First Teleconference on Common Colour Appearance

CIE R8-13 Focus Group

Monday 7th December (15:00 GMT)

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The topic of Common Colour Appearance has been discussed widely in recent times and the CIE recently established a reportership on this topic (R8-13). This teleconference was set up with a view to exploring various aspects of the topic.

Attendees

Attendee	Country	Affiliation	Status
Claas Bickeboeller	CH	Konica Minolta	Presenter
Andy Kraushaar	DE	Fogra	Attendee
Dietmar Fuchs	DE	ColorLogic	Attendee
Jürgen Seitz	DE	GMG	Presenter
Philipp Tröster	DE	Fogra	Presenter
Akihiro Ito	JP	Fuji Xerox	Attendee
Hirokazu Kondo	JP	Fujifilm	Attendee
Po-Chieh Hung	JP	Konica Minolta	Presenter
Yasuki Yamauchi	JP	Yamagata University	Presenter
Yasunari Kishimoto	JP	Fuji Xerox	Attendee
Peter Nussbaum	NO	Gjøvik University College	Attendee
Phil Green	NO	Gjøvik University College	Attendee
Craig Revie	UK	Fujifilm	Organiser
Gregory High	UK	Gjøvik University College	Presenter
Jan Morovic	UK	HP	Presenter
Paul Sherfield	UK	The Missing Horse Consultancy	Attendee
David McDowell	US	Retired	Attendee
Elena A. Fedorovskaya	US	RIT	Presenter
Jack Holm	US	Tarkus Imaging	Presenter
Ken Elsman	US	Global Graphics / CGATS	Presenter
Mike Rodriguez	US	Independent Color Consultant	Presenter
Veronika Lovell	US	Sun Chemical	Attendee

Agenda

Start time	Presentation
3:24	1. Po-Chieh Hung: Clear definition of Common Colour Appearance and suggested plan of work
12:20	2. Jürgen Seitz: References for color communication
21:40	3. Philipp Tröster: Fogra common colour appearance metric
42:05	4. Yasuki Yamauchi: A metric to evaluate the closeness of the two colours
1:01:38	5. Mike Rodriguez: Development of ISO 15339 CRPCs
1:20:00	6. Greg High: Specific usage cases for a model of common colour appearance
1:29:00	7. Jan Morovic: Evaluation of sets of reproductions under multiple conditions
1:38:25	8. Jack Holm: Artistic intent and Common Colour Appearance
1:52:30	9. Ken Elsman: Two important aspects for Common Colour Appearance
1:59:45	10. Elena Fedorovskaya: Common Colour Appearance research at RIT
-	11. Claas Bickeboeller: Testing ICC Profiles for Common Colour Appearance using Roman 16 images
2:07:30	Craig Revie: The way forward for Common Colour Appearance (general discussion)

Presentations and the recording of the meeting can be downloaded from the ICC web site (see http://color.org/resources/commonappearance.xalter).

Meeting notes

1. Clear definition of Common Colour Appearance and suggested plan of work

Po-Chieh Hung (CIE Division 8 director) explained the procedural issues involved in preparation for a new Technical Committee (problem statement, definition of key terms, analysis / discussion and definition of terms of reference for a TC).

Suggested definition "Image attribute which gives a sense of identity among a set of images which have different tone and colour". He said that factors are likely to include: gamut mapping, colour balance, colour rendering, tone mapping, image complexity and smoothness. In principle each of these factors could be evaluated separately and its contribution weighted to provide a function to estimate common colour appearance.

$$F_{cca}=w_{ic}I_c+w_{sm}S_m+w_{cb}C_b+w_{gm}G_m+w_{cr}C_r+w_{ls}L_s+...?$$

Po-Chieh also reviewed the requirements for establishing a new CIE Technical committee.

Q1: do we mean (a) common appearance among a family of images or (b) common appearance of a single image in multiple reproductions? We should discuss.

Q2: 'sense of identity' could mean 'same subject matter' but this is not what was intended and the meaning should be clarified.

