

# COLOUR CALIBRATION PROCEDURE FOR SCANNERS – A NEW FORMULA – OUTSTANDING REPRODUCTION OF COLOURS

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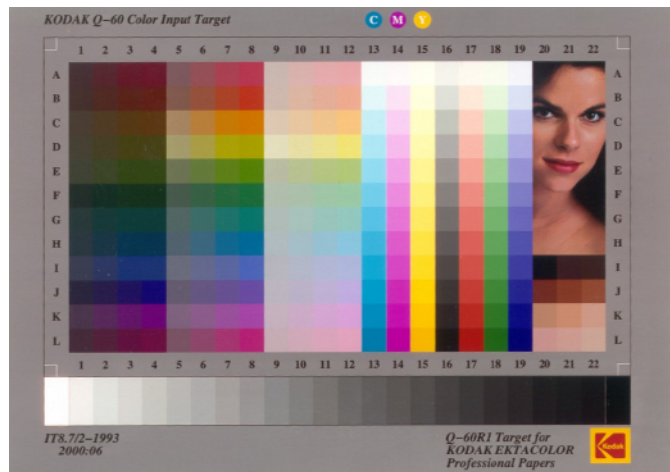
**Abstract – This paper describes a new colour calibration procedure for scanners and other input devices based on a new non-linear formula in conjunction with the standard DIN 6176 colourspace and IT8.7/2 targets. In this procedure a vector field is created, which associates each colour of the input colourspace with its own translation vector. This is the main advantage of this procedure, which allows attending local distortions of the colourspace in difference to approaches using global approximations. The simple procedure is successfully tested for a variety of real images (portrait photos, reproduction of paintings, ...), the results will be demonstrated.**

## INTRODUCTION

Scanning of coloured targets with desk scanners normally results in visible falsifications of colour, contrast and brightness. To minimize these falsifications and to provide a better basis for potential subsequent printing, a desk scanner can be calibrated with a reflective colour input target (ANSI Standard IT8.7/2, figure 1) combined with appropriate software.

An IT8.7/2 colour input target has up to 288 well defined coloured patches and for each of these patches the spectrophotometric measured reference colour value is known. These reference values are usually shipped together with the colour input target. The colour calibration procedure described in this paper uses standard IT8.7/2 colour input targets but also other proprietary colour input targets can be potentially applied.

The colour input target is used to measure the scanner's falsification in reproduction of colours for each of the patches (further referred as colour differences). An approximation for the complete uncalibrated colourspace can be done with an appropriate mathematical model in usage of the measured colour differences. This model and the quality of the colour input target are essential for the quality of the resulting scanner calibration.



**Figure 1: Kodak IT8.7/2 colour input target**

## PROCEDURE OVERVIEW

The calibration procedure is separated into two steps. The first step creates a colour calibration profile giving a translation vector for each of the coloured patches and the second step performs the backward projection of scanned images using this colour calibration profile for the evaluation of all colours of the input colourspace (16777216 colours of sRGB).

### Creation of colour calibration profiles

The creation of colour calibration profiles is fully automated. The measurement of the colour values of each of the scanned colour input target's patches are done by a set of image processing procedures. The combination of measured colour values and reference colour values represents the profile and can be saved as XML-file with the current implementation.

### Backward projection

During the backward projection, there are several colourspace conversions from the input colourspace of the uncalibrated scanned images to the working colourspace in which the colour transformation is done and finally to the output colourspace of the calibrated scanned images (figure 2).

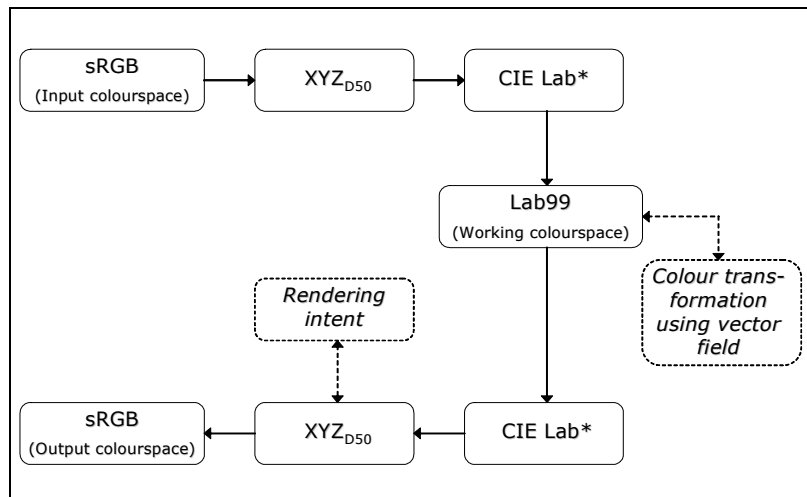


Figure 2: Colourspace conversions

These colourspace conversions are required, because the colour transformation is based on colour differences and has to be done in a working colourspace which provides a high level of equidistancy of colour differences. The standard DIN 6176 colourspace (also referred as Lab99) is a modification of the CIE Lab\* colourspace and is designed to provide a higher level of equidistancy of colour differences than CIE Lab\* [1].

sRGB is widely used and has been chosen as the input and output colourspace in the current implementation, but of course it is possible to use other colourspace for that.

