

ESTIMATION OF THE REAL COLOUR GAMUT

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ABSTRACT

In the present work, we have assessed the gamut of colour surfaces currently available for different colour technologies. Their colour reproduction capability have been analyzed by plotting CIELAB data under the illuminant D65 into constant lightness and hue-angle planes to be compared with MacAdam limits which define the human colour perception. Moreover, we have compared our colour collection with Pointer's real world surface, the best-known definition of the gamut of real world colour surfaces, and with a reference colour gamut defined by the technical committee ISO 12640-3. After this comparison, we checked that the current colour gamut do not reach the MacAdam limits, therefore it is necessary to develop new dyes, pigments and substrates in order to try to reach the perceptible limits of the human eye. On the other hand, Pointer's real world-surface should be updated taking into account the current colour gamuts. However, a deep study is necessary in order to define a new reference colour gamut. We have found coloured samples outside the ISO colour reference gamut which could be used to provide a real colour surface gamut.

Keywords: colour gamut, real colour surface, colour technology, colour solid

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INTRODUCTION

In colour reproduction, it is generally important for different reasons to know beforehand the colour gamut of reproducible colours¹. Some industries applying industrial colorimetry, such as textiles, plastics, leather, paints, usually keep a data base with their colour gamut, which only occasionally, following commercial criteria and fashion, is reproduced in a sampler to allow the customers to judge the colour generating capabilities of the manufacturer. However, few enterprises study whether their colour gamut reaches the MacAdam limits or whether it covers more or less homogeneously the Rösch-MacAdam colour solid¹.

In 1980, M.R. Pointer was interested in the colour gamuts analysis of different colour reproduction systems². He studied some colour gamuts belonging to different colour technologies. He defined a maximum gamut of real colours from four colour gamuts; 310 colour from the Matte Munsell Atlas; 768 colours from the Munsell Limit Colour Cascade; 1393 colours from ink and pain samples, textiles, coloured plastics and papers; and 1618 coloured samples tabulated by Royal Horticultural Society. To define the real colour surface he showed the coloured samples at 36 hue angles (h) from 0° to 350° at a 10° interval and 16 lightness (L*) levels from 15 to 90 at a 5 unit interval and also he compared this real colour surface with the MacAdam limits. In 2002, Pointer retook this subject, asking for the collaboration of all persons interested in the matter, to generate a large database of colour gamuts in current industry³.

On the other hand, the International Organization for Standardization (ISO) published in 2003 a report⁴ which accumulated a colour collection of real objects building a database that are suitable for evaluating the colour reproduction. And also, ISO 12640-3⁵ defined a "reference colour gamut" from this database and other series of new colour data measured from printed samples.

Recently, there have been different technological advances in the colorimetric properties of the substrates and the primary colorants. Therefore, it seems suitable to consider current colour gamuts together the ISO database⁴ in order to evaluate the capability of the colour reproduction systems comparing these gamuts with the MacAdam limits. That is, we are particularly interested in the comparison between the colour gamuts of different industries and the MacAdam and Pointer limits and in those aspects related to how the colour solid is filled, whether homogeneously or leaving certain void regions. But also, we compare the own colour gamuts with the “reference colour gamut” defined by the ISO 12640-3⁵ in order to know if this reference colour gamut can be used as “real-world colour surface” in the same way that the Pointer’s real-world colour surface, since for many applications (ICC profiles, development of new colour appearance model, colour management, etc.) it is very important to know this real-world colour surface.

MATERIALS AND METHODS

We used different colour gamuts in order to evaluate the current colour technologies and compare with the MacAdam limits and the Pointer’s real colour surface. These gamuts were:

- Colour gamut associated with textile sector provided by the company Colortex (Alicante, Spain) with 564 samples.
- Chromatic chart belonging to the company Valentine (Barcelona, Spain) with 1760 samples.
- Collection of NCS colour charts composed of 1750 samples.
- Munsell colour system composed of 1269 samples
- Printed samples with the HP DesignJet 120 printer using different kind of paper, with different grammage and finishing.
- Printed samples using different printing technology: HP 4600 Laserjet, HP 6600 Indigo, Xerox Docucolor 12, HP 1220 Inkjet, Heidelberg GTO y Helioklischograph K405; with the same substrate (100 g/m² and matte or non-coated appearance)
- A new ISO standard on Graphic Technology—Standard object colour spectra database for colour reproduction evaluation⁴ divided into different categories and sub-categories:

