A NEW STANDARD FOR VISUALISING COLOUR GAMUT

An IEC standard is under development to provide an informative and quantitative visualisation of colour capability, replacing the chromaticity plot, as **Euan Smith** explains

AUTHOR DETAILS

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A key performance factor of an electronic display is the range of distinguishable colours it can reproduce. The sensation of colour has three dimensions which can be expressed in various ways, for example amounts or red, green and blue, or degrees of hue, saturation and lightness, but in each case three quantities are required. How should the range of colour a display can reproduce be expressed?

A common method is to use a CIE 1931 xy chromaticity plot, however this is really a relic of CRT displays. Chromaticity area is not colour gamut, and its use can be highly misleading.

Chromaticity is a property of hue and saturation, independent of lightness, and was designed to characterise light sources. However, lightness matters on a display. A brown and a yellow can have the same chromaticity but are clearly different colours. The use of this plot likely persists through inertia, because it is simple to measure (typically measuring the three primary colours) and to reproduce in 2D media too.

The CIE and IEC both recommend the use of CIELab (CIE 1976 L*a*b*) to assess colour capability. CIELab is a colour space where a given point in that space represents the perception of a colour, mapped in terms of L* (lightness), a* (red-green colour difference) and b* (yellow-blue colour difference). It was chosen to characterise colour capability because a numerical distance in CIELab space, from any position and in any direction, roughly corresponds to an equal degree of perceptual colour difference. An enclosed volume in such a colour space is a good measure of total colour capability, however it typically requires ~600 colour measurements to fully map the surface, and a 3D plot is hard to reproduce and interpret in typical print media.

To resolve these issues the Gamut Ring plot was developed. The Gamut Ring plot is, in essence, a 2D transform of the 3D CIELab colour space. A given colour gamut in CIELab space is sliced up in steps of 10 L*. Those slices are flattened, in a way which preserves the hue angle and makes the 2D area numerically equal to the 3D CIELab volume.

Starting from the lowest lightness slice, each subsequent slice is stretched around the previous one, to produce a set of "gamut rings." Rings are generally shown coloured to indicate the hue angles represented. The axes of the gamut ring plot are labelled a*rss and b*rss and are a transform of the CIELab a* and b* units such that an area in a ring plot has units of CIELab volume.

The Gamut Ring plot still has one issue, however, which is the ease of comparison to a reference standard. In any reproduction media a colour is expressed with respect to a colour standard. Computer graphics commonly uses sRGB, DCI-P3 was developed for digital cinema, and BT.2020 for wide colour gamut displays.

COLOUR STANDARDS

Each colour standard defines a limited range of colours which can be reproduced, and the ability to produce colours outside of the standard within which image data is provided is of little utility. If your TV signal can only define a colour within the broadcast standard being used, what good is it being able to reproduce colours outside that standard? What matters is the colour capability of a display with respect to a target colour standard – what fraction of the volume (in CIELab or similar) of colours specifiable in a given standard can be reproduced by a particular display.

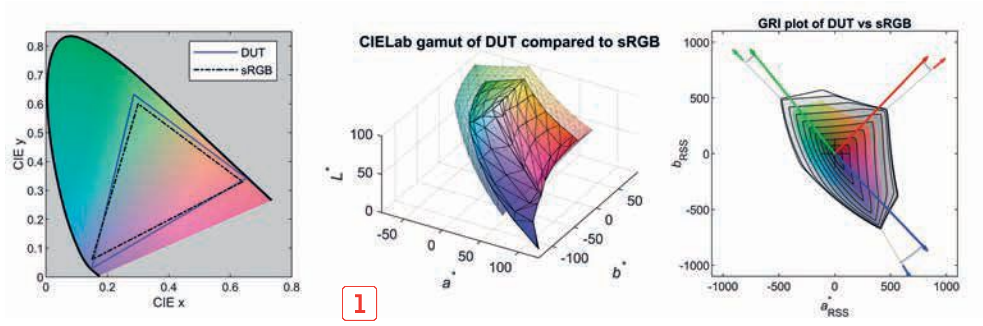
IEC 62906-6-1 is a new standard under development that standardises the Gamut Ring Intersection (GRI) plot as a means to visualise at what lightness, hue and saturation a display can reproduce the colours specified by a target colour space. This standard is specifically for laser displays, however it is anticipated that the proposed visualisation method will be similarly standardised for other display types.

The basis for the GRI plot is a Gamut Ring plot for the reference colour standard. The CIELab colour gamut is calculated assuming a perfect additive display response, and the gamut rings calculated as described above. These reference rings are rendered in grey. The colour gamut of the device under test (DUT) is measured and the CIELab gamut hull calculated and intersected with the reference CIELab gamut (i.e. any colour capability outside the reference gamut is discarded). The ring calculation proceeds as before, however this time instead of each ring being stretched around the previous ring, they are aligned and rendered in colour over their respective reference ring.