In this paper the rendering intent will not be discussed, but it should be noted, that all results given here are using the “absolute colourimetric rendering intent” (ICC definition, [2]), because of measurement purposes.

## THE COLOUR TRANSFORMATION IN DETAIL

The innovation of the calibration procedure described in this paper is the colour transformation formula, which creates for each colour of the uncalibrated colourspace its own translation vector leading to the calibrated colourspace.

A colour in the working colour space can be described as vector:

$$\vec{C}_{Lab99} = \begin{pmatrix} L99 \\ a99 \\ b99 \end{pmatrix}$$

The vector between two colours will be defined as colour difference vector:

$$\vec{\Delta E}_{C1/C2} = \vec{C}_2 - \vec{C}_1 = \begin{pmatrix} L99_{C2} - L99_{C1} \\ a99_{C2} - a99_{C1} \\ b99_{C2} - b99_{C1} \end{pmatrix}$$

and the colour difference will be defined as the magnitude of the colour difference vector:

$$\Delta E_{C1/C2} = |\vec{\Delta E}_{C1/C2}| = \sqrt{(L99_{C2} - L99_{C1})^2 + (a99_{C2} - a99_{C1})^2 + (b99_{C2} - b99_{C1})^2}$$

The colour calibration profile mentioned before represents a set of colour difference vectors. For each of the coloured patches  $i$  of the IT8 target such a vector was created from the reference colour  $\vec{Ref}_i$  and the measurement colour  $\vec{Meas}_i$ . To create the vector field, the colour transformation formula has to compute an approximation as translation vector for each colour of the uncalibrated colour space on the basis of the well known colour difference vectors from the calibration profile. In Figure 3 this process is schematically illustrated in 2D with a calibration profile consisting of two colour difference vectors. Each colour difference vector  $\vec{\Delta E}_{Ref_i / Meas_i}$  from the calibration profile will be weighted and added to the colour's position vector  $\vec{C}$ . The weighting depends on the colour difference between  $\vec{Meas}_i$  and  $\vec{C}$  – the smaller the difference the higher the weighting (figures 3-1, 3-2).

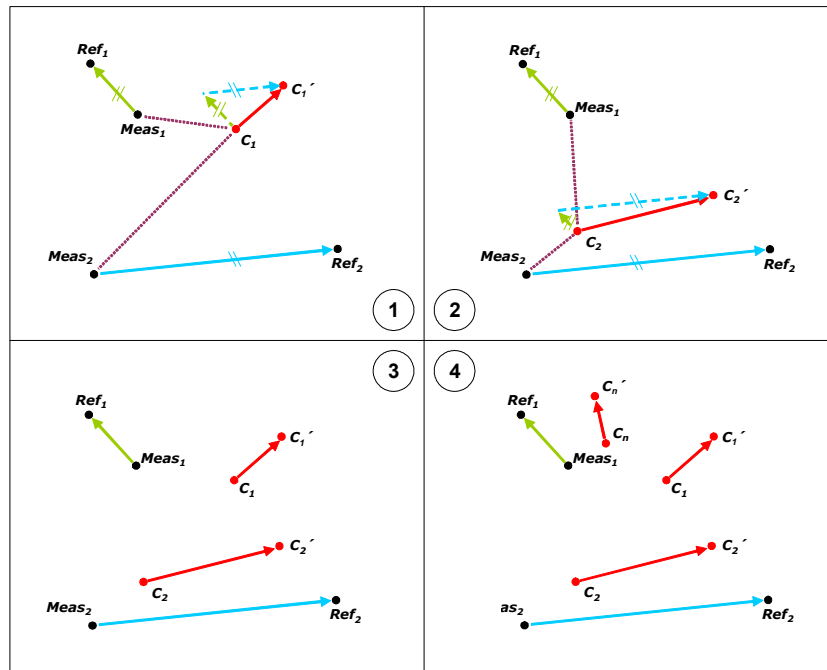


Figure 3: Creating a vector field

For each colour of the uncalibrated colour space ( $C_1, C_2, \dots, C_n, \dots$ ) is the translation vector computed in this way – a vector field has been created (figures 3-3, 3-4).

