

# BOOK REVIEWS

**Review of Visual Color and Color Mixture** by Jozef B Cohen, Univ. Illinois Press, Champaign, IL 2000 pp 288, \$39.95 cloth

Jozef Cohen's book, *Visual Color and Color Mixture*, summarizes his insightful and meticulous research into the algebra of color matching and the geometry of color representation. Though colorimetry and the nature of color matching have been well-known for a long time, Cohen was among the first to synthesize the knowledge into a cohesive mathematical framework based on linear algebra with its accompanying benefits of exactness and completeness. The book articulates this view of color, while simultaneously providing the reader with historical insights into its development. It continues further and explores the connections of the developed theory with aspects of color beyond color matching and colorimetry.

Cohen's style of writing is thorough and precise and reflects his pedagogical background. He frequently questions fundamental assumptions to expose true underlying principles. Common errors and misuse of nomenclature are either avoided entirely, or if mandated by common usage, are clearly noted as such. He uses an informal narrative style of writing analogous to a classroom lecture, making back-and-forth inter-connections between the material and emphasizing important facts through repetition. Examples are used to illustrate results and ideas throughout the book. The reader is presumed to have some familiarity with linear algebra, though the level of sophistication required is not unduly high. An introductory undergraduate class in linear algebra in mathematics or engineering disciplines should provide sufficient background.

The first six chapters define the context for the work. Notation and terminology is established in the first two chapters. In the next four chapters, Cohen painstakingly reconstructs the historical evolution of color science in general and trichromacy in particular through the work of Newton, Thomas Young, Helmholtz, Maxwell, and Wyszecki. Hints of the underlying theory that is to emerge are interspersed through several of these chapters.

Chapters 7–10 develop the mathematics supporting the book. The linear algebra of color matching and color representation is developed and Cohen's Matrix-**R** formulation is presented. Interrelations among color matching functions, color fundamentals, Matrix-**R**, and orthogonal color representations are illustrated in significant detail. Traditionally, spectral curves are represented in a high (e.g. 31) dimensional vector space and the corresponding colorimetry is represented by tristimulus values in a 3-D space. Using the Matrix-**R** formulation, Cohen reconciles these different representations. Unambiguous representation of colors as spectral fundamentals instead of tristimulus values allows comparison and interrelation with the corresponding or different spectral curves. Several interesting computer renderings are used to

illustrate the geometry of color fundamentals using an orthogonal coordinate system.

Chapters 11 through 15 demonstrate applications of the Matrix-**R** formulation and associated theory and its inter-relation to other constructs in color science. Examples stemming from a transformation of primaries in a color matching experiment are the primary focus of Chapter 11. Chapter 12 addresses the determination of preferred orthogonal axes for color fundamentals using decompositions of Matrix-**R**. In Chapters 13 and 14, Cohen explores the history of complementary color theories and shows how Matrix-**R** may be used to determine and characterize complementary monochromatic stimuli. Out of necessity, the tenor of the presentation in these chapters changes from mathematical rigor to philosophical discussion, empirical investigation, and analysis of observations for salient trends. Chapter 15 explores the issues underlying color specification and highlights some of the limitations of the existing system particularly with regard to luminous-efficiency functions. Chapter 16, entitled "A Synthesis of Color Theories by Matrix-**R** Operations", starts with a discussion of various color theories that have been proposed as transforms of the basic CIE colorimetry system. The chapter, however, was cut short by Cohen's death and both the chapter and the book seem to end abruptly. The introduction to the book notes that two additional chapters were planned but could not be completed.

The orientation of the presentation from a historical perspective makes for difficult reading in several places. In the early chapters, Cohen often gets ahead of himself anticipating results that are only justified later. Readers unfamiliar with the material may find this departure from a linear presentation a little hard to follow but are rewarded for their patience in subsequent chapters where the mysteries are clarified. A large number of references point the reader to additional detail on both the main discussion and a variety of side issues. Historical anecdotes distributed throughout the book make the presentation fairly entertaining reading for a technical publication.

