Introduction to Color Imaging Science

Color imaging technology has become almost ubiquitous in modern life in the form of color photography, color monitors, color printers, scanners, and digital cameras. This book is a comprehensive guide to the scientific and engineering principles of color imaging. It covers the physics of color and light, how the eye and physical devices capture color images, how color is measured and calibrated, and how images are processed. It stresses physical principles and includes a wealth of real-world examples. The book will be of value to scientists and engineers in the color imaging industry and, with homework problems, can also be used as a text for graduate courses on color imaging.

HSIEN-CHE LEE received his B.S. from National Taiwan University in 1973 and Ph.D. in electrical engineering from Purdue University in 1981. He then worked for 18 years at Kodak Research Laboratories in Rochester, New York. There he did research on digital color image processing, color science, human color vision, medical imaging, and computer vision. He is now Senior Vice President of Advanced Imaging at Foxlink Peripherals, Inc., Fremont, California. With more than 20 years of research and product development experience in imaging science, he has given many lectures and short courses on color imaging, color science, and computer vision at various universities and research institutes. He has published many technical papers and has 14 US patents in inventions related to color imaging science.
Introduction to

Color Imaging Science

HSIEN-CHE LEE
This book is dedicated with love and gratitude to my mother, my wife Hui-Jung, and my daughter Joyce for their many, many years of help, support, patience, and understanding.
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Glossary

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Preface

To understand the capturing, the processing, and the display of color images requires knowledge of many disciplines, such as image formation, radiometry, colorimetry, psychophysics, and color reproduction, that are not parts of the traditional training for engineers. Yet, with the advance of sensor, computing, and display technologies, engineers today often have to deal with aspects of color imaging, some more frequently than others. This book is intended as an introduction to color imaging science for engineers and scientists. It will be useful for those who are preparing to work or are already working in the field of color imaging or other fields that would benefit from the understanding of the fundamental processes of color imaging.

The sound training of imaging scientists and engineers requires more than teaching practical knowledge of color signal conversion, such as YIQ to RGB. It also has to impart good understanding of the physical, mathematical, and psychophysical principles underlying the practice. Good understanding ensures correct usage of formulas and enables one to come up with creative solutions to new problems. The major emphasis of this book, therefore, is to elucidate the basic principles and processes of color imaging, rather than to compile knowledge of all known systems and algorithms. Many applications are described, but they serve mainly as examples of how the basic principles can be used in practice and where compromises are made.

Color imaging science covers so many fields of research that it takes much more than one book to discuss its various aspects in reasonable detail. There are excellent books on optics, radiometry, photometry, colorimetry, color science, color vision, visual perception, pigments, dyes, photography, image sensors, image displays, image quality, and graphic arts. Indeed, the best way to understand the science of color imaging is to read books on each of these topics. The obvious problem is the time and effort required for such an undertaking, and this is the main motivation for writing this book. It extracts the essential information from the diverse disciplines to present a concise introduction to the science of color imaging. In doing so, I have made unavoidable personal choices as to what should be included. I have covered most of the topics that I considered important for a basic understanding of color imaging. Readers, who want to know more on any topic, are strongly encouraged to study the books and articles cited in the reference list for further information.

I would like to thank Professor Thomas S. Huang of University of Illinois, for his wonderful lectures and his suggestion of writing a book on color imaging. I would also like to thank Professor Thomas W. Parks of Cornell University for his numerous suggestions on how to improve the presentation of the material and for his help in constructing homework.
problems for students. During the time he and I cotaught a course on color imaging science at Cornell, I learned a lot from his many years of teaching experience. My career in imaging science began under Mr. James S. Alkofer and Dr. Michael A. Kriss. They let me wander around in the interesting world of color imaging under their experienced guidance. I appreciate their encouragement, friendship, and wisdom very much. I am also very grateful to my copy-editor, Maureen Storey, for her patient and meticulous editing of my manuscript.

During the preparation of this book, my wife took care of the family needs and all the housework. Her smiles brightened my tired days and her lively description of her daily activities kept me in touch with the real world. She loves taking pictures and her casual comments on image quality serve as reality checks of all the theories I know. My book-writing also required me to borrow many weekends from my daughter. Her witty and funny remarks to comfort me on my ever increasing time debt just made it more difficult for me to figure out how much I owe her. Certain things cannot be quantified.