News no. 5

Munich, December 2007

Why do colours sometimes fail to match visually when they match instrumentally?

Andreas Kraushaar

Using the proper calibration, an outstanding colour accuracy, which lies within the measuring accuracy of modern handheld colour measuring devices, can be achieved today with the current generation of proof systems.
It is thus possible, for example, to match an individual offset print with a maximum colour difference of approx. ΔE^*_{ab} =1. The variations of a typical print run are naturally more extensive. In this scenario, the practitioner expects an almost perfect visual match between the proof and the production print. This, unfortunately, is sometimes not achieved in production – proof and production print can often differ distinctly, in spite of minimum ΔEs.

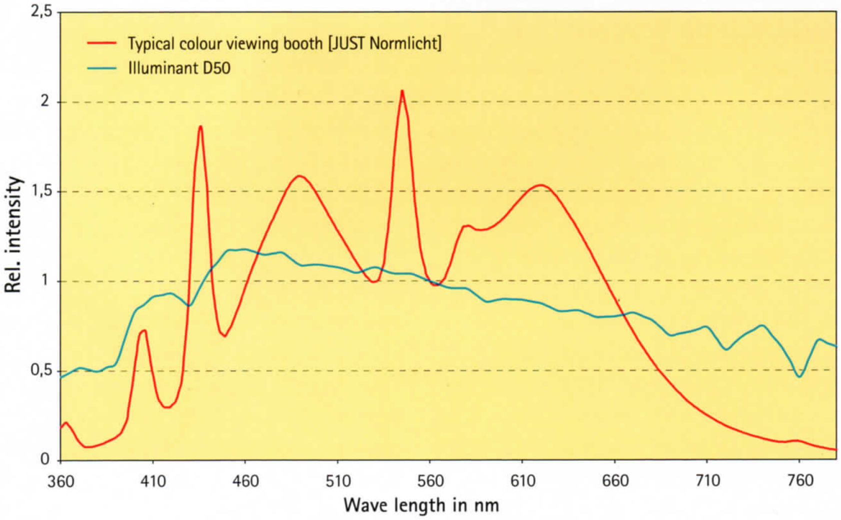

Fig 1: Relative radiant power distribution for illuminant D50 [blue] and a typical colour viewing booth.

Problem description

For many years, the accuracy with which off-press and on-press proofs were produced was poorer than the accuracy of the colour measuring devices available. A remaining visual difference between proof and press sheet was generally attributed to that inaccuracy. The practitioner had to accept the promise that the visual match will get increasingly better with smaller CIELAB-colour differences between proof and production print.
Today, with the current generation of proofing systems and with the proper calibration, an accuracy that lies within the measurement accuracy of modern handheld colour measurement devices can be achieved. The latter was examined in Fogra Research Report [Nr. 52.034]. It displays a CIELAB colour distance ΔE^*_{ab} between 0.5 and 1, taking into account the variability of typical offset print samples.
It is possible for high-quality proof printing systems, when using just one measurement device, to attain a colorimetric accuracy that cannot be improved any more measurably. Here is an example: One takes a randomly selected offset print that includes the ECI2002 test chart. This is measured spectro-photometrically. A proof matched to this print can be reproduced with a maximum colour deviation of ΔE^*_{ab}=1 using the colour patches of the ECI2002. In other

words this means that proof and production print do not show significant colour differences. Accordingly, proof and production print should be indistinguishable – when observed by the standard observer and under standard viewing conditions. This is equally valid for two comparable proof prints.

Colour matching practice

Distinct visual differences are still observed in the colour matching practice: proof prints that are within the pertinent tolerances, such as the Ugra/Fogra media wedge stipulated in the MediaStandard Print 2006, may not perfectly match with the production run. This situation is independent of the used colour difference formulae such as CIELAB, CIEDE94 or CIEDE2000.
Potential buyers of a proofing system primarily evaluate it based on its ability to produce a proof print that simulates the production print accurately, and finally make a decision on the grounds of their visual judgement. Manufacturers of proof printing systems are thus forced to establish a visual correction, which inevitably impairs larger measurable differences. This leads to situations that occur, like for example at the Digitalproof Forum, an event for the comprehensive assessment of proofing systems, organised by the bvdm and ECI. Two proof prints are made on the basis of an offset print; one based on objective colour measurement values, while the other is matched visually. This is most counter-productive for the purpose of a standardised workflow. Printer, proofing system manufacturer and above all, the customers of print products need a simulation or reproduction of the final print whose quality is objectively accessable.