Two minor criticisms of the book are its use of somewhat archaic mathematical terminology that is not commonly seen in contemporary mathematics and the sparseness of references to mathematical texts in linear algebra. These texts present the related concepts of projection matrices, orthonormal bases, and vector geometry in a more general setting and often in greater mathematical depth. Readers fluent in linear algebra and vector spaces may also find the presentation and proofs somewhat long-winded and indirect. Despite these criticisms, the book is sure to serve as a valuable reference in the field of color science and color vision and is a useful addition to the text collections of color scientists and students of color, particularly, those with a mathematical bend and a penchant for the history of color science.

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**Color Vision and Colorimetry: Theory and Applications.** Daniel Malacara. SPIE, PO Box 10, Bellingham, WA 98227, www.spie.org, 2002; 176 pp. paperback \$62 list price, \$50 SPIE members

This book is a hastily written monograph by an expert in an adjacent but different field (optical testing and instrumentation). The Preface is dated March 2002 and I received it in June. Such haste suggests that little reviewing or editing was done, so not surprisingly the book is rife with errors. Contrary to the advertisement in the preface, it is definitely not for students or neophytes.

Some of the errors are typographical: e.g., the omission of the deltas in Fig. 5.23 illustrating the concept of  $\Delta H^*$ ; the omission of the exponent 2 in Eq. 6.20 for K/S in terms of reflectance for an opaque layer; the misspelling of many names (e.g., “Fetchner” on p. 7); inconsistencies between the citations and the reference lists (e.g., the confusion of F.E. Ives with his son H.E. Ives; and date errors including the Kaiser-Boynton “1966” citation on p. 6 that appears to anticipate Land in describing Retinex theory (the real date is 1996).

More serious are errors in the uses of terms: e.g., interchanging the terms “light”, “color”, “chromaticity”, and “reflectance”; defining a “spectrally pure” light beam in terms of its chromaticity instead of its wavelength composition (p. 1); juxtaposing 3x3 matrices operating on vectors with the term “projective transformation” (p. 49); referring to the chromaticity denominator  $X(\lambda) + Y(\lambda) + Z(\lambda)$  as “weight  $w$  for a colored light beam with spectral power  $P(\lambda)$ ” (caption of Fig. 6.1); and defining correlated color temperature (in a section with many  $xy$  diagrams) as closest in chromaticity without referring to the  $u, v$  coordinates (p. 66).

Still more serious are statements of “fact” that are not true but condition the organization of the entire book. For example, Section 1.3 (theories and experiments in color vision) says that Maxwell’s colored image “proved” the Young-Helmholtz theory, and then states in the next paragraph that zone theories (combining Young-Helmholtz and opponent theories) are “now discarded.”

Yet even the author’s description of trichromatic theory (the core of Young-Helmholtz theory) is very muddy. Chapter 3, describing this theory, starts with a particularly opaque version of Grassmann’s laws, which was adapted from Grassmann’s text as presented in MacAdam’s 1993 SPIE book:

- “(a) To specify a color, three elements are necessary and sufficient: the hue, the luminance, and the luminance of the intermixed white, which defines the saturation.
- (b) For every color, there is complementary color, which, when mixed, becomes a colorless gray.
- (c) Two lights of different color with the same hue and saturation, when mixed, produce another color with identical hue and saturation independently of their power spectra.

- (d) The total luminance of any mixture of light is the sum of each light’s luminance.”

Without the rather extensive text Grassmann uses to explain his laws, these laws in their original statement (somewhat modified, e.g., to replace “intensity” by “luminance”) are difficult to connect with the familiar linear algebra of mixing and matching lights. Furthermore, to the modern ear, this statement mixes up terms from basic and advanced colorimetry. Certainly this is not the way a novice will learn about the basics of color matching.

It gets worse. The figures in Chapter 3 are strangely out of step with the text. (Section 3.3 talks only about matching luminances, yet is called “color-matching” and has a figure with three primaries.) Then, the color-matching functions are introduced without explaining their negative portions in terms of the usual algebra. Finally, the tristimulus values are explained in a Byzantine way, supported by a figure whose illegibility yields to confusion when a magnifying glass is brought to bear. This figure (3.5) shows three projectors on the “reference field” side of the match, labeled by a spectrum  $P$  sampled at three (presumably primary) wavelengths. On the “matched field” side of the match are nine projectors, labeled with the same spectrum  $P$  at the same three wavelengths, weighted by the  $r, g, b$  color-matching functions. If someone understands this figure, please let me know.