The colour transformation formula  $f$  reads as follows:

$$\vec{C}_j^r = f(\vec{C}_j) = \begin{cases} \vec{Ref}_i & \text{if } \vec{C}_j = \vec{Meas}_i \\ \vec{C}_j + \frac{\sum_{i=1}^I (g(\Delta E_{Meas_i/C_j}) \cdot \vec{\Delta E}_{Ref_i/Meas_i})}{\sum_{i=1}^I g(\Delta E_{Meas_i/C_j})} & \text{if } \vec{C}_j \neq \vec{Meas}_i \end{cases}$$

correction term

$I$ : Number of colour difference vectors in profile

with the weighting function  $g$ :

$$g(\Delta E_{Meas_i/C_j}) = \frac{1}{(\Delta E_{Meas_i/C_j}^2)^2} = \frac{1}{((L99_{Meas_i} - L99_{C_j})^2 + (a99_{Meas_i} - a99_{C_j})^2 + (b99_{Meas_i} - b99_{C_j})^2)^2}$$

## RESULTS

To evaluate the quality of the described colour calibration procedure and its colour transformation formula, there are several analysing strategies. In this paper, there will be two different strategies described. First, there is the analysing of quality using one standard colour input target and one half (as part) of its coloured patches for the creation of the calibration profile and the other half of its coloured patches to determine the calibration quality. The second strategy is to scan a photo with two different scanners and to compare colour differences between the uncalibrated scan results and between the calibrated scan results. It has to be noted, that all colour differences  $\Delta E$  are given in CIE Lab\* colourspace (CIE 1976 definition) for comparability with other publications.

### Analysing of quality using one IT8.7/2 target

An AGFA IT8.7/2 target has been scanned by an ordinary scanner without any scanner calibration. The average colour difference over all coloured patches has been determined as  $\Delta E_{All} \approx 5.88$ .

In figure 4, there is one useful selection of coloured patches for the profile creation illustrated (1<sup>st</sup> half: H1). The average colour difference over all patches of H1 has been determined as  $\Delta E_{H1} \approx 5.83$  and over all patched of H2 (2<sup>nd</sup> half – complement of H1) it has been determined as  $\Delta E_{H2} \approx 5.92$ .

After back projection of the target's image with the colour calibration profile created from H1, the following average colour differences have been determined as  $\Delta E_{All} \approx 1.60$ ,  $\Delta E_{H1} \approx 1.11$ <sup>1</sup> and  $\Delta E_{H2} \approx 2.08$ .

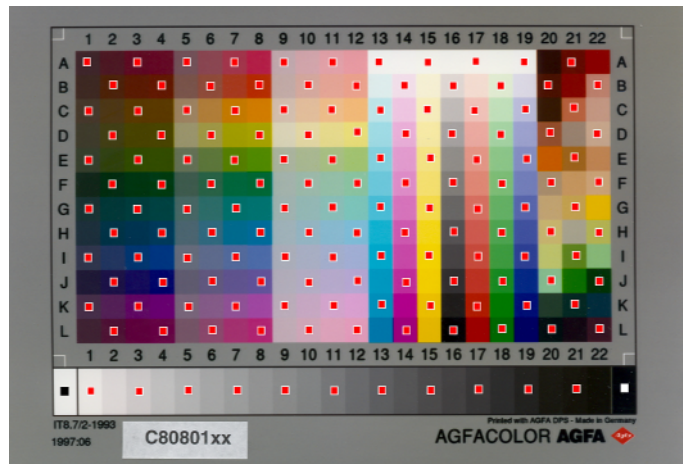


Figure 4: Selected patches of an AGFA IT8.7/2 target

<sup>1</sup> Cannot be 0, because of clipping out-of-gamut colours and quantization.

This proves that colours which are not defined in the profile have been significantly improved by this scanner calibration procedure.

### Analyzing of quality using two different scanners

This analysis shall prove that the calibration procedure developed is able to harmonise the scan results of two different scanners (and hypothetically one of the scanners could be an ideal scanner without any falsifications). In figure 5, there is a photo of the “Capitol Rotunda Ceiling” (Capitol, Washington D.C., USA), which was scanned with two different scanners. The scan results were combined with a diagonal cut. On the left, there are the uncalibrated scan results and on the right there are the calibrated scan results. The colour differences between the uncalibrated scan results are obvious and the colour differences between the calibrated scan results nearly disappear<sup>2</sup>.



**Figure 5: Uncalibrated (left) and calibrated (right) scans of a photo showing the "Capitol Rotunda Ceiling"**

In figures 6 and 7, there are the colour differences shown in detail. At the fine-drawn darts the colour difference between the uncalibrated scan results have been determined as  $\Delta E_{\text{Figure6 (uncalibrated)}} \approx 8.83$  and  $\Delta E_{\text{Figure7 (uncalibrated)}} \approx 9.70$ , between the calibrated scan results they have been determined as  $\Delta E_{\text{Figure6 (calibrated)}} \approx 2.62$  and  $\Delta E_{\text{Figure7 (calibrated)}} \approx 3.22$ .