Q3: does the 'family of images' have a single source? The simple case is a single source but perhaps the scope should include multiple sources. Perhaps in the first instance the scope should be limited to a single source.

2. References for color communication

Jürgen Seitz (GMG) reviewed the need to have a reference for colour communication and to ensure that the reproduction is consistent with the reference even in cases where the colour gamuts of the devices being used to make the reproduction are very different from each other. Today there are many options for printing each of which has its own set of variables.

Historically we used physical references such as a film transparency and are used to the differences between the reference and its reproduction on printing systems such as newsprint, coated and uncoated offset printing. We need an equivalent to the film transparency reference for the modern world of digital reproduction. One option would be to use a proof of an exchange space such as Fogra 39 and then find a measure to describe the quality of a relative match. We may need more than one reference.
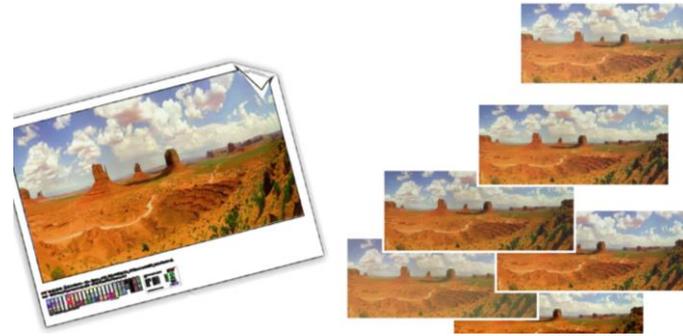
Q1: is this just a discussion about image quality rather than common colour appearance? Reproduction quality would seem to be more like absolute proof rather than a 'relative proof' the principles of which we have still to define. If we have a single reference and five different outputs we still have to ensure that their colour reproduction is well aligned with the reference.

3. Fogra common colour appearance metric

Philipp Tröster (Fogra) described an experiment conducted at Fogra which was designed to find out whether 'Common Colour Appearance' really exists and if so could they define a metric.

Definition: "If an image, for example a company logo is shown on different devices the degree of colour consistency amongst this set of stimuli can be defined as common appearance".

Experiment examined a variety of profile making software packages to see whether their perceptual rendering intent gamut mapping strategy achieved common colour appearance across a number of different printing systems (CPRPCs). Rank order (38 participants) and pair comparison (15 participants) experiments were conducted. These results showed a clear preference that was shared among the participants in the experiments.

The results were examined in conjunction with colour name boundaries to determine the relationship between common colour appearance and colour names and there seemed to be a correlation between the preferred mapping of the colours in the experiments and the number of colour names crossed.

Q1: do different colour have more significance depending on whether they are related to the main subject of the image or some content that is a memory colour? This aspect has not been tested.

Q2: it seems intuitive that crossing colour names would not be preferred but there may be a number of colours that don't cross colour name boundaries and some will be preferred more than others. These selections could be quite different visually - how should colours within the same name be selected? This aspect has not been tested.

4. A metric to evaluate the closeness of the two colours

Yasuki Yamauchi (Yamagata University) presented the result of some research to define a new metric for colour difference for a case where the set of matching colours is constrained to a colour gamut, for example CRPC1 – CRPC7.

Observers were asked to select the 'closest perceptual colour' with a reference which was out of gamut. This process was repeated for a number of colour gamuts to create a 'trend line' for each reference colour. A new metric for colour difference is proposed as the distance between a proposed match and the trend line for a given reference.
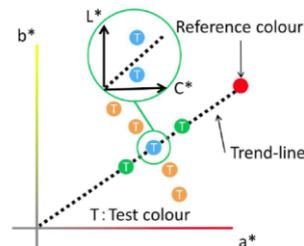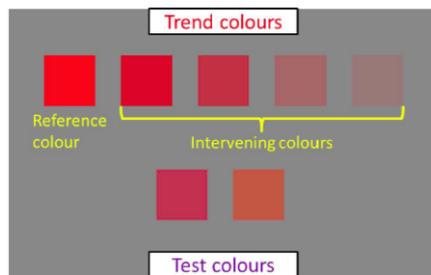
The experiment started with a reference colour in AdobeRGB was identified and the closest colour in CRPC7 was identified, the closest colour to these two colours in CRPC5 were identified and this was then repeated for CRPC3 and in this way a trend line was constructed. In some cases the loci of colours followed the hue angles but in other cases do not.

