the scanner to capture fine details.
2. Dynamic range. Another aspect of quality is the ability to show details in the dark areas of the original film or print. The dynamic range of a scanner is the difference from the lightest to the darkest area of an original that show significantly resolved detail.
3. Noise. The level of noise in homogeneous colored areas also contributes to the image quality that can be obtained from a scanner.
4. Color reproduction quality. A fourth quality aspect is the accuracy of color reproduction in comparison to the original. This quality criterion is not discussed in this paper.

Besides these four main quality characteristics of a scanner there are further significant aspects that influence the quality of digital image data. These aspects are, for example, sharpness, selective color corrections, automatic and manual color cast removal, etc. These parameters are mainly performed or influenced by the scanner software.

Development of Test Charts

When we started our work in 1998, standardisation for measuring characteristic data of scanners was just at its starting point. A lot of work for the characterisation of digital still cameras was already done and we had to find out whether some of the methods could be adapted for the analysis of scanners.

The first step in measuring any of the above mentioned characteristics was to develop a suitable test chart.

A test chart should be made of a material similar to the material of the originals, so that the measurements are not influenced by artifacts like glare due to the surface structure of the material. A second aspect is that the chart has to be better than every other usual film or print material in the specific field of test, so that the measures become meaningful.

For the SFR measurement described in Refs. [1] and [2] a testchart is needed that consists of elements with sufficiently fine detail, such as edges, lines, square waves, or sine wave patterns, as well a greyscale for the OECF determination.[3] The latter is also needed for the determination of dynamic range and noise. The two requirements usually excludes that the same material can be used. Very high resolution photographic material usually have a high gamma that makes it difficult to reproduce greyscale patches with different densities.

During the development of our method we were able to produce reflective test charts on a graphic arts paper named Agfa DDP that are suitable for scan resolutions up to 3000 ppi. This material is capable to provide the fine detailed structures with high contrast, but it is useless for the greyscale. So we had to combine it with a typical greyscale made of a different material. The development of the Working draft for the ISO standard[2] lead us to a commercially available reflective chart which is suitable up to about the same resolution of 3000 ppi. This Chart consists of sharp low contrast edges and the needed greyscale. For film scanners we currently combine a chart with the detailed structures made of holographic film, - which is suitable for resolutions up to 10.000 ppi - with a commercially available greyscale from X-Rite or Agfa which has patterns with densities up to 3.9 and 4.3, respectievly. We hope to find something similar to the reflective targets in the near future that can be produced in a mass production.

The problem we have with the actual ISO chart at the moment is that this chart is useless for the determination of dynamic range and noise. For these measures the maximum density should be equal or higher than 2.1. Due to the chart's structured matt surface the scan also shows artifacts as shown in Figure 1 with the illumination of some scanners.

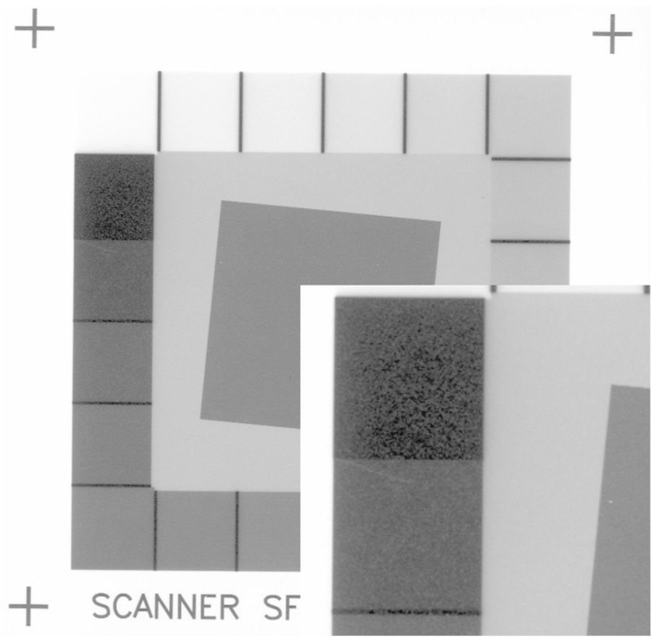


Figure 1. ISO Chart with artifacts due to the matt surface (brightened for better visualisation).