(1) Photographic materials

- a. Transparencies
- b. Reflection prints

(2) Offset prints

(3) Computer colour prints

- a. Dye sublimation printer
- b. Electrostatic printer
- c. Ink-jet printer

(4) Paint (not for art)

(5) Paints (for art)

- a. Oil paints
- b. Water colours

(6) Textiles

- a. Synthetic dyes
- b. Plant dyes

(7) Flowers and leaves

(8) Outdoor scenes (Krinov data except for flowers and leaves)

(9) Human skin

- a. Bare North Asian skin
- b. Foundation-applied North Asian skin
- c. Bare South Asian skin
- d. Foundation-applied South Asian skin
- e. Bare Caucasian skin
- f. Bare Negroid skin

Apart from the ISO gamut and the printed samples with the HP DesignJet 120 inkjet printer, the spectral reflectance, $\rho(\lambda)$, of each patch was measured using a Minolta CM-2600d spectrophotometer. For the printed samples with the HP DesignJet 120 inkjet printer a Gretag Spectroscan Spectrolino spectrophotometer was used to obtain the spectral reflectance. The spectral reflectance of the ISO gamut was taken from the database of the technical report. The tristimulus values XYZ under illuminant D65 and the CIELAB descriptors $L^* a^* b^* C_{ab}^* h_{ab}^*$ were computed for each sample.

The work involves evaluate colour reproduction capability of current colour technology analyzing by plotting CIELAB data under the illuminant D65 into constant lightness and hue-angle planes to be compared with MacAdam limits which define the human colour perception. Therefore, for this study we have taken into account the MacAdam limits under D65⁶ and Pointer's real-world colour surface² and the reference colour gamut⁵ previously transformed by the CAT02 transform of the CIECAM02 colour appearance model⁷. And then, we select some constant lightness L^* and constant hue-angle h_{ab}^* profiles in which the samples of each colour gamut and the MacAdam and Pointer loci and the reference colour gamut must be plotted. Thus, once all the patches of each gamut colour are measured, the CIELAB data are grouped in parallel ordering them by increasing lightness L^* and hue-angle h_{ab}^* . Then, CIELAB data are plotted into constant lightness planes with a variance of $\Delta L^* = 5$. On the other hand, the same CIELAB data now ordered by hue are plotted into constant hue-angle planes with a variance Δh_{ab}^* related to the hue-angle range of the major hues of the Munsell notation (R, YR, etc).

RESULTS

After being grouped the data, we plot all the samples in constant lightness profiles in order to compare with the MacAdam limits, Pointer's real-world surface and the reference colour gamut defined by the ISO technical committee. The total number of coloured samples used in this work was more than 110,000 belonging to different colour technologies of which 73,259 samples correspond to our colour collection and the rest corresponds to SOCS gamut. In the next figure (Figure 1) each coloured sample is represented by gray points. The solid line corresponds to the MacAdam limits, the red solid line is for the Pointer's real-world colour surface and the blue solid line corresponds to the ISO reference colour gamut. For all the lightness profiles the colour gamut composed by all the measured samples is greater than Pointer's real-world surface. In fact, Pointer's real-world surface does not included any samples with a lightness value lower than $L^*=15$ and higher than $L^*=95$, but we check there are coloured samples in these lightness profiles, although the MacAdam limits are not covered in any constant lightness plane. If we pay attention to the colour reference gamut, we check this colour gamut is wider than Pointer's real-world surface although from our colour data we would not define exactly the same reference colour gamut.

As it can be seen from the figure 1, our study with industrial colour gamut has not always exceeded the colour reference gamut defined by ISO. For example in the constant lightness profiles $L^* = 45, 50$, the ISO reference gamut is greater than our colour collection with more blue and green colour with higher chroma. But on the other hand, we have to point out we have collected more dark colours ($L^* = 1-15$) useful to update both Pointer's real world colour surface and ISO gamut reference. Therefore, these data should be taking into account to define a real-world colour surface.

