CIE Division 8
Technical Committee 8–03: Gamut Mapping

Minutes of 14th April 2000 Meeting in Derby, UK

Compiled by Todd Newman and edited by Ján Morovic

1. Attendees

Attendees are listed in alphabetical order and TC 8–03 members are marked with a *.

Péter Bodrogi *
Rob Buckley
Gus Braun *
Mark Fairchild *
Phil Green *
Byoung–Ho Kang *
Ronnier Luo *
Lindsay MacDonald
Marc Mahy *
John McCann *
David McDowell
Peter McGinley
Ján Morovic (TC Chairman) *
Hideto Motomura *
Todd Newman (Division Director) *
Klaus Richter
Pei–Li Sun
Julian Shaw

2. Agenda

1. Publication of GMA Survey
2. On–line GMA archive
3. Review of Guidelines
4. GMA presentation
5. Any other business
6. Next meeting

3. Publication of GMA Survey

Dr. Ján Morovic reported that he had submitted his survey to Color Research and Application. To everyone's surprise, it was reject. He and Dr. Mark Fairchild agreed that Dr. Morovic would submit it to the Journal of IS&T.

4. On–line GMA archive

Dr. Morovic proposed that we start an on–line archive of information about GMAs. This will be kept on the TC8–5 web site. Developers can give details on the implementation of the GMAs. The information could be either detailed implementation steps or source code (either C or Matlab).

5. Review of Guidelines

The bulk of the meeting was spent reviewing the fifth draft of the guidelines for conducting joint experiments. Dr. Morovic presented an overview of the changes first, and then we went through section by section. The main change to the document was

adding the testing of virtual media. These are media that may not be physically realisable because of their large gamuts. The advantage of using such large gamuts is that we can push GMAs to their limits. For virtual media you would be obliged to use the preferred reproduction, because accuracy is not possible. The testing would just be comparisons of different prints made with different GMAs.

5.1. Media and Test Images

Mr. Phil Green (London College of Printing) will take on revising the section on test images. The group agreed that there would be one image that everyone had to include in their test suite to allow inter–comparison of results. Other images would be offered, but would be optional.

Mr. Todd Newman argued that we needed physical images as our baseline, because otherwise we cannot compare experimental results.

There was a general discussion of what color space our test images should be in. People were trying to figure out how to be able to support many different media, have a large gamut image if possible, and still have data that we could compare between researchers.

Dr. Mark Fairchild proposed that we have the same images in ROMM RGB and some display RGB. We could then compare results of gamut mapping tests done with images that represented the same thing, even if the actual image content was different. Todd Newman added that there are well–defined mappings for both ROMM RGB and sRGB64 into the sRGB gamut. Thus it would be easy to take originals in either ROMM RGB or sRGB64 and create the appropriate display image. Dave McDowell suggested that our reference images could be in the ICC's PCS gamut. However, that throws out the advantage of the wide–gamut.

Klaus Richter explained how SC28 made their images. The image to have a 16 step grey scale and images with a wide range of colours.

Dr. Gus Braun explained that Dr. Geoff Woolfe's idea in proposing the large gamut images was that we should start with virtual media. If you have a universal algorithm, it should work either with rendering to sRGB or rendering to print. If you need a different algorithm to go to sRGB or to print, we haven't followed the guidelines for a universal algorithm.

Mr. Dave McDowell reminded the committee that SCID sRGB images are available within ISO TC130. SCID is also working on images with a large gamut. These images are in CIELAB space. TC130 has five images in 16bit code values.

Dr. Morovic suggested that we examine all the cases for an original image. These are; virtual gamut, CRT, and transparency. First, we have virtual gamut to physical. As stated before, these can only be tested with a preferred match. By definition, there is no observable image with which to make accuracy assessments.

For CRT to print, we could test with sRGB originals. Mr. Newman added that if experimenters calibrate their monitors, they should be able to get very close to the specification for sRGB, and thus have a high degree of similarity in their source images.

To calibrate from transparency to print we need to send digitised images, a common target, and measurements to go with the target. From that people should be able to create a profile.

We should have same image in all the combinations. The level of inter–comparison is limited, but you'd get more useful results than if they were different images. The group agreed that we had covered the issue of test images well enough.

Dr. Gus Braun raised the issue that there's a connection between the color appearance model and the gamut mapping algorithm. If different experimenters use different appearance models, we cannot compare their gamut mapping results. There was then a long discussion of how we could compare results across experiments. The basic consensus was that we have to be careful to set the actual experimental conditions to be as close as possible.

Dr. Ronnier Luo pointed out that we could do all the measurements at one site and then share those between laboratories. Everything could be "pre–calculated" and the laboratories would just be doing psychophysical testing. The sense of the meeting was that this would not be acceptable.

The group considered the following work–flows to be most significant:

- Electronic camera to CRT
- CRT to print
- Electronic camera to print
- Transparency to print (large gamut print, smaller print newsprint)
- Reflection print to print (Marc Mahy adds, but decides it's not so critical.)
- Virtual scene to print

We then looked for volunteers to write up each workflow for the guidelines.

Dr. Braun said that Kodak would put together a ROMM to print workflow.

Mr. Newman agreed to write up a CRT to print workflow

Mr. Green agreed to write up the transparency to print workflow.