Cause study- Lighting

The most obvious reason for lacking agreement between the measured and the visual colour difference lies in non-standard lighting. Here the lighting in typical viewing booths used for colour matching and the one used in colour measurement devices differ significantly from the CIE standard illuminant D50.
Various handheld measuring devices measure using filament incandescent [bulb] or LED light that by nature possess a much smaller portion in the blue and UV region of the spectrum than prescribed for standard lighting D50 [5000 K]. The second factor comprises the light present at the time of the colour matching, which as a rule neither concurs with the standard lighting type D50 nor with the lighting used during colour measurement. Standardised light boxes and colour matching cabins are mostly equipped with fluorescent lamps, which have a colour temperature of approx. 5000 K, though they omit another relative spectral power distribution – see fig. 1.
The different percentages of UV in measurement and colour viewing are of great importance, especially in the context of the different amounts of optical brightener in proofing and production papers. The equipment of adjustable UV LEDs in colour measurements devices and colour matching cabins promise interesting potential for improvements in that field.

Another building block of the solution - "basic colorimetry"?

Firstly, CIE colorimetry as the basis must be explained to be able to analyse further reasons for the disagreement between measurement values and visual judgement. It is of fundamental importance in, and key for possible solutions for the understanding of this problem.
For decades now, the printing industry has been using the standards of the International Lighting Commission CIE [French: Commission Internationale de l'Eclairage], established in 1931. The CIE system allows the specification of colour matches for a standard observer using colour matching functions. These colour matching functions for normal human observers are the fundamental basis of colorimetry and date back to experiments performed by Wright and Guild. In this experiment, test persons adjusted a non-textured test colour patch against a non-textured adjoining reference colour patch with the help of three controls [for the red, green and blue constituents of the test colour]. The matching field subtending a visual angle of 2°.
The average of all test persons was transformed to the so-called "CIE 1931 2°-normal observer". Though, two colours that have the same CIEXYZ tristimulus value cannot be differentiated from one another under the conditions described above. The similarity of colours with the same colour values is a fundamental basis of the "basic colorimetry". In contrast, "advanced colorimetry" concerns itself with the appearance and/or perception of colours in the human brain where colours are not necessarily identical, if their CIEXYZ values are virtual identical. In fact, further factors like e.g. the ambient lighting and the image structure also contributes to the final judgement. Based on this, it becomes obvious that colour appearance is dependent on many factors.

› To be continued in Fogra News no. 6

Ideen eine Zukunft geben

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Continuation of News no. 5

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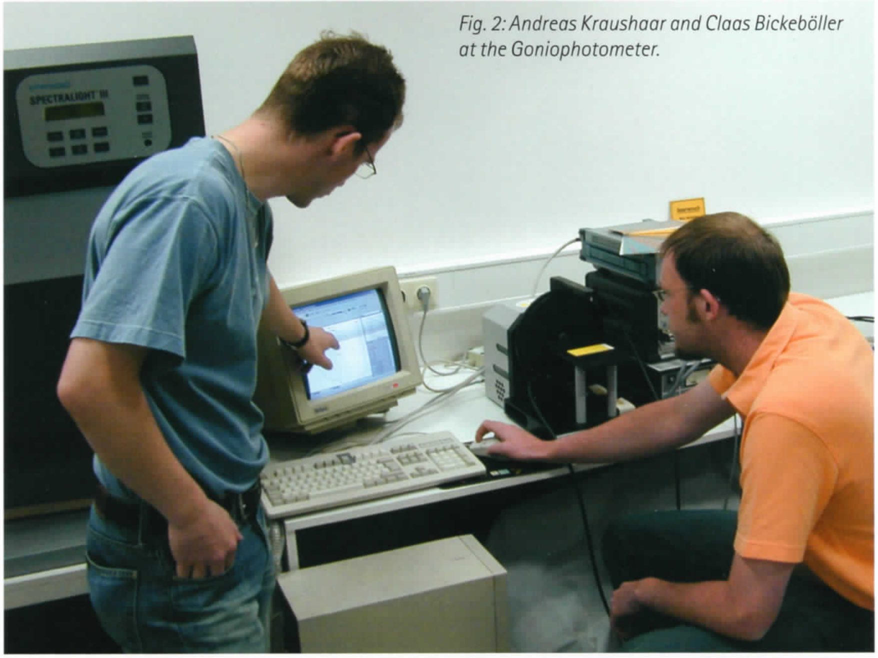

Fig. 2: Andreas Kraushaar and Claas Bickeböller at the Goniophotometer.