Determining Resolution

For the magazines, a nice thing to publish is a resolution given in one number. We investigated two different ways. First we used the SFR measurement of the SFR as given in Ref. 2 and second we used an USAF Testchart for visual resolution analysis, contact copied on the test material from a chromium original made by Heidenhain in Germany.[5]

The edge for SFR measurements, in combination with the grey patches for the OECF determination, and the USAF Chart are scanned at the highest given physical resolution of the scanner under test.

Figure 2. The test charts created by Image Engineering.

For the USAF chart, the structure with the highest frequency which shows well separated lines is determined by looking at the image in an image processing software like Adobe Photoshop® at a suitable magnification level of at least 100%. The frequency of the structure is the value for the visual resolution.

For the SFR measurement, the OECF curve[3] is determined from the greyscale and entered to the analysing software. The latter can be downloaded from the ISO TC42 WG18 website http://www.pima.net/standards/iso/tc42/wg18/wg18_POW.htm.

After marking the ROI (region of interest), the edge is analysed. The result is a contrast curve in relation to the original frequency. The resolution number published is calculated at the frequency where the SRF is 30%.

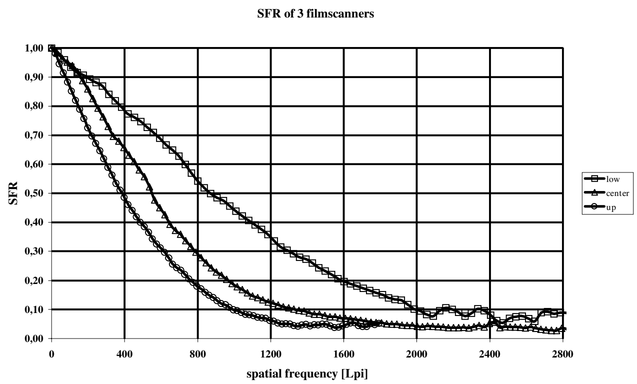


Figure 3. SFR results of three different film scanners

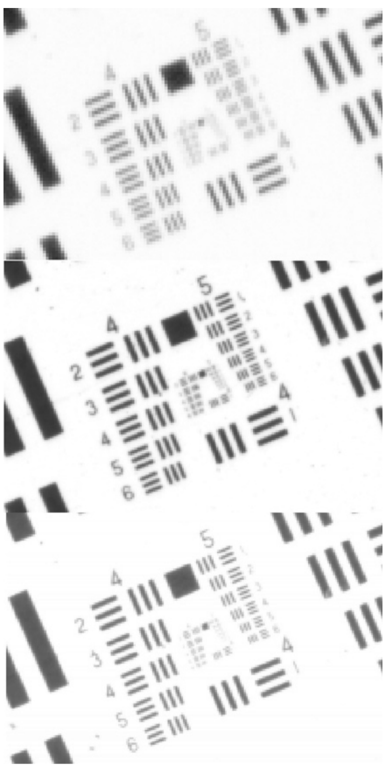


Figure 4. The related images for the visual analysis

Our experience shows that the value from the visual analysis is about the same than the value of the SFR analysis. The two main reasons why the SRF method works with scanners but causes problems with digital consumer cameras are that with scanners, unsharp masking can usually be switched off and there is no demosaicing.

Color Misregistration

A useful peripheral product of the SFR algorithm is the color misregistration of the scanner.[6] When calculating the line spread function, the position of the maximum can be determined with a high accuracy of about 1/10 of a pixel. The Kodak SFR software stores the result together with the SFR analysis.

Checking the Resolution at Different Places of the Scanning Field

To check wether the resolution is even over the scanning field, the SFR or visual tests can be performed at different places. In case there is a problem with different resolutions at different places, the geometric positioning of even resolutions give a hint on the kind of problem that has to be solved. For example a not accurately adjusted mirror or a mechanical problem.

A Different Approach

A slightly different approach to measure the resolution was developed by Agfa with their 'Field Quality Check Guide'. This guide was created for product supporters to check the scanners for possible problems and to compare the scanners with the related products of Agfa's competitors. The Agfa target consists of patches with horizontal and vertical lines arranged in different frequencies. A scan with the maximum physical resolution is followed by the determination of contrast for the highest visible frequency using the histogram of Adobe Photoshop®. The method seems to be suitable and minimum values for the contrast help to verify whether a scanner is in a given quality range or not.