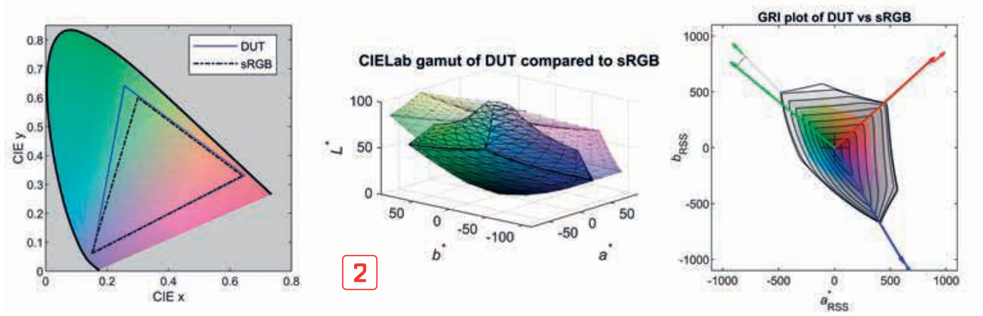
The aim of the GRI plot was to recover the ease in which a chromaticity plot can compare display performance to a reference gamut. It provides a clear reference or target to compare the measured performance to, while maintaining the benefits of the Gamut Ring plot of being quantitative (area equal to gamut volume) and maintaining hue angle.

Figure 1 shows an example comparison between different visualisations for colour capability for a typical hybrid laser/phosphor laser projects (red and blue lasers and a phosphor for green). The data was provided by Karl Lang of Lumita.

The Chromaticity plot seems to match the target sRGB gamut well. Conversely, the CIELab plot shows that the test gamut does not cover the reference standard, particularly at high lightness, but it is difficult to tell from a single view of the 3D



1. Visualisations of a Laser Projector Device Under Test (DUT) compared to sRGB – CIE1931 Chromaticity (left), CIELab (centre) and Gamut Ring Intersection (right).



2. Visualisations of a RGBW LCD Device Under Test (DUT) compared to sRGB – CIE1931 Chromaticity (left), CIELab (centre) and Gamut Ring Intersection (right).

plot everything that is going on. The total gamut coverage of 56% (half that suggested by the chromaticity plot) can be calculated, but is not visually apparent.

The GRI plot, however, shows clearly both the overall performance (the area of the coloured DUT gamut compared to the uncovered grey) and a general loss of coverage at high lightness. Most impacted is the range from red to magenta, despite the left-hand plot suggesting that this should be completely covered. The arrows are an additional indicator to show the hue of the nominal test and reference colour primaries.

MODERN DISPLAYS

The reason that Chromaticity is no longer appropriate is just that a modern display has become a complex digital device. A CRT display produced a colour by driving an amount of red, green and blue signal onto the appropriate electron guns, a simple 1:1 mapping to the requested signal. However, a modern display may use complex digital processing to improve various aspects of display performance, and in particular may reproduce colours using more than just the three traditional colorants.

Take projection systems as an example - many consumer projectors have a single SLM (spatial light modulator) to encode an image onto a light field. This is illuminated in phases – e.g. red, green and blue – in rapid succession to build up an image. However, that same system may also drive the red and green (blue laser plus phosphor) sources together to produce a yellow drive phase, which will be brighter than the individual sources. Doing this will increase the peak luminance, while washing out some of the lighter colours.

Most images captured from real life lack the brightest saturated colours, so it is often a good engineering decision to sacrifice some rarely required high-lightness colour performance for greater luminance or efficiency. However, when this compromise is made, it should be clearly reflected in how the colour performance is specified and communicated.

> "A MODERN DISPLAY MAY USE COMPLEX DIGITAL PROCESSING TO IMPROVE VARIOUS ASPECTS OF DISPLAY PERFORMANCE, AND IN PARTICULAR MAY REPRODUCE COLOURS USING MORE THAN JUST THE THREE TRADITIONAL COLORANTS"

In Figure 2 a slightly more extreme example is shown, with the same three plots as before, but for an RGBW (RGB plus white subpixels) LCD display.

As before the Chromaticity plot looks good, however the CIELab plot shows strong signs of a white boost – the plot has been angled to show clearly the rising peak in the centre leading to white, missing even more of the sRGB gamut. The GRI plot shows this clearly, with little colour capability in any of the upper three rings. It is likely that bright colour on this display will be rendered either somewhat dim or washed out.

There are probably two barriers, aside from familiarity to the adoption of gamut ring plots. The first is measurement complexity, although modern metrology systems make this much less onerous. The second is algorithm complexity, which is why open-source code to perform the calculations has been developed.

The algorithms involved are described in a paper presented recently at SID Display Week (doi.org/10.1002/jsid.1292) and for the GR plot in section 5.32 of the international display measurement standard (IDMS), which is freely available to download from the ICDM (www.sid.org/Standards/ICDM). The GRI plot is planned for the IDMS on the next release.

Matlab code has been open-sourced and made available on GitHub (github.com/CIELab-gamut-tools/gamut-volume-m) and continues to be actively developed. Simplified versions of the same code have been produced for inclusion in both IEC and ICDM standards, and so, barring round-off error, all should produce the same results.

The use of chromaticity to characterise colour performance is a relic of the days of the CRT and is no longer applicable for modern displays. The Gamut Ring and Gamut Ring Intersection plots have been developed, transforming the 3D CIELab colour space into a 2D plot which is quantitative, easy to interpret and communicate.

The GR plot has been standardised by the IEC and ICDM, and the first standard for the GRI plot is in development now by the IEC.

3. According to Euan Smith (pictured) the first standard for the GRI plot is in development now by the IEC