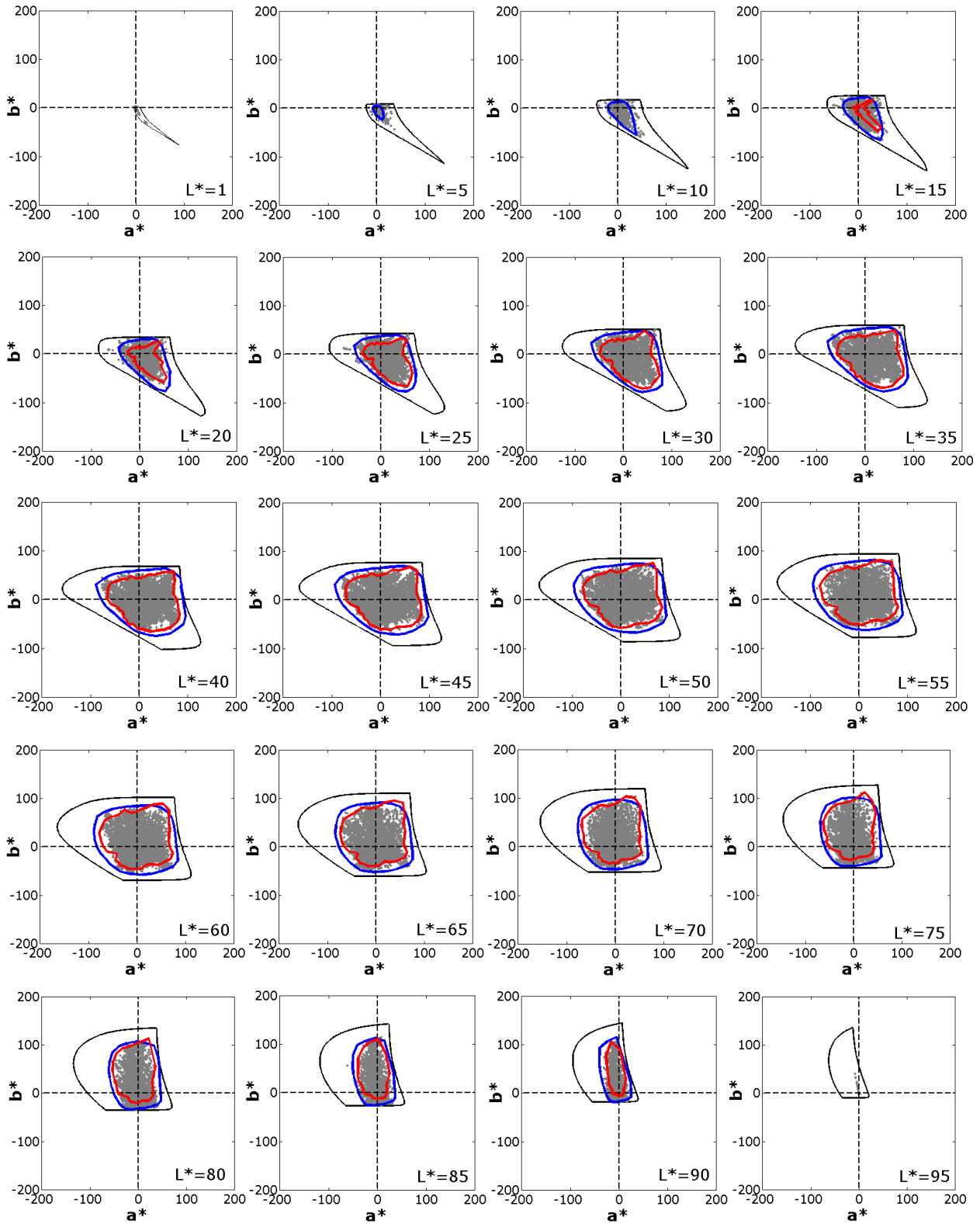


Fig 1. Colour collection of samples associated with different colour technologies in constant lightness planes. The solid line corresponds to the MacAdam limit, the red solid line is for the Pointer's real-world colour surface and the blue solid line corresponds to the ISO reference colour gamut.

To complete this study, besides the comparison in constant lightness profiles, we show an alternative comparison. We compare our colour collection with MacAdam limits, Pointer's real-world colour

surface and ISO reference gamut in constant hue-angle planes. Figure 2 shows all the colour gamuts for the major hues of the Munsell (R, YR, Y, GY, G, BG, B, PB, P, RP). We found that Pointer's real-world colour surface is smaller than the surface composed by all the measured coloured samples of this study; for example, in the B profile there are more light and saturated colours. On the contrary, in the YR profile, Pointer's real-world surface offers more lighter colour with greater chroma, in special in that plane we found that Pointer's real-world surface is greater that ISO reference gamut. In general, the region of dark and light colours with a low chroma is covered, but for some hue-angle profile there are not many colours in the region of colours with intermediate lightness and high chroma (P, BG, G).

