CIE Division 8 and the Philosopher's Stone

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Alchemy is the art of manipulating life, and consciousness in matter, to help it evolve, or to solve problems of inner disharmonies.

Jean Dubois[1]

Abstract

The work of a CIE Division 8 may be compared to the labors of an alchemist. Alchemists tried to combine the four elements: earth, air, fire, and water to create the Philosopher's Stone, which was a substance that would bring wealth, health, and power. Division 8 is struggling to combine color practice, color science, color engineering, and color standards. The progress of each of the six technical committees (TCs) in CIE Division 8 is presented. Four of the five original TCs will present technical reports by 2003. Two of the TCs will then be closed. The TCs have succeeded by finding the appropriate blend of these four elements.

Introduction

We in the color imaging community have much to learn from the ancients. The Greek philosopher Empedocles taught that everything in the world was made from different combinations of four elements: earth, air, fire, and water. The alchemists of the middle ages tried to transmute materials by combining these four constituent elements into new materials. The medieval alchemists sought to create or find the Philosopher's Stone that would not only turn lead into gold, but also cure illnesses, prolong life, and bring about spiritual revitalization. Similarly, in working for the benefit of the color imaging community, CIE Division 8 must balance the four elements of color practice, color science, color engineering, and color standards. The Philosopher's Stone for Division 8 would allow us to create methods and standards that were useful, timely, widely practiced, and theoretically justified.

The Greek physician Hippocrates taught that the human body contained four fluids (blood, phlegm, yellow bile, and black bile) called "humors." We can relate the four humors to the four color elements. The humor related to the element of Water was phlegm, which makes people unwilling to change (phlegmatic). Clearly, this describes the inertia tendency of current color practice. The humor related to the element of earth was black bile, causing melancholy. This represents many people's opinion of the color standards process. Yellow bile, related to the element of fire, made people choleric, prone to unending disagreement, and unwilling to compromise. This frequently describes the behavior of color scientists as well. Finally, the element of air and the related humor of blood tended to make people somewhat blithe, strong-willed and "bloody minded." This, to me, suggests the independence and competitiveness of color engineering in the corporate world.

The preceding analogies are obviously somewhat facetious. However, it is true that to do its job well CIE Division 8 must balance the needs and tendencies of current practice, standardization, commercial development, and color science. Each brings value to our work: there is much accumulated wisdom embedded in current practice; standardization can harmonize our practices; commercial development brings innovation and accommodates individual preferences; and our work is most useful when grounded in scientific knowledge. But each of those forces can also be a problem when it is excessively dominant. We are trying to solve problems that have not been solved by current practice, so too much inertia will prevent progress. Unchecked the standardization process can bring about excessive regulation and conflicting standards. The commercial desire for "product differentiation" can prevent users from getting predictable results. Color scientists face a large and complex problem; it will be years or decades before they can reach a robust general theory.

The alchemists were not the only people to combine elements, of course. Why not compare Division 8's work to something more scientific, like chemistry? The difference is that physical sciences like chemistry are quite deterministic. Most of the elements that the technical committees (TCs) within Division 8 struggle with are not deterministic at all. Changing color practice, color engineering, and color standards is a matter of personal and group psychology. Influencing opinions and behavior has not yet reached the mechanistic level of science that chemistry has. It is only a slight exaggeration to say that it is closer to magic than science. Accordingly, we can look at the work of each TC as an effort to find the appropriate blend of the four constituent elements as an alchemical experiment.

Color Appearance Modeling for Color Management Applications (TC8-01)

The CIECAM97s color appearance model (CAM) represented a consensus opinion among a set of color scientists, CIE TC1-34. However, as color engineers applied this model in the imaging industry, they found problems. The goal of TC8-01 is to find ways to improve the model, based both upon the earlier consensus and upon more recent experience.

By the time this paper is due, a subcommittee within the TC will have developed a proposed revision of CIECAM97s, to be called CIECAM02. The revision will have a linear, and therefore easily invertible, chromatic adaptation transform. It will have revised lightness and chroma scales that better fit the experimental data. It will also feature a post-adaptation non-linear response compression function based on a power function instead of a hyperbolic function. Clarifications have been made in setting the parameters for the model. Finally, several of the equations within the model have been simplified to improve computational speed. The result should be more useful to both color scientists and color engineers. The TC will vote on the report at its meeting in November 2002. Following a vote by Division 8, the report should be ready for voting by the CIE in time for the CIE Session in San Diego, CA in July 2003.