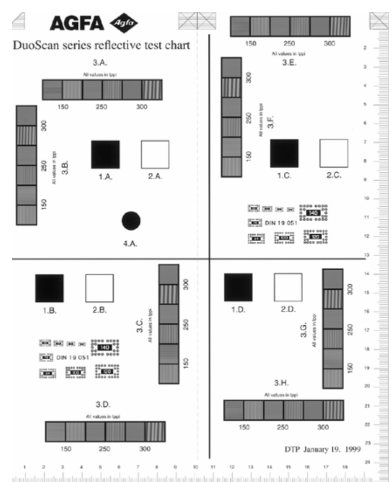


Figure 5. Agfa's 'Field Quality Check Guide' Target

Determination of the Dynamic Range

To prevent a number of meaningful words for the physical characterisation of scanners from being misused for marketing aspects, standards for a number of so far not standardised quality values should be created in the near future. Looking at technical specifications of scanners does not tell the user much about the quality of the images achieved by a scanner. What, for example, does the color depth of a scanner tell the user? Is it the maximum capable contrast in the original? Is it the bit depth of the A/D converter, or the number of possible colors in the image? Is the latter be produced by some bit enhancement algorithms or other kinds of calculations?

One of the values that should be standardised is the term ‘dynamic range’. A possible definition can be: the scanner dynamic range is the difference of the minimum unclipped density of an original to the maximum density of an original that can be reproduced with a signal-to-(total)-noise ratio - including temporal and fixed pattern noise - of at least 1.

We tried to measure the dynamic range that fits this definition by scanning a greyscale with a maximum density higher than the expected maximum density of the scanner and adjusting the gamma curve of the scanner software in a way that the fields with the higher densities can be best differentiated. This is usually reached by adjusting the gamma of the digital output to about 1.5. The grey patches are automatically analysed like the OECF patches by using a self written Adobe Photoshop® plug-in. This plug-in writes the mean values and the standard deviation for the red, green, and blue channels as well as for the Y, R-Y, and B-Y value of every patch into a text file. For further analysis, this text file can be exported to a program like Microsoft Excel® or Matlab®. The dynamic range can be determined from the OECF – including the gamma adjustment. The signal to noise ratio is calculated as described in Section 6.2 of Ref. 7.

Transparent greyscales are commercially available with maximum densities up to 4.3.

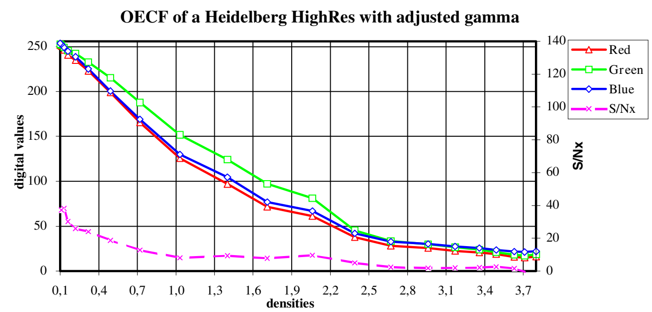
For 35mm film scanners, there is still a problem to produce spectrally neutral greyscales with suitable maximum densities. The maximum densities we reached with typical black and white film material, which can be exposed in an image recorder, are around 3.0.

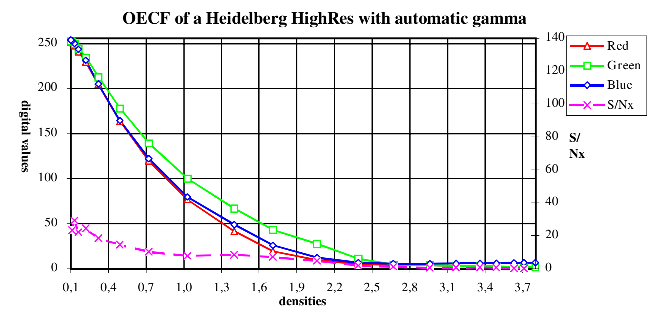
Our results of measuring the dynamic range are consistent with the visual analysis of the scanned greyscales and scanned test images. Looking at values given in the specifications of midrange scanners, our results match the specifications, in most cases with an accuracy of +/- 0.1 densities. Looking at the specifications of scanners for the consumer market, one can conclude that most manufacturers do not provide accurate data.