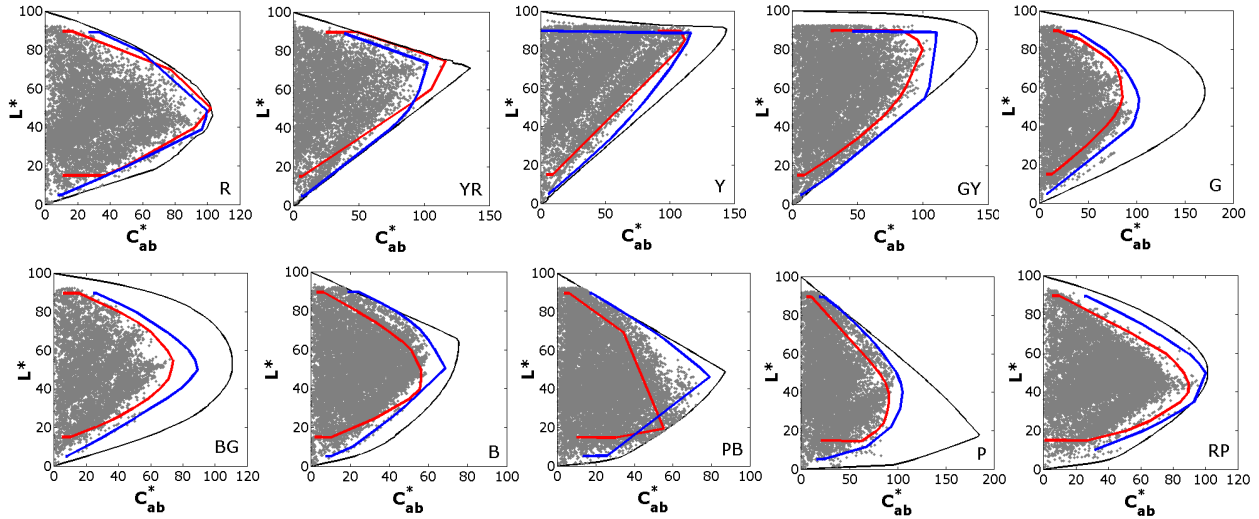


Fig 2. Colour collection of samples associated with different colour technologies in several constant hue-angle planes. The solid line corresponds to the MacAdam limit, the red solid line is for the Pointer's real-world colour surface and the blue solid line corresponds to the ISO reference colour gamut.

This comparative allows us to analyze the colour gamut in other way, completing the previous analysis with other kind on information. After seeing the previous figures, again we observed our colour database has not always exceeded the ISO reference gamut (G, BG). However, for several hue-angles profiles our collection is outside the ISO reference gamut and Pointer's real-world surface, in special for the PB and B profiles. Therefore, these results confirm that it is necessary consider our colour collection to define a real colour gamut.

CONCLUSIONS

In this work, we have done a wide colour collection in order to evaluate the current colour technologies regarding to their capabilities of colour reproduction. On one hand, we have compared in constant lightness and hue-angle profiles this database with the MacAdam limits which define the human colour perception. The aim of this comparison was to evaluate whether the current colour gamut reaches the MacAdam limits or whether it covers more or less homogeneously the Rösch-MacAdam colour solid. We have found that the coloured sample are well distributed in the chromatic diagram a^*b^* however, MacAdam limits are almost never reached for the analyzed colour gamuts. Thus, we think that more research is necessary to obtain new dyes and pigments in colour technologies or new substrates for trying to reach the perceptible limits of the human eye.

On the other hand, in this work we also compare our colour collection with different reference colour gamuts: Pointer's real-world colour surface and the "colour reference gamut" defined by the ISO technical committee. After this comparison, we have found Pointer's real-world surface should be updated since there are many coloured samples outside the surface. Moreover, we have found coloured samples outside ISO colour reference gamut which has been recently defined, above all for dark

colours and very light colours. We can conclude that a deep study is necessary to define a new reference colour gamut that could be useful for different applications.

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