The high point of the book is Chapter 7 on color measurement. I have never seen accuracy and the various forms of precision described so clearly, with good supporting figures. Table 7.2 is particularly valuable. In a glance it shows the logical relationship among accuracy, precision, reproducibility, and repeatability (short and long term). The column “acceptable value in colorimeters” should be useful to all practitioners. (However, it would have been nice to read how these numbers were obtained.) The text discussion of how measurement interacts with color computation is quite clear, and is well supported by a flow diagram (7.7). In short, Chapter 7 has much to teach that is based on the author’s ample experience with instruments and what you can expect from them.

Having said this, I must remark that the last section of Chapter 7 (on visual colorimeters) contains a serious error about illuminant substitution. Here is an abridged selection from the first two paragraphs:

“A visual colorimeter is a color-matching device with a split color field. Half of the field is covered by the body of the color to be measured, illuminated by a reference-white light source. The other half of the field is formed by a white surface, illuminated by three light sources whose colors are well determined—typically red, green, and blue. [ . . . ] The adjustment of the colorimeter is not simple and requires skill. This adjustment process can be simplified with other complex arrangements. For example, the white light source illuminating the colored body to be measured can be substituted by three colored lamps with the same colors as the lamps illuminating the white reference field.”

In conclusion, I think the publication of this book was a mistake, especially on the rushed time schedule in which it must have been done. I hope in any future editions this monograph will be properly reviewed, edited, and refocused to the desired audience.

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## Publications Briefly Mentioned

**CIE Publ. 148-2002 Action Spectroscopy of Skin with Tunable Laser**, CIE Central Bureau, Vienna, Austria; many be purchased from CIE/USA, TLA, 7 Pond Street, Salem, MA 01970. ISBN 3 901 906 17 7; pp. 14

This research report discusses the examination with a tunable laser of the action spectroscopy of the skin. In order to determine action spectra with high accuracy, improved experimental methods are needed. This concerns the irradiation sources as well as quantitative measurements of the

skin reactions. We reevaluated action spectra for erythema and pigmentation in humans with a tunable, highly monochromatic irradiation source and with an instrumental measurement of skin reactions. The irradiation system consisted of an excimer laser pumped dye laser and an ultraviolet fiber optic system. The skin color after irradiation was determined with a colorimeter using the CIELUV system. By applying laser a very high spectral resolution in action spectra could be obtained. For example, the maximum of the erythema action spectrum in the ultraviolet-B range was measured at 298.5 nm and an additional maximum was found at 362 nm in the ultraviolet-A region. Our results suggest a photochemical mechanism boundary at 330 nm. The erythema and pigmentation curves are compared with spectra from the literature determined with conventional irradiation sources (lamps and monochromators), with the current standard erythema curve of the CIE, as well as with other photobiological action spectra; especially with spectra for UV damage and tumor induction in the UV-A.

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## NEWS

### RIT Color Science Offers Graduate Scholarships

The Masters of Science Degree Program in Color Science is currently seeking highly qualified applicants for Fall 2003. Scholarships and assistantships are available for those who qualify. Funding can consist of up to full tuition assistance and a 12-month stipend (total of about \$30,000 per year). Request your graduate application today! The deadline to be considered for funding is February 15, 2003.

The Rochester Institute of Technology, Chester F. Carl-

son Center for Imaging Science, offers students a unique opportunity to earn a M. S. Degree in Color Science with the Munsell Color Science Laboratory, a preeminent academic laboratory dedicated to color science and imaging in the United States.

For more information see us at: <http://www.cis.rit.edu/mcsl> or contact: Colleen M. Desimone, RIT Munsell Color Science Laboratory, 54 Lomb Memorial Drive, Rochester, NY 14623. Phone: 585-475-6783, Email: Desimone@cis.rit.edu

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