Q1: was a more hue-uniform colour space such as IPT or CIECAM02 used to plot the trend line? The plot shown was CIECAM02; some trend lines follow the constant hue lines but others do not.

Q2: did you consider the work by Po-Chieh Hung at RIT for constant hue loci? A poster was shown at the CIE meeting in Manchester comparing this result with Po-Chieh's work.

Q3: what happens for near-neutral colours? Our method cannot be applied for near-neutral colours without some additional constraint.

5. Development of ISO/PAS 15339 CRPCs

Mike Rodriguez (Independent Color Consultant) was responsible for much of the development of the set of characterised printing conditions for a variety of printing systems that now form the basis of ISO/PAS 15339. Mike explained the principles behind their development.

Some work which had been shown widely prior to the teleconference was the mapping of the CMYK SCID images on to these CRPCs to produce sets of images that most observers agree share a common colour appearance. One such set of the Musicians image was used at the introduction of the teleconference and is shown below.

The sets of printing inks used for these reference printing conditions have their primary and secondary hues aligned along lines of constant hue. This arises largely due to the standardisation (by ISO TC130) of the ink sets used for the printing systems involved.

The second goal was to 'calibrate' the neutral scale so that the set of printing systems would share similar CMY tonality with a curve with similar tonality for K.
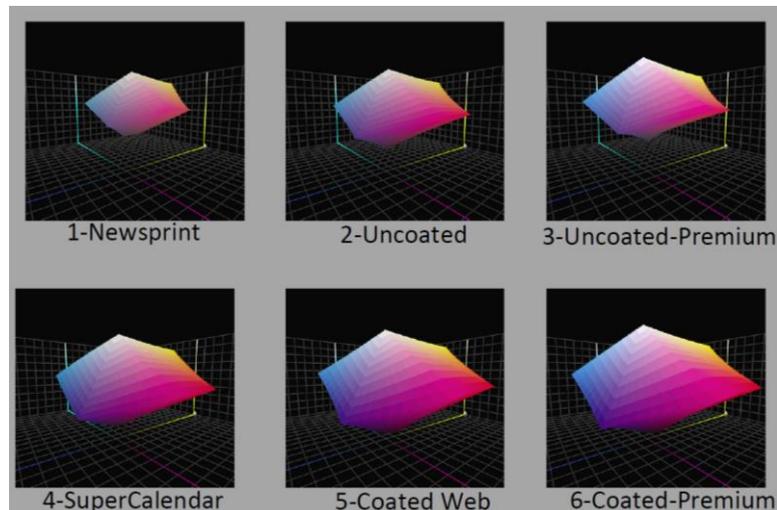
Q1: this opens an interesting possibility that for a set of devices we could choose the CRPC that was closest to the device gamut and make a proof on that device. This is far from optimal and if the device has a very different shape could present a serious problem.

Q2: this is a good way to separate 'how to create a common appearance' from 'how to evaluate common colour appearance'.

Q3: the CRPC family of curves has a common colour appearance because the neutral scale is identical for much of the scale and this may be the underlying reason for their common colour appearance.

Looking at the way in which a set of colours defined by CMYK values is mapped between these CRPCs may provide insight into how to achieve common colour appearance.

6. Specific usage cases for a model of common colour appearance

Greg High (Gjøvik University College) is starting work towards a PhD and his topic will be 'Common Colour Appearance'. Greg presented some initial ideas as to what aspects of this topic could usefully be studied with a view to understand how to achieve common colour appearance between a set of images.