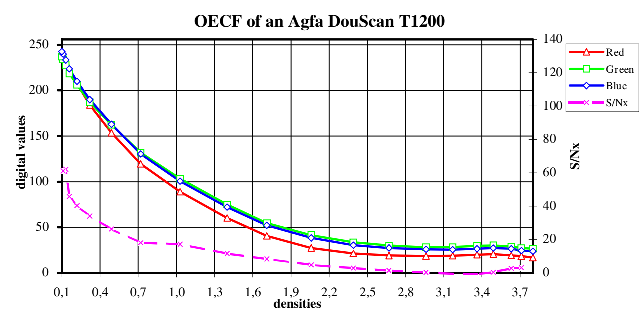
Since the measurement of the dynamic range is simple, and the given value gives the user an impression of one of the most important image quality aspects of a scanner, it should be mandatory for manufacturers to report it.

Noise

We still have some difficulties measuring noise. To measure noise at different density levels, the patches of the greyscale need to be very homogenous They should be scanned at the maximum physical resolution, or at least at a level where no interpolation has an influence on the result. With our greyscales used for dynamic range measurements, we have trouble with the grain structure, especially in the lighter patches. We first wondered where the high standard deviations, meaning absolute noise level, for these lighter patches came from. Taking a closer look we found that the reason was the grain structure of the photographic material. Especially at high resolution (> 1500 ppi), the structure is often clearly visible in the scans. At the present time we have no idea how to produce a greyscale on photographic material that will enable us to measure noise. This grain structure seems to have no influence on the results of the dynamic range measurements, using our method, because it seems to get less important at higher densities.







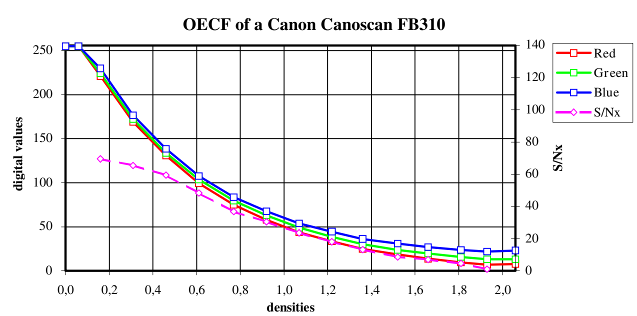


Figure 6. Typical OECFs for measuring dynamic ranges of scanners.

In the near future, a scanner standard similar to the one for digital cameras[8] should be developed keeping the above mentioned problem in mind.

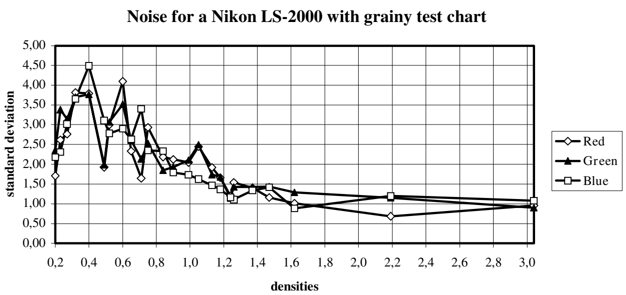


Figure 7. The measured absolute noise levels with a typical testchart using a Nikon film scanner.

Conclusions

The resolution can be measured using a test chart for visual analysis but due to possible aliasing artifacts, which decrease the accuracy, the SFR method is more precise. In contrast to our results with digital cameras the SRF method works well for all scanners for which the unsharp masking can be switched off. The reported SFR should be an average of at least 4 measurements because the SFR can vary. In most cases this variation is caused by an inaccurate positioning of the original in the focal plane of the scanner. This in some cases is a difficult thing to do.

The OECF measurements with a high gamma value give significant information about the scanners capabilities to reproduce high contrast originals. Noise measurements are necessary for the exact determination of a dynamic range but the grain structure of the typical greyscales causes problems.

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Biography

Dietmar Wueller studied photographic sciences from 1987 to 1992 at the Fachhochschule in Cologne (Germany). Studies were followed by scientific work in the area of Light- and Colour measurement at the Institute for Light and Building Technique in Cologne and work in a prepress company. In 1995 he opened a training and testing center for digital image processing.