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Introduction to Color Imaging Science by Hsien-Che Lee, Cambridge University Press, 2005, ISBN: 0-521-84388-X, 695 pages, hardbound. *Reviewed by Gaurav Sharma, University of Rochester, New York, gaurav.sharma@rochester.edu.*

Color images are everywhere around us: on our computer monitors, televisions, digital cameras, magazines and newspapers, and even cell phones! Yet, as signal and image processing researchers, we often overlook or oversimplify problems in color image processing. In most conventional electrical and computer engineering curricula, color receives a passing mention in image processing and graphics courses. Moreover, a majority of published research focuses on single channel (monochrome) images, treating color as simply three different (possibly correlated) channels. In practice, however, to comprehend practical systems that deal with color images, we must recognize and organize our knowledge around three key facts: 1) color images arise from physical stimuli in the world, 2) their common representations arise from (generalized) spectral sampling of the physical stimuli, and 3) the images are invariably intended for visual consumption by a human observer. Any introductory book on color imaging science must accordingly present the key principles of the field in a coherent framework that ties into our existing knowledge of physics, chemistry, optics, and vision. The book *Introduction to Color Imaging Science* by Hsien-Che Lee satisfies these multidisciplinary requirements extremely well.

The book fills a void in current engineering curricula, where signal and image processing are typically taught but the basic science of imaging is not covered comprehensively. The few courses that are currently offered on this topic utilize a number of books from distinct fields. The current book will therefore serve as a useful text at the senior undergraduate or graduate level. In addition, the book is also useful for practicing engineers working on imaging science applications. An undergraduate degree in sciences or engineering should provide most of the background necessary to use this book. Readers, however, may occasionally need to refer to alternate sources or fundamental texts to follow the equations/derivations. Fortunately, the book includes a healthy list of more than 1,000 references for this purpose.

The book is organized into 22 chapters and an appendix that provides color-matching functions, cone fundamentals, and standard illuminants. A glossary of common terms is also included. The first chapter serves as an introduction to the subject and provides an overview of the book. The remaining chapters are organized into six parts.

In the three parts immediately following the overview chapter, the book covers the fundamentals of color imaging. The material in these parts is set in a more abstract and general setting, with only minimal references to specific color devices and technology. In Chapters 2–8, the author covers light and color. After a short introduction to the nature of light, the key concepts of radiometry, black body radiators, the physical theory of light-matter interaction, and principles of photometry and colorimetry are introduced. Signal processing audiences should find the sections on radiometry and the bidirectional reflectance distribution function particularly useful. These are often overlooked in texts on image processing and color imaging, though the material is often found in texts on computer graphics and vision. Chapters 9–11 cover optical image formation in imaging systems and in the human eye. Here, the author covers the geometry of perspective projection, geometrical/physical optics, lens radiometry, aberrations, and imaging distortions. Chapters 12–14, which are on the physiology and psychophysics of human vision, serve as a concise overview of the human visual system elements that follow the retinal optics—going from the retinal mosaic, via the neural pathways, and to the brain. The structure and functions of these elements are presented along with visual phenomena that result as a consequence (of the structure and function) and also the models used to represent them in color imaging. Color order systems that develop a perception-based representation of color are discussed in Chapter 14.

The latter three parts of the book are devoted to principles and techniques for color technology devices, and the evaluation and processing methods that are often closely coupled with these devices. Tools for color imaging, such as color measurement, color device calibration, and tone and color reproduction are presented in Chapters 15–18. Color image capture and display devices are described in Chapters 19 and 20. Film and digital cameras and scanners are discussed, as are cathode ray tubes, liquid crystal, plasma, and electroluminescent displays. Color printing technologies including offset lithography, xerography, and inkjet, along with halftoning and printer calibration techniques are also included here. The sixth and final part in Chapters 20 and 21 addresses image quality and image processing. Specifically, Chapter 20 summarizes principles for conducting subjective and objective image quality evaluation, and Chapter 21 covers image processing. This final chapter is likely to be one of the most instructive parts for signal processors, even though the subset of image processing operations covered (segmentation, edge detection, and denoising) should already be familiar ground. Since the chapter illustrates how color imaging principles are applicable in these problems, particularly in the choice of color space and vectorial treatment instead of separable processing of color channels, it has a clear pedagogical value.

On page 2 of the book, the author states that "This book is written based on the belief that for a beginning color imaging scientist or engineer, a basic, broad understanding of the physical principles underlying every step in the imaging chain is more useful than an accumulation of knowledge about details of the various techniques." As a result of this philosophy, the book mostly focuses on concepts when presenting the topics that are covered and does not provide overviews or surveys of existing techniques. This is strictly true in the first three parts, while latter parts in Chapters 15–19 introduce specific methods and techniques to illustrate design principles.

Across the six parts of the book and across the different chapters, there is a significant variation in the level and depth of coverage of different topics. This is quite understandable (and partly even desirable) given the extensive ground that the book covers. Not doing so would have implied an unmanageably large book that may have overwhelmed many readers. For the most part, this nonuniformity in presentation matches the perspective of engineers/scientists working on color imaging systems. This is particularly true in the first three parts, where, for instance, the physics/chemistry of materials that leads to color variation is presented in a few brief paragraphs and the discussion of colorimetry occupies an entire chapter. In the latter parts, however, the lack of balance is more striking and somewhat arbitrary. For instance, in Chapter 22, the generally applicable considerations discussed in sections 22.1–22.2 are followed by a discussion of very specific color image processing techniques (segmentation, edge detection, and denoising). Though not presented as such, these are best viewed as limited and not necessarily representative samplings out of a large number of (equally salient) image processing applications.

It is useful to compare the book against other books in related areas (Chapter 1 includes a categorized list). The book *The Reproduction of Colour* by R.W.G. Hunt (John Wiley and Sons, 2005) is probably the closest in terms of content, although very different in flavor. The present book is more rigorous, covers more background in science (particularly in optics, radiometry, and image formation) and less in technology (e.g., film and hardcopy reproduction). The *Digital Color Imaging Handbook* by G. Sharma (CRC Press, 2003) is complementary to the present book, since the former combines a significantly abbreviated and shorter introduction to the science of color imaging with extensive chapters on algorithms and techniques.

The organization of the book is well suited for both self-study and classroom instruction. Most chapters include problems that could form the basis of homework assignments. One challenge when using the book for classroom instruction seems to be its large size and monolithic character, which do not seem amenable to partitioning into semester/quarter size units. Since the author has already used the material in teaching classes, it would have been beneficial if the book included better guidelines as to how the material could be organized into a one or two semester course sequence. One shortcoming of the book, which is surprising given the subject area, is the lack of any color figures or plates. Due to the emphasis on concepts rather than techniques, this is not a serious handicap. For readers new to color, however, this may make it more difficult to relate the concepts to the perception and practice of color imaging.

Hsien-Che Lee is to be commended on the excellent mix of breadth and depth that he skillfully covers throughout his book while preserving scientific precision. The book will serve as a useful text for courses in this area and should readily find an easily accessible spot on the shelves of most color imaging scientists and engineers. [SP]