[...] This is also evident in the colour definition according to DIN 5033:
"Colour in the sense of a standard is a sensation that is delivered by the eye, i.e. a facial perception. The colour is that facial perception of a part of the field of vision that appears unstructured to the eye, by which this part can solely be differentiated from a simultaneously observed, equally unstructured adjoining area; when observed through one stationary eye."
The colour difference is thus the difference in perception [german: Empfindung]; and that's the reason for the "E" in ΔE^*_{ab}.
Based on the co-relations described, one can already recognise that in the illustrated case of colour matching of a proof and an offset-print some requirements of CIE colorimetry are violated. The following factors and thus possible sources of error are to be considered for the disagreement between the colour measurement values and the visual assessment:

Observer

Many have questioned that the 1931 colour matching functions are not the best representation of the human visual system's cone response
The spectral sensitivity of the [different] cone types of the retina of human observers vary considerably from person to person. This is the reason for the so-called observer metamerism. It identifies the case in which an observer perceives two colours as identical, while another observer sees a colour difference. This variability among observers without any kind of colour deficiency is depicted in Fig. 3. Here a set of 24 typical colour matching functions, compiled by Hill [RWTH Aachen] can be seen. It contains the 1931 2° – as well as the 1964 10° – normal observer.

Size of the field of view

The third error source has its cause in the dependence of colour vision on the size of the field of view. As explained above, the normal observer is valid only for the colour matching of objects that are compared at an angle of approx. 2°. These are about the size of a thumb of an outstretched hand. In concrete terms, this of course depends on the size of the object of the particular subject to be observed.
Initial tests at Fogra have shown that the application of the 1964 10°- normal observer, e.g. for the calibration of a proof printing system, indicate the possibility of promising results.

Surface effects

At this point one must mention one more group of error sources that can be considered for the inadequate concurrence of colour measurement values and visual assessment. Differing properties of the proofing substrate in comparison to production paper, like, for example, texture, gloss or opacity can be ranked among them. A goniophotometer can be used for the assessment of these parameters. A detailed handling of these factors, as well as the entire "optical brightener problem" would go beyond the scope of this article. The interested reader is referred to Fogra research report [Colour management for printing on optically brightened paper, No. 32.144].

Conclusion and perspective

The continuous use of measurement technology on the basis of recognised industrial standards like e. g. the ProcessStandard Offset Printing [PSO] enable a reliable and constant high quality from data creation up to the finished print product. However it must sometimes be considered that there might be a disagreement between of colour measurement values and the visual assessment which throws a huge challenge into the direction of quality management and thus for standard-conformant print production. This is valid even more in the times of rising "drive" for quality.

Fogra is taking on this challenge through intensive research on this subject. The first step will be to examine in detail the error sources discussed here as well as their individual contribution to the over-all effect. Building on that, the angle-dependent characterisation of print-typical surfaces [prints, proofs] will be addressed.

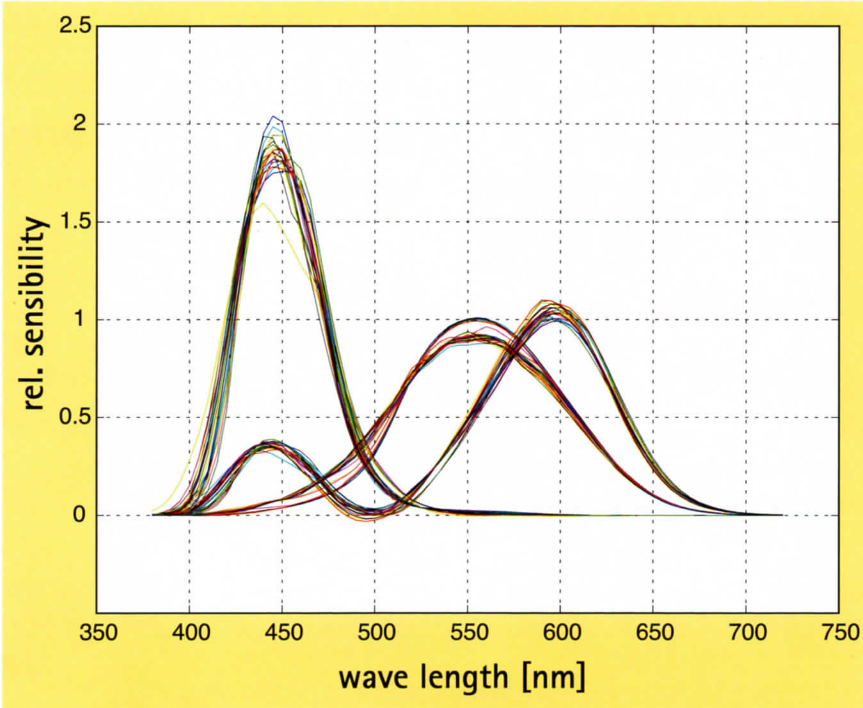

Fig. 3: 24 different colour matching functions according to Hill.

Further, Fogra is working on methods that make it possible for the practitioner to produce proof prints that result in better visually proof to print matches.