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Color Appearance Models

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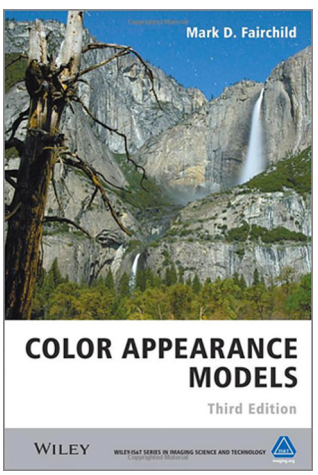

Color science is a multidisciplinary field with broad applications in industries such as digital imaging, coatings and textiles, food, lighting, archiving, art, and fashion. Accurate definition and measurement of color appearance is a challenging task that directly affects color reproduction in such applications. *Color Appearance Models* addresses those challenges and offers insight into the preferred solutions. Extensive research on the human visual system (HVS) and color vision has been performed in the last century, and this book contains a good overview of the most important and relevant literature regarding color appearance models.

The first two chapters contain an introduction to human color vision and psychophysics, while the fundamentals of colorimetry, CIE color space, and color difference specification are reviewed in Chapter 3. As stated in Chapter 4, any newcomer to the field must first learn the language of that discipline to be able to communicate accurately and effectively. The color appearance definitions and terminologies, such as hue, brightness, lightness, chroma, and saturation, are presented in Chapter 4 and are frequently used in the rest of the book. Color order systems such as the natural color system (NCS) and the Munsell system and the corresponding requirements are discussed in Chapter 5.

A brief but excellent overview of the most important color appearance phenomena, such as simultaneous contrast, the Stevens effect, and the Hunt effect, are presented in Chapter 6. References to the classical papers for the corresponding color appearance phenomena are also provided. Color constancy and other contextual and structural effects are also briefly discussed at the end of the chapter.

Viewing conditions have profound effects on color perception. Definitions and descriptions of various elements of visual conditions and their relation to color appearance models are presented in Chapter 7.

Adaptation is one of the important mechanisms of color vision, and modeling chromatic adaptation is a key component of all color appearance models. A comprehensive treatment of chromatic adaptation with references to prominent literature on this subject is presented in Chapter 8. A few specific chromatic adaptation models are presented in Chapter 9 and build on the information presented in the previous chapters.

Definition of color appearance models and a framework for constructing them are covered in Chapter 10, where the CIELAB is discussed as an example of a simple color appearance model. Chapters 11 to 16 contain a presentation of more complex models, such as the one by Nayatani et al., Hunt, RLAB, ATD, LLAB, IPT, CIECAM97s, and CIECAM02. These chapters follow a general framework where the objectives and the methodology of the corresponding model are first described, followed by the definition of the input data to the model. This is followed by the presentation of the chromatic adaptation model and the opponent color dimensions utilized in the color appearance model. Calculation of appearance correlates (hue, lightness, brightness, chroma, and saturation) is discussed next. In many applications, it is necessary to use color appearance models in reverse direction, so the inverse of a model and the phenomena predicted by the model are presented next. Finally, a section explains the inadequacies of the described model and presents possible next steps. Currently, the CIECAM02 is considered one of the best available models that has drawn its strengths from other existing models. However, color appearance is an active area of research with new developments reported all the time.

Any sound scientific model should be supported by observations and data. The first part of Chapter 17 discusses four groups of tests for the evaluation of color appearance models. This is followed by a discussion of the CIE technical committees in charge of collecting data and testing color appearance models. In order to illustrate the relative performance of color appearance models, several images are rendered and presented in the last part of Chapter 17 based on predictions of the various models.

Chapter 18 addresses the application of color appearance models in certain areas of color measurement, such as color rendering, color difference, and indices of metamerism. Current techniques and recommendations as well as future directions in each area are also discussed.

Device-independent color imaging is covered briefly in Chapter 19. Definition of the problem, levels of color reproduction, and some general solutions are discussed. Device calibration and characterization and three main approaches are also presented in this chapter.

Image appearance modeling is a natural extension of color appearance modeling as the spatial and temporal aspects of color vision are incorporated in the model. The basic concepts of image appearance modeling and an example, the iCAM, are presented in Chapter 20. The brightness and contrast of display devices have improved significantly in the past several years. High dynamic range (HDR) imaging is a new area of great interest in color imaging. Various issues in color appearance for HDR applications are addressed in the final chapter of the book, which has been added since the second edition.

The first and second editions of this book were published in 1998 and 2005, respectively. In comparison to the second

edition, several sections in chapters 8, 14, 16, 17, 18, and 20 have been added or revised. Also, a new chapter, "High Dynamic Range Color Space," has been added. Furthermore, some figures have been revised, and new figures, mostly in Chapter 8 and 18, have been added. Typographical errors in the 2nd edition have been corrected.

The transitions from one chapter to another are smooth, and one can read the book cover to cover to get a comprehensive understanding of color appearance. It is also possible to read a group of chapters independently. Advanced readers can skip the introductory chapters and start at a chapter on a specific model. The images and plots presented in the book are of good quality and are helpful in illustrating the underlying concepts.

The ideas are presented clearly and succinctly, which makes the book suitable for self-study. The book does not contain exercises or problems, but it can still be used as a companion text for graduate or undergraduate courses in multidisciplinary programs addressing color and appearance phenomena. An accompanying webpage is available at http://www.cis.rit.edu/fairchild/CAM.html, which contains useful data as well as examples of numerical calculations of a few color appearance models. Although the book contains an extensive number of useful references with Index and References sections at the end, in my opinion, it can benefit significantly from a glossary of terms and concepts.

An interesting observation by the reviewer was that by replacing the word "CIELAB" in Section 21.4 with "IPT," one would get a replica of the text presented in Section 21.5, except for the numerical parameters in the equations.

The book is also available in softcopy format. I had access to both printed and softcopy formats, but I liked the printed version more than the e-book because I did not like the page layout and font sizes of the bulleted paragraphs in the e-book.

Overall, *Color Appearance Models* is a suitable companion to the reference books in the field of colorimetry, color reproduction, vision science, and digital imaging. It is also a good starting point for those interested in color constancy, color gamut mapping, and color management. The book is useful for students, scientists, and engineers in multidisciplinary fields dealing with color issues. Those working in archiving and entertainment industries can also benefit from it. Finally, the book can be used as a tutorial with basic knowledge of mathematics and physics for learning about color appearance.

Mahdi Nezamabadi received his PhD in imaging science from the Rochester Institute of Technology in 2008. He was a member of the Spectral Imaging Group of the Munsell Color Science Laboratory and worked on design and implementation of an accurate end-to-end spectral color reproduction system. He also studied the effect of image size on the color appearance of image reproductions. He joined Dolby Laboratories in 2007, where he performed research on image quality and color management of HDR video. He has been with Canon USA since February 2014. His interests are appearance of softcopy color reproduction, video color processing, image quality, and phenomena such as adaptation and metamerism.