In the section on test images, we again agreed to have one mandatory image and three or four recommend images. The mandatory image would have to be available in wide gamut, sRGB, and transparency. Dr. Fairchild wanted to make it clear that everyone should do the one mandatory image and at least three others of their own choice. If any of the optional images are used then at least the same number of other images should be used in addition to them. Otherwise, we could end up with only the four images being tested, and fail to find problems with other images.

Mr. Newman asked the group what they thought about testing illustrations and computer graphics as well as photographs. Is a "universal" GMA only supposed to work for photographs? The consensus was that these should be tested only in the CRT to print workflow, because that is where such images are used most often.

In the discussion of the media, there was a tension between the desire to make sure experimenters include enough information to allow someone to reproduce their work and the desire not to overburden experimenters gather information that is hard to acquire. The group agreed not to require experimenters to determine a modulation transfer function for the medium. We did decide that experimenters should either report the angular subtense of the image or its physical size and distance from the observer. (From which angular subtense can be computed.)

Lighting issues were discussed at length. (It is the CIE, after all.) We discussed the issue of illuminant metamerism as well. Accordingly, we decided that experimenters should report the manufacturer and model of the light source and luminaire. This was in lieu of asking everyone to measure the illuminance at half nanometer intervals,

which was the required accuracy to adequately characterise fluorescence according to Dr. John McCann.

There then ensued a long discussion of fluorescence. The conclusion was that we cannot ignore it, because of its effects on metamerism. However, it was very hard to know what to do about it. Dr. Morovic proposed that if we did not allow office lighting as one of the test environments, this would be an easier problem. That is because typical office illumination is done with fluorescent lamps that have very spike spectra. Mr. Newman agreed that this would be acceptable for the experiment. Instead, everyone should use some daylight simulator. But D50 will not be required.

The group was much more flexible when it came to the issue of representation of gamut boundaries. Rather than pick between mountain range (Braun and Fairchild) and segment maxima (Morovic), we will let people use any representation they like, provided they describe what was used. Dr. Luo also suggested that someone could look at the issue of gamut boundary descriptions specifically.

Similarly, the group decided that experimenters could use either the gamut of the medium or of a specific image.

5.2. Gamut Mapping Algorithm

The group next discussed which GMAs should be mandatory for all experiments. The idea was to have one clipping algorithm and one compression algorithm. Dr. Morovic proposed merging in chroma–dependent lightness scaling with sigmoidal compression as the compression algorithm. He proposed that the clipping algorithm be designed to produce minimum ΔE in CIELAB using the CIE 2000 color difference equation. If that equation is not published by the time we want our experiment to start, we could use minimum ΔE 94. The group agreed that the 1:2 weighting would be appropriate for either colour difference formula.

Dr. Morovic will provide reference implementations of these two algorithms. For the experiment to be a success, he feels there has to be at least two groups using the same two algorithms.

5.3. Colour Space

Next the group had to define what colour space to use for the experiments. Again, they were rather liberal in deciding that any space could be used, so long as it is reported.

John McCann made two comments. First, what we really want is an isotropic space. Second, do not use a calculated space, but use the raw data in a 3D lookup table. In this case the raw data are the Munsell values. He stipulated that the Munsell renotation data (Newhall, Nickerson and Judd) is a compromise of data with white, black, and grey surrounds. Also it has been extrapolated to go all the way out to the spectrum locus. Nevertheless, he feels this data is more accurate than trying to fit experimental data with a formula. Dr. Luo observed that the Munsell space was very different from other spaces.

Other spaces were also discussed: CIE TC1–55 is looking at a new color space. So is TC1–36. IPT is a strong contender.

The group did agree that we will need guidelines on how to use CIECAM97s. The agreement was to reference Nathan Moroney's paper.

Regardless of the space used for mapping, the group agreed that experimenters should report the gamut boundaries used in CIELAB.

5.4. Experimental Method

The group recommended that experiments should have at least 15 observers. They also felt we should recommend the use of some color vision test. The Ishihara test would be a minimum. Mr. Green observed that in experiments he had performed, those who performed better on the Munsell 100 hue test did better on color judgements.

6. GMA Presentation by Dr. Hideto Motomura (Matsushita Research Institute of Tokyo)

Dr. Motomura presented a GMA that he had developed and wished the TC to consider. The algorithm was based on categorical color distribution. That is, the goal was to make sure that colours on the source device were mapped to colours on the destination device that would be given the same name. (Red maps to red; green to green, etc.)

Colors were first plotted on an L* versus hue chart. Then the Mahalanobis distance was used to figure out which colour name an observer would give a colour. Dr. Motomura had developed a model to predict the names, so that this mapping was based on prediction, not measured data. He did not present the model in detail, however.

The algorithm consisted of a pre–mapping step and then a mapping step. In the pre–mapping, the source gamut is brought inside the destination gamut. This, of course, yields over compression. The compression is done with linear chroma compression.

Then in the mapping step, the categorical naming is used to preserve color names. This also re–expands the gamut. This was done with a rotation based on the categorical color weighting.

7. Next Meeting

The TC will meet at the Color Imaging Conference on Monday, November 6, before the Color Imaging Conference. The exact time of the meeting was not set.