In order to develop a predictive model for common colour appearance we need to consider: viewing conditions, which should match real world viewing; observer adaptation to different substrates, particularly where more than one substrate type is involved; a measure for visual (dis) similarity; gamut mapping constraints.

Commonly we use either sequential viewing or simultaneous (side-by-side) viewing with a standard viewing geometry and illumination. While these standard conditions make the experiments reproducible they may not represent actual viewing situations.

- *Colorimetrically consistent reproductions*
- *Pleasing reproduction, but unrelated to another reproduction*
- *Related reproductions (but different substrates, colorants, gamuts, etc.)*

Greg reviewed the differences between the reproduction objectives when retargeting and repurposing images:

Retargeting: colorimetric match, process control driven, side-by-side viewing.

Repurposing: reproduction not constrained by reference, 'optimised' for each device and intended viewing condition and viewed in absence of a reference.

A common colour appearance model needs to model: differences between a reference and reproduction system (substrate and context); account for different viewing modes (model known appearance effects) and predict a re-rendering and constrained gamut mapping that gives optimal colour appearance.

Q1: is the objective to develop metrics for each printing condition? Yes, this could be seen as the differences between two processes or perhaps better could consider viewing separately from the printing process.

7. Evaluation of sets of reproductions under multiple conditions

Jan Morovic (HP) chaired CIE TC 8-03 whose objective was to recommend a preferred gamut mapping

Use case: at HP they have many printers which produce output on many kinds of media and they would like to be able to deliver consistency of reproduction across these different media. For this use case it would be helpful to be able to quantify how common the colour appearance is among a set of reproductions. To be useful, this work should focus on the consistency of a set of reproductions rather than looking at how well a single reproduction reproduces a reference.

Metric and recipe: there may a temptation to go towards a recipe for creating sets of images before we have a reliable metric that measures what it is we are trying to do. A simplistic approach would be to define a recipe first and generate a set of reproductions that exactly follow the recipe – the problem with this approach is that this may not be the 'best set' of reproductions possible and if not the metric is weak.

I agree with Jan's analysis here but one approach towards understanding this area better could be to evaluate a range of 'recipes' and look at the relative merits of each approach. Understanding the common factors in the approaches may provide insight.

Experience of gamut mapping: TC 8-03 studied the problem of assessing the best reproduction of an original and the TC were unable to provide a recommendation. In some ways this is a simpler problem as there are only two images involved and so it may be useful to consider the objectives of this work and also to identify some acceptable fall-back should the ideal result not be achieved.

Q1: the more complex the use cases the more difficult a solution may be. Would it be possible to identify a subset of reproduction systems for which we could develop rules for achieving common

colour appearance? This would be a good approach and having a solution given a set of constraints would be valuable.

Q2: it may be useful to focus on the development of a framework for print buyers to measure their expectation and to study the use-case for assessment of reproduction of an original on a print in the first instance.

8. Artistic intent and Common Colour Appearance

Jack Holm (Independent) said that he has recently been working in the area of motion picture where there are similarities with graphic arts reproduction. The concept of common colour appearance may be related to 'artistic intent' and Jack compared these two concepts.

When considering how to reproduce content on different media, a content creator may make colour rendering choices based on the characteristics of the medium. In these cases common colour appearance is not maintained across media. When creating an original, the content creator is constrained by the set of colours available on the medium and may not even consider what could be achieved if other colours were available. When mapping to a different medium there is no guarantee that colour appearance will be maintained and perhaps in some cases even colour naming is not maintained.

> • The fundamental question:
> *"What color appearance would the content creator choose for each medium?"*

Ideally the content creator will choose the desired colour appearance on each medium. If we knew what the content creator would choose we would be able to maintain the artistic intent. Someone who wishes to demonstrate the capability of a particular medium / printer combination may make one set of choices for a reproduction where a content creator probably has a different objective and will make a different set of choices.