Color Difference Evaluation in Images (TC 8-02)

The goal of TC8-02 is to derive an industrial color-difference evaluation method that is appropriate for images. Current color difference formulas (CIELAB, CMC, etc.) are designed for color patches that subtend 2 degrees or more of the field of vision. Color patches in images tend to be much smaller. The method must be based on a quantitative model of color-differences under conditions typical of commercial imaging applications.

This TC started off trying to respond to requests from the user community by racing to form a standard very quickly. However, we found that neither is there common practice in industry nor is there much academic research upon which to base a standard. So the TC will have to first develop a consensus among experts by created some coordinated research reports. The TC will provide the following items in its final report:

- a color difference equation with an option to add three spatial filters
- a method for evaluating color reproduction fidelity including test images
- a TC Technical Report on Methods to derive color differences for images.
- experimental data sets available on the web
- a summary report on a collaborative research programmed for investigating the perceptibility and acceptability thresholds using a set of color difference images based upon SCID/XYZ images across different test sites.

The TC plans to provide Division 8 with a voteable draft technical report by January 2003. The report can be used to coordinate further testing of the color difference equation with and without the spatial filtering. This will give us the information we need to pick a recommended method.

Gamut Mapping (TC 8-03)

The goal of TC8-03 is to study, develop and recommend a baseline solution for cross-device and cross-media image reproduction, a process commonly known as "gamut mapping." Figure 1 illustrates the difference between the gamut of a monitor and an inkjet printer. This solution will provide a standard procedure to calculate the color gamut of an image, an imaging system, or its components, and either one algorithm, or a set of algorithms and rules for use in specific applications.

Figure 1. Comparison of printer gamut (solid) and monitor gamut (mesh)

The TC faces a challenge greater than the usual lack of consensus about best practices. Many industry experts believe that selecting an acceptable gamut mapping algorithm is always image-dependent, and that we cannot select a fixed set of rules that will always yield an acceptable reproduction. Some companies believe that they have a proprietary advantage to their gamut mapping algorithm, and so they do not want a standard to be created. Both sets of beliefs make it hard to come to a consensus. However, standardized baseline behavior is vitally important for reliable and unambiguous communication of color information across networks. So the goal for the TC is to try to forge agreement, again by using the technique of coordinated research.

The TC has decided to proceed by first developing a standard experimental design for gamut mapping research. The design requires standard experimental conditions, some standard algorithms to be tested in each experiment, and some standard images to be used in each experiment. If researchers use this design, it will be possible compare results between experiments. This has not generally been possible in the past. Intercomparison of results should allow the color community to converge upon a baseline more rapidly.

The TC has prepared a final draft technical report. The TC should vote on it in 2002, and Division 8 and the rest of the CIE in 2003. Of course, this represents only the first step in the process. We then need to perform the research and compare the results before we can begin formulating a standard. While we would have liked to produce a recommendation by now, we will best influence color practice if we base our work on research, rather than rushing to make an arbitrary standard.

Adaptation Under Mixed Illumination Conditions (TC 8-04)

This is another area where Division 8 intends to extend the work done by color scientists in another division in order to make it more useful to color practitioners. CIE TC 1-27 has done fine work on appearance matching between video displays (soft copy) and paper (hard copy). However, their work requires that people completely adapt to each viewing condition. Both consumers and professional graphic artists want to compare an electronic original side by side with its hard-copy reproduction. (See Figure 2.)

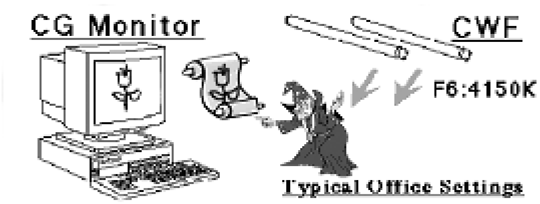

Figure 2. Typical color comparisons

This causes some problems for color scientists. The primary one is figuring out what stimulus will appear white to people in this situation. As most color appearance models do, CIECAM97s and CIECAM02 require us to specify a white point. We know people find neither paper white nor the monitor white to be a "true white" in this situation.

The TC compared results from several experiments. All the experiments found that observers were between 40 and 60% adapted to the video display and 60 to 40% adapted to the ambient illumination. This may seem like a wide range, but it should be expected. Fairchild and Reniff suggested the possibility of two mechanisms for chromatic adaptation, the first being a rapid mechanism with a time constant of 0.9 to 1.5 second, and the second being a slower mechanism with a time constant of 38 to 53 second[2]. The visual system reaches a 60% adaptation level within a few seconds, but takes minutes to reach full adaptation. If observers are glancing back and forth between monitor and a print, they are not fully adapting to either level. Since we did not control the amount of time observers spent with each fixation, we must expect that experimental results will show a wide range of adaptations. TC8-04 feels that they have gleaned as much as they can from this research. They plan to produce a draft technical report by the end of 2002 to be voted on by the CIE in 2003. The report will propose a simple extension to color appearance models like CAM02 to account for mixed adaptation.