**Figure 6: Colour differences of uncalibrated (left) and calibrated (right) scans in detail**

<sup>2</sup> Because this paper is printed in black white, the colour differences in Figures 5-8 have been boosted (contrast, gamma) by the author to become visible. In the coloured version of this paper the colour differences have not been boosted. It can be requestes by e-mail as pdf-file.

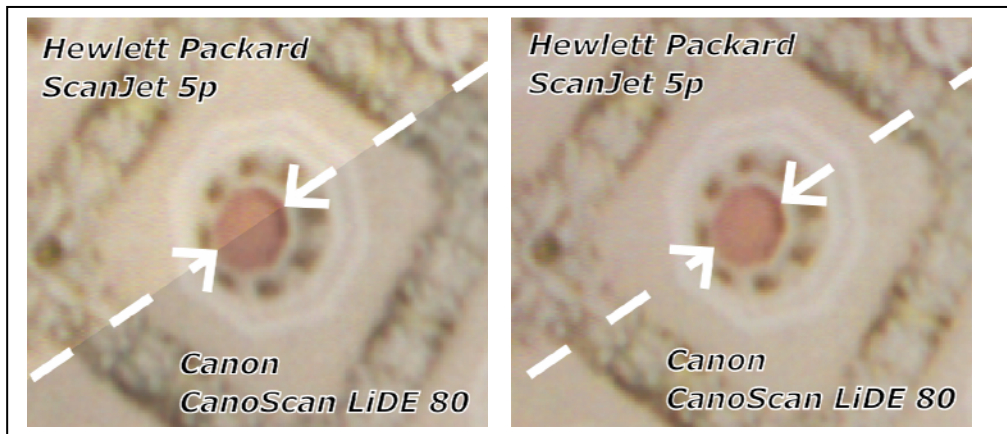


Figure 7: Colour differences of uncalibrated (left) and calibrated (right) scans in detail

This is a significant harmonisation of colour, lightness and contrast of the scan results.

### A short comparison with an other colour calibration software

To compare the described colour calibration procedure with other colour calibration software, the uncalibrated scanned photo has been back projected with AGFA ColorTune software. This software creates and uses ICC profiles for calibration. The calibration results of AGFA ColorTune in figure 8 are showing a good approximation of colours.

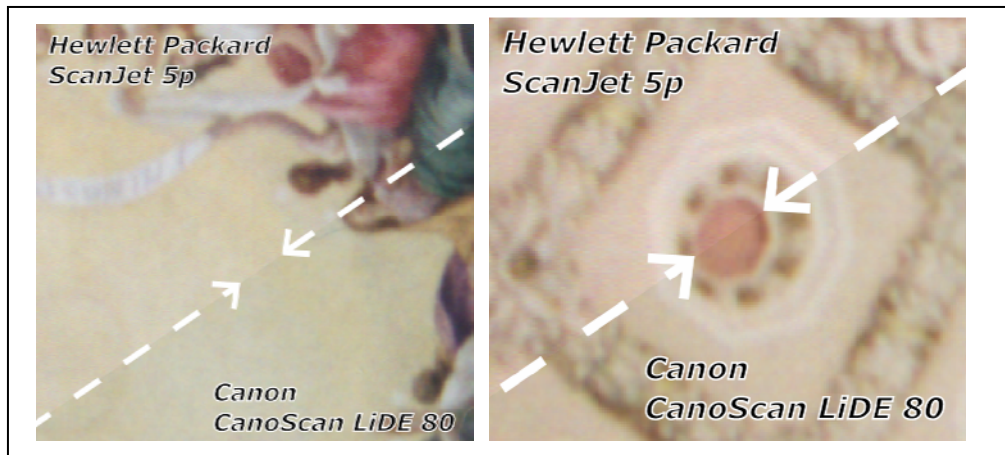


Figure 8: Colour differences of AGFA ColorTune calibrated scans in detail

The measured colour differences between the scan results are  $\Delta E_{\text{Figure8 / left (calibrated)}} \approx 4.01$  and  $\Delta E_{\text{Figure8 / right (calibrated)}} \approx 4.59$ . The comparison shows, that the procedure developed gives a really remarkable improvement of calibration quality.

### References

- [1] Hendrik Buring, "Eigenschaften des Farbenraumes nach DIN 6176 (DIN99-Formel) und seine Bedeutung für die industrielle Anwendung", [http://kb-bmts.rz.tu-ilmeneau.de/gcg/Vortr\\_02\\_pdf/GCG\\_%202002\\_%20Buring.pdf](http://kb-bmts.rz.tu-ilmeneau.de/gcg/Vortr_02_pdf/GCG_%202002_%20Buring.pdf), 2002, p. 1
- [2] ICC (ed.), "Specification ICC.1:2001-12", <http://www.color.org/newiccspec.pdf>, 2002, p. 83