When the media and/or viewing conditions are similar enough, the artistic intent chosen for each reproduction medium may have approximately the same colour appearance. Colour re-rendering may be necessary but in some cases this could be programmed. We should be aware that content creators may ask for a 'common colour appearance' across media when in fact they want their desired artistic intent on each medium.

Q1: in graphic arts we may wish to automate the choices that the content creator would make. At least in the cinema industry this is as unlikely to happen as getting rid of the director or actors.

Perhaps for the graphic arts use case the problem is that the content creator is not available to select or to approve the colour rendering and so the artistic impression (rather than the intent) of the reference is all that can be maintained.

9. Two important aspects for Common Colour Appearance

Ken Elsman (Global Graphics) summarised the results from a CGATS task force set up to define a metric to determine whether a SWOP proof was in conformance with the standard. Although the objective of this task force was to determine a colour match some of the points identified by the committee may be relevant for our work.

Conclusions – 2 uncovered variables from experiments:

- Color appearance is altered (white point adaption) if even small amounts of media background is visible (as compared to Craig's samples) so might need to be removed when comparing prints. Observers always noticed this in experiments. Needs some discussion.

- Observers consistently noticed contrast changes (also known as dynamic range) made to an image, even complex ones, which is likely to occur to some degree across the printing gamuts being investigated. Needs some discussion in my opinion?

Ken outlined the work done by the committee and highlighted two key points that we should be aware of for our work. As part of this work they developed a method to determine the 'dominant colours' in an image as differences in these colours are likely to be the most significant. They identified that there are thresholds for the minimum pixels needed (presumably area) before a colour difference is observed. Media colour difference is important in this work (side-by-side comparison). Neutral colours are most critical and observers noticed even small contrast differences.

10. Common Colour Appearance research at RIT

Elena Fedorovskaya (RIT) presented some considerations for experimental design that she developed in conjunction with Prof Bob Chung (RIT).

We should use source or reference stimulus where each stimulus is at least two colours and should have at least three or more stimuli (reproductions) to compare against the reference. We are interested in maintaining smooth transitions between stimuli.

We are interested in studying the colour agreement or correspondence of stimuli to each other. We also need to consider other aspects such as contrast changes and we may be better to think in terms of visual agreement rather than just colour.

Elena suggested a range of metrics that we should consider.

- Delta E between corresponding colors?
- More complex analysis: divergence, collinearity (in appropriate coordinates), PCA, ICA
- Emphasis on Chroma, saturation?
- Hue deviations?
- All colors?

- Memory colors?
- Expanse colors / background colors?
- Changes along the daylight locus?
- Learnings from studying other spaces – e.g. Natural Color System

The concept of *common visual appearance* is good and we should keep this in mind for our work but my concern is that if we broaden our work to consider other aspects such as resolution, texture and gloss etc. we may not be able to make much progress and so my suggestion is that we focus on the colour aspects at first.

11. Testing ICC Profiles for Common Colour Appearance using Roman 16 images

Claas Bickeboeller (Konica Minolta) was unable to join our teleconference but sent a presentation whose main message was that we need to consider reproduction across a set of media with different colour gamuts and not just consider how well an original is reproduced on a single medium.

Claas's presentation uses the Roman 16 images to show this and these images may be useful for our work.

Trivia

Jan briefly alluded to 'Every time you use PowerPoint Edward Tufte kills a kitten'.
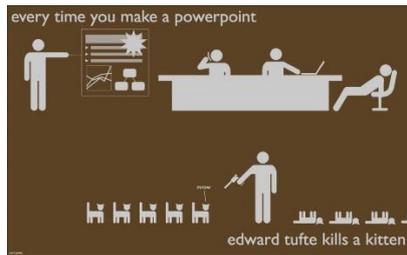
 You may like these:

https://www.youtube.com/watch?v=DbbWac7GHH4;
https://www.youtube.com/watch?v=Th_1azZA2OY.

I think the presentations in our teleconference were quite focused but perhaps we should consider other ways of sharing information!