Communication of Color Information (TC 8-05)

TC8-05 aims toward the goal of unambiguous color communication of images. A significant trend in the color standards community is to achieve unambiguous communication through a well-defined standard color encoding. There are many proposals put forward at this time: e-sRGB,[3] scRGB,[4] ROMM-RGB,[5] RIMM-RGB.[6]

TC8-05 does not plan to put forward yet another standard color encoding. Instead, its purpose is to help rationalize the process and, hopefully, to minimize the number of standard color encodings. TC8-05 is hoping that it can help the other standards bodies by providing a methodology that can help them select new color spaces in a more methodical manner. The plan is to develop appropriate criteria and metrics to serve as a guideline. The TC is also working with other standards bodies to develop application profiles that may be used to weight the relative importance of the metrics.

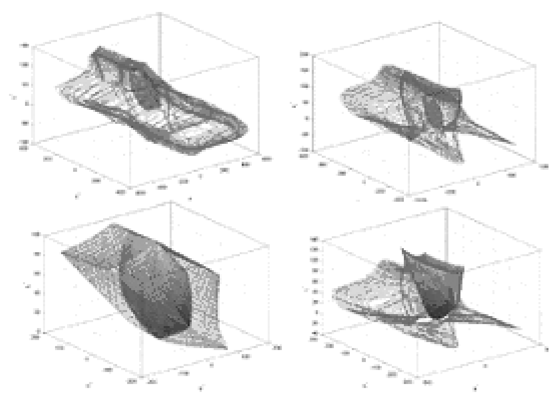

Figure 3. Comparison of the gamut of a gamut of surface colors (shaded) and four proposed extended gamut color encodings (wireframes). Starting with the top left and proceeding clockwise the encodings are: e-sRGB, e-sYCC, ROMM RGB, and s-YCC.

The idea is to develop a series of criteria by which to measure spaces (such as hue uniformity) and metrics to measure these criteria (such as a method to quantify hue uniformity). Figure 3 illustrates a comparison of a gamut of real world surface colors and the gamuts of four proposed extended gamut color encodings.[7] The TC has prepared metrics for the absolute and relative size of the gamut, quantization error and efficiency, and complexity. Standards bodies can then decide which criteria are important to its clientele, and use the CIE's method for quantifying the degree to which a proposed standard meet those criteria. These results have also been useful for companies to decide which color encodings they wish to support.[8] TC8-05 plans to have a set of evaluations available by November of this year. They will produce a draft technical report in 2003.

Vocabulary (TC8-06)

You might think that vocabulary was not a technical issue, but it is. Often, our most heated arguments actually spring from inconsistent use of terminology. Terms such as “contrast” and “flare” can have very different uses in different technical fields. As these fields are brought together through the use of computer systems, we find that inconsistent use of terminology can lead to inconsistent use of technology. The work of this technical committee will be to create a master vocabulary of technical terms relating to image technology. This may either supplement the International Lighting Vocabulary or be published as a separate document. Of course, this is another area in which it is important to form and maintain active liaison with other standards bodies.

The TC is collecting terms and definitions from within the CIE and from other standards groups working in the imaging field. These will be incorporated into a draft Technical Report by the end of 2002 and ready for balloting in 2003.

Conclusion

The work of each TC can be viewed as an alchemical experiment. For each task, we must blend the four elements of color practice, color engineering, color science, and color standards. I think that the experiments have been going quite well. Four of the initial five TCs in Division 8 are going to produce a technical report within its first session. Two of the TCs will have completed their tasks and will be closed. Four years may seem slow compared to the rate of change in the color engineering and some color standards groups. But it is surprisingly rapid for color science, most color standards groups, and certainly for color practice in general. And of course, most (perhaps all) alchemists labored their whole lives and never created the Philosopher’s Stone. Compared to these groups, CIE Division 8 is showing remarkable progress in its alchemical efforts.

References

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Biography

Todd Newman is Directory of CIE Division 8: Image Technology. He received his AB in Philosophy from Harvard in 1981. He has worked at Microsoft, Digital Equipment Corporation, and Silicon Graphics, Inc. He currently works for Canon Development Americas, Inc., where he manages the Color Imaging Group. Mr. Newman was the first Chairman of the International Color Consortium. He is currently focused on color appearance modeling, gamut mapping, and the development of color management systems.